Beyond Transparency:
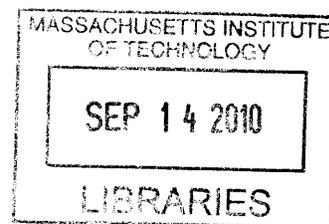## Collective Engagement in Sustainable Design

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Beyond Transparency:
Collective Engagement in Sustainable Design

Leonardo Bonanni

Abstract

For a timely answer to the question of *sustainability*, or how to provide for future generations, there needs to be shared accounting of our social and physical resources. Supply chain transparency makes it possible to map resource flows and ensure dependable production while avoiding social and environmental problems. Open channels of communications can support a collective effort to account for the impacts of supply chains and engage more people in the invention of long-term solutions, or *sustainable design*.

This thesis proposes a crowd-sourced approach to resource accounting through the democratization of sustainable design. A web-based social network called *Sourcemap* was built to link diverse stakeholders through an open forum for supply chain transparency and environmental assessment. The scalable system points the way towards comprehensive sustainability accounting through the distributed verification of industrial practices.

Sourcemap was developed over a two-year period in partnership with regional organizations, large businesses and SME's. Small business case studies show that an open social media platform can motivate sustainable practices at an enterprise level and on a regional scale. The public-facing supply chain publishing platform actively engages communities of producers, experts, consumers and oversight groups. Thousands of user-generated contributions point towards the need to improve the quality of transparency to form a broadly accessible resource for sustainability accounting.
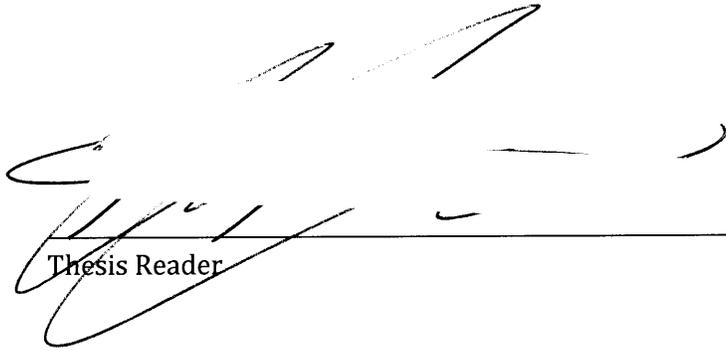
Beyond Transparency:
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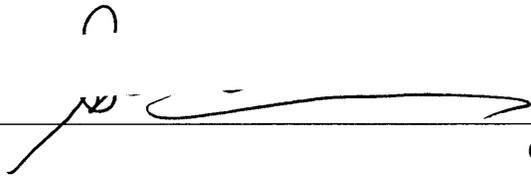
Beyond Transparency:
Collective Engagement in Sustainable Design

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Acknowledgements

Introduction | A Pluralistic Definition of Sustainability

A major hurdle to sustainability lies in how to define the concept itself. The United Nations states that sustainable development "meets the needs of the present without compromising the ability of future generations to meet their own needs."[1] These *needs* are multi-faceted – environmental, social, and economic– the "three pillars" of sustainability.[2] As the UN's definition implies, measures of sustainability will change over time; they also reflect the needs of individual communities, so they can vary by location. In short, sustainability does not have universal measures: it is **development that meets the long-term environmental, social and economic needs of communities**. Understanding these diverse needs will rely on a representative system based on advocacy by diverse stakeholder groups.

Life-Cycle

Sustainability is the reconciliation of environmental, social and economic priorities. So while many groups have converged on "carbon footprint" as a measure of sustainability, comparing products on global warming contribution alone could have negative consequences for society and the environment. A drill made with plastic gears will have a lower footprint at retail than one with metal gears; it might also break much sooner, requiring the purchase of another drill. Environmental engineers practice *Life-Cycle Assessment* (LCA) to arrive at more holistic measures of environmental cost.[3] These analyses are qualified by the length of life of products and the impacts of manufacturing, using and throwing them away. So a LCA might conclude that a cheap drill is only suitable for an infrequent user, for whom the additional cost of producing a durable drill would be wasted.

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[1] World Commission on Environment and Development. Our Common Future. Oxford University Press, 1987. Available at http://www.oup.com/us/catalog/general/subject/Economics/International/?view =usa&ci=9780192820808 (Retrieved 2010-08-04)

[2] Sustainability – From Principle To Practice. *Goethe-Institut*, March 2008. Available at http://www.goethe.de/ges/umw/dos/nac/den/en3106180.htm (Retrieved 2010-07-14)

[3] Giudice, F., LaRosa, G., Risitano, A. Product Design for the Environment: a Life Cycle Approach. Boca Raton, FL: CRC Press, 2006.

Locating Sustainability

Product life-cycles have a myriad of impacts beyond carbon footprint: solid, air-, and water-borne waste and damage to ecosystems and human health. Unlike the universal measure of global warming, the impact of these systemic factors depends on *where* they occur. Emissions from manufacturing will vary based on the type of power plant that supplies each factory: a coal-burning plant emits more carcinogenic compounds into the air than a hydro-power station, which may have more impact on ecosystems. Manufacturing also taxes water supplies, which vary widely by region. And some pollutants, like nitrogen oxides (NOx), will have more impact on air quality in an urban setting than in a rural one.[4]

Location is also fundamental to determining social impacts. Economic investment in a region can be directly correlated to life expectancy, so that manufacturing in certain countries will raise the lifespan of its residents, while investing in others will shorten lives.[5] This is related to how capital is invested in local infrastructure as a function of corruption and degree of development.

Development plays an important role in sustaining culture. One of the entrepreneurs visited as part of this research, a brewer on the Isle of Skye, explained how the consolidation of brewing in the UK resulted in the depletion of cultural resources on the island. Barley –the main farmed ingredient in beer– was once grown on Skye. But with the shift of beer production to large, centrally-located plants, small breweries could not compete and the barley industry collapsed. The specialized knowledge needed to grow barley on Skye has since been lost, and brewers today rely entirely on imported ingredients. The efficiency gains from large-scale manufacturing resulted in the depletion of local economic and cultural resources.

A Collective Approach

Sustainability is tied to *when* (in life-cycle) and *where* (on Earth) industrial processes occur. Mass-produced products can have long lives and be made of ingredients from dozens of countries. Their stories are described by supply chains: the network of materials, processes and sites involved in manufacturing and distribution. Academics, industry and

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[4] Sillman, S., The relation between ozone, NOx and hydrocarbons in urban and polluted rural environments. Millenial Review series, Atmos. Environ., 33, 12, 1821-1845, 1999. Available at http://www-personal.umich.edu/~sillman/web-publications/Sillmanreview99.pdf (Retrieved 2010-08-04)

[5] Norris, Gregory A. Social Impacts in Product Life Cycles: Towards Life Cycle Attribute Asssessment. International Journal of Life Cycle Assessment #11, Special Issue 1(2006), pp. 97-104. Available at: http://www.springerlink.com/content/360656144202524p/ (Retrieved 2010-08-03)

non-profits have converged on the modeling of supply chains to measure sustainability.[6] But global supply networks are too complex to be overseen by any single group. Advocacy efforts have relied on Multi-Stakeholder Initiatives (MSI's) to bring together governments, industry and NGO's to improve labor and environmental standards. Some industries have adopted a collaborative approach to ensure quality and traceability in their supply chains.[7] Emerging techniques of user-generated media could make it possible for more communities to represent their interests in a global discussion of sustainability. The three pillars – the economic, social and environmental needs– could be defined through the self-representation of different groups. This thesis introduces an approach based on supply chain transparency that gathers contributions from diverse geographic and professional communities in the pursuit of strategies for sustainable development.

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[6] *Just Supply Chains* was formed to "to evaluate different strategies for improving conditions of work, compensation, and association...[and] build a community of scholars and practitioners who will meet regularly to exchange ideas and collaborate on promoting just supply chains." More information at http://fsi.stanford.edu/research/just_supply_chains (Retrieved 2010-08-04)

The *Sustainability Consortium* develops "methodologies, tools and strategies to drive a new generation of products and supply networks that address environmental, social and economic imperatives." More information at http://www.sustainabilityconsortium.org/ (Retrieved 2010-08-04)

[7] Rx-360 is "creating and monitoring a global quality system that assures patient safety by enhancing product quality and authenticity throughout the supply chain" More information at http://rx-360.org/ (Retrieved 2010-08-04)

SILICON

PETROLEUM
PALLADIUM
RHODIUM
NIOBIUM
GOLD
BERYLLIUM
RUTHENIUM

NICKEL
RUTHENIUM
VANADIUM

SILICON PURIFICATION
WAFER FABRICATION

WAFER FABRICATION

SELENIUM

GALLIUM

MANGANESE

PETROLEUM

STEEL
STAINLESS STEEL
FERRITE
MAGNESIUM
BARIUM
ANTIMONY
ARSENIC
ZINC

COPPER
GOLD
GALLIUM
GERMANIUM
CADMIUM
BARIUM

LCD SCREEN
WAFER FABRICATION

BATTERY
CADMIUM
WAFER FABRICATION
SILICON PROCESSING

WAFER FABRICATION
BROMINE

TANTALUM

ALUMINUM
BISMUTH
SILICON
COBALT
PETROLEUM
TIN

LAPTOP ASSEMBLY

PLASTICS
TERBIUM
YTTRIUM

WAFER FABRICATION
CHIP ASSEMBLY

PETROLEUM

TANTALUM

NIOBIUM

CHIP ASSEMBLY

CHIP ASSEMBLY

CHIP ASSEMBLY

COBALT
NIOBIUM

TIN
CHIP ASSEMBLY

PETROLEUM

GERMANIUM

CHROMIUM
GOLD
RHODIUM
MANGANESE
VANADIUM
PLATINUM

ZINC
TITANIUM
VANADIUM
BARIUM

LEAD
GOLD

LEAD
INDIUM
TITANIUM
NIOBIUM

PLATINUM
SILVER
RUTHENIUM

WAFER FABRICATION
COLORADO

BORON
SILICON PROCESSING

BERYLLIUM
COPPER
SILICON
EUROPIUM

PHOSPHORUS

SILVER
BISMUTH

PLATINUM

MERCURY
BISMUTH
GOLD

SILICON
TANTALUM
NIOBIUM

LEAD
GOLD

COPPER
LITHIUM

LITHIUM

Suspected Supply Chain for a Laptop Computer
February 2007

Related Work | The Black Box of Supply Chains

We are at a critical moment in the pursuit of sustainability: environmental and social problems are increasingly evident but there is a lack of information to guide sustainable decision-making. Without understanding the impacts of goods and services, we buy into systems that deplete natural resources, worsen environmental and social problems and endanger humans and ecosystems. Supply chains are conventionally held secret, limiting the stakeholders who can prevent environmental, social and health and safety problems.

Understanding industrial practices is essential to making sustainable decisions. Historically, environmental and social disasters worsen when buyers are ignorant of supplier practices. This was the case during the disastrous exploitation of ivory during the Nineteenth Century. A growing European middle class developed a taste for ivory knife handles, piano keys and billiard balls. Demand rose to 500 tons per year, with annual slaughter estimated at 65,000 elephants.[8] While it had once been possible to trade for ivory on the shores of Africa, the growing scarcity of elephants prompted traders –and their military escorts– to advance into the interior of the continent in search of more material. At the same time, the end-consumers (and perhaps even the manufacturers) were misinformed about ivory supplies and the material's true cost. Towards the end of the century traders began killing younger animals, prompting the collapse of elephant populations that endures to this day.

Miscommunication plagues modern supply chains, which are so complex that they can be nearly impossible to trace. Consider your computer: inside the plastic-and-metal case are fifty materials sourced in over two dozen countries. Several of the minerals essential to semiconductor production are going to be exhausted in the short term. Supplies of Indium, a key ingredient in LCD screens, are expected to last a decade at current rates of use.[9] Material extraction can also pose important social problems. One third of global tin extraction is contained on two Indonesian islands devastated by the artisanal (and illegal) processes

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[8] Johnson, Marion. By Ship or by Camel: The Struggle for the Cameroon's Ivory Trade in the Nineteenth Century. The Journal of African History © 1978 Cambridge University Press Available at http://www.jstor.org/stable/181164 (Retrieved 2010-07-28)

[9] Cohen, David. Earth's natural wealth: an audit. New scientist, 23 May 2007. Available at http://www.science.org.au/nova/newscientist/027ns_005.htm (Retrieved 2010-08-04)

used to extract it.[10] Part of the trade in Cobalt and Tantalum, a metal used in circuitry, funds armed conflict in the Democratic Republic of Congo, where at least 2.5 million people have been killed since 1997.[11] Collective ignorance of supply chains also poses security problems: this year the US Government Accounting Office reported that most rare earth minerals –metals essential to microchip manufacturing– are only sourced in China, giving that country control over the production of (among other things) US military hardware.[12]

Commodity minerals are mixed from many sources worldwide, so it can be impossible to trace them to the country of origin. But raw material extraction is only the first black box of the semiconductor supply chain. Most computers are manufactured in a small area outside of Shanghai where manufacturers fill orders for major computer brands. These global companies communicate directly with their direct "first-tier" suppliers, but many parts originate with third- and fourth-tier suppliers that have no direct link.[13] Manufacturers and suppliers often have only handshake agreements; most communication is face-to-face. So while buyers control the suppliers of screens and hard drives, they may have little information about the source of subassemblies like keyboards and power supplies. Numerous labor issues have been reported in the factories of first-, second- and third-tier suppliers to major computer brands. In 2006 Hong Kong-based Students and Scholars Against Corporate Misbehavior uncovered widespread child labor, excessive overtime, pay below minimum wage and numerous occupational hazards at several factories supplying Dell, Acer and Toshiba.[14] This year, Apple

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[10] GreenhouseGasMeasurement.com (Steven B. Young, Goretty Dias, Alberto Fonseca, Meghan Spilka O'Keefe). Social and Environmental Responsibility in Metals Supply to the Electronic Industry. Global e-Sustainability Initiative & Electronic Industry Citizenship Coalition, 2008. Available at http://www.gesi.org/files/20080620_ghgm_ser_metalstoelectronics.pdf (Retrieved 2010-08-04)
[11] Harden, Blaine. The Dirt in the New Machine. The New York Times, August 12, 2001. Available at http://www.nytimes.com/2001/08/12/magazine/the-dirt-in-the-new-machine.html?pagewanted=6 (Retrieved 2010-07-21)
  Death rates in the war in DRC: DR Congo war deaths 'exaggerated' BBC News, 20 January 2010. Available at: http://news.bbc.co.uk/2/hi/africa/8471147.stm (Retrieved 2010-07-21)
[12] Robison Peter and Ratnam, Gopal. U.S. Smart Bombs Rely on Metals Dominated by China, Agency Says. Bloomberg Businessweek, April 14, 2010. Available at: http://www.businessweek.com/news/2010-04-14/u-s-smart-bombs-rely-on-metals-dominated-by-china-agency-says.html (Retrieved 2010-08-02)
[13] Cheng, Z., Dedrick, J. and Kraemer, K. Technology and Organizational Factors in the Notebook Industry Supply Chain. Institute for Supply Management 2006. http://pcic.merage.uci.edu/papers/2006/CAPSenglish.pdf (Retrieved 2010-07-30)
[14] Students and Scholars Against Corporate Misbehavior, "Clean up your Computer" Campaign. Available at: http://sacom.hk/wp-content/uploads/2008/09/yonghongelectronicsreport_eng.pdf (Retrieved 2010-07-30)

discovered that even its direct suppliers are guilty of child labor, unpaid overtime and poor working conditions.[15]

Computers have some of the most difficult supply chains to trace because of the number of materials, processes and countries involved. But relatively simple products like food and medicine also suffer from a lack of supply chain traceability. This year alone, a recall of cured meat products was traced to an unknown supplier of salmonella-tainted red pepper,[16] and the widest recall of pain killers to date was the result of pesticides used to treat wood pallets.[17] These secondary ingredients are several steps removed from the manufacturer's direct control, and there are no reporting mechanisms in place to trace them. To date neither the producers nor the government have been able to identify the origin of the contaminants.

Supply chains end at retail, but a lack of traceability can cause problems even after the end of a product's life. It is estimated that half to three-quarters of our discarded electronics are smuggled to China, India and Nigeria where they are 'recycled' in the most primitive ways: crushed and burned to reclaim metals like lead, copper and gold.[18] Some of these scavenged materials find their way into lower-grade products: after discovering that 12% of children's jewelry contains the toxic metal cadmium, the US Consumer Product Safety Commission issued a blanket warning against ever giving children inexpensive jewelry.[19]

These horror stories represent important risks to humans and the environment, to natural resources, and to the quality and efficacy of goods. They point to an erosion of trust between consumers, government and industry. Rebuilding the latter through widespread adoption of transparency and traceability could ensure sustainable development of human and natural resources in the long term.

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[15] Apple Supplier Responsibility 2010 Progress Report. Available at
http://images.apple.com/supplierresponsibility/pdf/SR_2010_Progress_Report.pdf
(Retrieved 2010-08-04)
[16] US Food & Drug Adminstration, Red & Black Pepper Spice Recalls Linked to the Salmonella Montevideo Outbreak Investigation (Updated March 30, 2010). Available at http://www.fda.gov/Food/NewsEvents/WhatsNewinFood/ucm206052.htm (Retrieved 2010-07-15)
[17] US Food & Drug Adminstration , "Johnson and Johnson's Recall of Children's Tylenol and Other Children's Medicines." Available at http://www.fda.gov/ NewsEvents/ Testimony/ucm213640.htm (Retrieved 2010-07-15)
[18] Chea, Terence. American consumers unwittingly fuel toxic global trade in electronic waste. November 19, 2007, The Associated Press. Available at: http://nl.newsbank.com/ (Retrieved 2010-08-02)
[19] New York State Department of Health, "Cadmium in Children's Jewelry." Available at: http://www.health.state.ny.us/environmental/chemicals/cadmium/ cadmium_jewelry.htm (retrieved 2010-07-14)

Related Work | Best Practices:
Towards a Collective Approach

Social and environmental monitoring can help mitigate many of the sustainability risks associated with industrial supply chains. These time-consuming methods are difficult to apply universally, so industry consortia have been formed to collectively establish standards and enforce compliance. This collective approach could be expanded through open communication platforms to allow for more timely and localized measures of sustainability.

Life-Cycle Assessment

Scientific approaches to environmental assessment converged in the early 1990's when the International Standards Organization (ISO) released the 14000 guidelines for environmental auditing and assessment.[20] The cornerstone of this standard is *Life-Cycle Assessment* (LCA), a comprehensive measure of the material and energetic inputs and outputs over the life of a product.[21] Raw material extraction, manufacturing, shipping, use and end-of-life are evaluated along a number of impact categories: material, energy and water use, solid, air- and waterborne waste, and systemic impacts to health and ecosystems. Tens of thousands of LCA's have been conducted, but these touch on proprietary formulas so their results are usually held private. Industry-average data is sometimes made available to the public, and software based on this information has been introduced to make environmental assessment accessible to engineers and designers.[22] The privatization of the underlying raw data makes it difficult to verify the data, reducing its accuracy and the accuracy of industry averages. Perhaps more importantly, barriers to LCA tools and information could slow the spread of environmental assessment and its adoption in new domains.

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[20] ISO 14000 Family available at
http://www.iso.org/iso/theiso14000family_2009.pdf (Retrieved: 2010-08-04)
[21] Giudice, F., LaRosa, G., Risitano, A. Product Design for the Environment: a Life Cycle Approach. Boca Raton, FL: CRC Press, 2006.
[22] Solidworks Sustainability. More information at
http://www.solidworks.com/sustainability/ (Retrieved 2010-08-04)
   Sustainableminds: http://www.sustainableminds.com/ (Retrieved 2010-08-04)

Codes of Conduct

Social sustainability is measured through monitoring for compliance with the voluntary *Codes of Conduct* of individual companies.[23] This becomes necessary when manufacturing is outsourced to countries where governments are unable to enforce labor standards. Codes of Conduct are designed to prevent forced or child labor, ensure adequate compensation and benefits, and limit overtime and hazards to health and safety. Supplier factories are visited by internal and external auditors to ensure compliance. In 2005, Nike's 90-strong compliance staff audited 575 of its 830 first-tier supplier factories, or nearly 70%. Last year HP, a leader in supply chain transparency, reached 60% of its 700+ direct suppliers.[24] These companies are exceptional in their audit capacity, but they can only account for first tier suppliers. Out of a global pool of more than 100,000 direct and indirect suppliers, Wal-mart audited 515 factories in 2009.[25] New techniques are needed to allow for the monitoring of such vast supplier networks.

Consortia

Industry consortia have been formed to collectively establish and enforce supply chain standards. The Electronics Industry Citizenship Coalition (EICC) establishes a code of conduct for labor standards to which many of the world's largest electronics companies adhere.[26] The US pharmaceutical industry is forming an industry group called *Rx-360* to jointly audit supplier factories.[27] And the *Sustainability Consortium* is establishing environmental reporting standards so that product sustainability can be assessed from the multiple tiers of suppliers involved.[28]

As part of establishing standards for supply chain monitoring the consortia are investigating communications channels for sharing data between stakeholders. New media plays an important role in these efforts: the EICC hosts a web-based file repository, Rx-360 uses a web-based form to reporting counterfeiting, and the Sustainability Consor-

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[23] Locke, Richard M., Qin, Fei and Brause, Alberto. Does Monitoring Improve Labor Standards? Lessons from Nike. Industrial and Labor Relations Review, Vol. 61, No. 1 (October 2007). Available at http://web.mit.edu/polisci/research/wip/LockeQinBrause.pdf (Retrieved 2010-08-04)
[24] HP Supply chain responsibility website: http://www.hp.com/hpinfo/globalcitizenship/society/supplychain/index.html (Retrieved 2010-07-16)
[25] Walmart Global Sustainability Report 2010 Progress Update: http://cdn.walmartstores.com/sites/sustainabilityreport/2010/WMT2010GlobalSustainabilityReport.pdf (Retrieved 2010-08-04)
[26] Electronics Industry Citizenship Coalition: http://www.eicc.info/ (Retrieved 2010-07-30)
[27] Rx-360: An International Pharmaceutical Supply Chain Consortium http://rx-360.org/ (Retrieved 2010-07-30)
[28] Sustainability Consortium: http://www.sustainabilityconsortium.org/ (Retrieved 2010-07-17)

tium is investigating software that would support sustainability reporting between multiple tiers of suppliers. These groups have identified the need for transparency between supply chain stakeholders to mitigate various risks to quality and efficacy of products and to society and the environment.

Related Work | Beyond Transparency: Crowdsourcing Verification

Supply chain transparency is the disclosure of Bills of Materials (BOM's), suppliers and/or production sites between two or more groups. It is a reality for many industries where quality control depends on product traceability. *Radical transparency* –in which supply chain information is published to the public domain– is sometimes practiced as part of marketing and public relations. But a new generation of quality and sustainability initiatives is looking to transparency as a way of involving more stakeholders in the monitoring and reporting of industrial practices.

Labeling

In 1992 the US EPA started the Energy Star program, a voluntary certification of energy-efficient appliances which gives manufacturers the right to post the program's logo –an *eco-label*– directly on approved products.[29] To comply, companies submit reports to the EPA showing that their products are 20% more energy-efficient than industry averages. There are hundreds of eco-labels associated with various measures of environmental and social sustainability.[30] Two of the most stringent are the German *Grüne Punkt* (Green Dot),[31] which mandates the producer pays a tax for packaging disposal, and the EU's *Restriction of Hazardous Substances* (RoHS)[32] which requires producers to eliminate many toxic materials. These eco-labels represent a limited degree of supply chain transparency in that manufacturers provide information to oversight bodies. In the case of the RoHS, manufacturers share their BOM; to get Energy Star certification, efficiency statistics are reported, and in the case of the Green Dot, end-of-life strategies are disclosed. Eco-labels are known to influence purchasing decisions, but so are far less rigorous claims on product packaging.[33] "Greenwashing" is a major

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[29] Energy star: http://www.energystar.gov/ (Retrieved 2010-07-29)
[30] Ecolabel Index: http://www.ecolabelindex.com/ (Retrieved 2010-07-29)
[31] Grune punkt (Germany): http://www.gruener-punkt.de/ (Retrieved 2010-07-29)
Pro-e (Europe): http://www.pro-e.org/ (Retrieved 2010-07-29)
[32] RoHS: http://www.rohs.eu/english/index.html (Retrieved 2010-07-29)
[33] Sammer, Katharina and Wüstenhagen, Rolf. *The influence of eco-labelling on consumer behaviour - results of a discrete choice analysis for washing machines.* Business Strategy and the Environment, Vol. 15, No. 3, pp. 185-199 (2006) US: http://dx.doi.org/10.1002/bse.522 (Retrieved 2010-07-29)
  BBMG Conscious Consumer Report: Redefining Value in a New Economy. Available at http://www.bbmg.com/ccr_order/ (Retrieved 2010-07-29)

problem: companies present misleading, unverified (or unverifiable) claims of sustainability as part of marketing campaigns. It can destroy the trust between industry and consumers, making it increasingly difficult for companies to communicate legitimate sustainability efforts. But greenwashing works because its claims are as verifiable as the 'real' eco-labels: neither the true nor the fake sustainability measures are available for scrutiny. Disclosing the figures and the methods behind sustainability claims could eliminate the threat of greenwashing and go a long way towards restoring consumer trust.

Traceability

A number of industries have implemented traceability schemes to ensure product quality and reassure consumers. Food and drug manufacturers document individual batches of product so that contamination can be traced to a production site. Traceability is being extended to the unit dose to ensure the authenticity and efficacy of pharmaceuticals.[34] The United Nations' Kimberley Process aims to ensure that proceeds from the diamond trade do not fund armed conflict.[35] Numbered shipping bags are given to authorized mines and each shipment is registered for traceability. In the wake of BSE outbreaks in Europe and Japan, the beef industry worked with governments to institute end-to-end traceability across supply chains.[36] Every cut of beef at retail bears a unique identifier tracing it through processing to the original cow. The existence of the Japanese beef traceability system is reassuring to consumers, even though they rarely seek out information about specific cuts of meat.[37]

Transparency

Nelson, Gabriel. 'FTC Moves May Signal Start of 'Greenwashing' Crackdown. The New York Times, February 3, 2010. Available at http://www.nytimes.com/gwire/2010/02/03/03greenwire-ftc-moves-may-signal-start-of-greenwashing-cra-90834.html (Retrieved 2010-07-28)

[34] Amann, Steffen. EAHP Working Group on Single Dose Packed Drugs Available at: http://www.eahp.eu/content/download/21095/134424/file/Standards92.pdf (Retrieved 2010-07-29)

[35] Kimberley Process Available at http://www.kimberleyprocess.com/ (Retrieved: 2010-04-04)

[36] National Livestock Breeding Center. Available at https://www.id.nlbc.go.jp/english/ (Retrieved: 2010-07-28)

[37] Souza Monteiro, D., Caswell, J. A., The Economics of Implementing Traceability in Beef Supply Chains (June 2004). University of Massachusetts, Amherst Working Paper No. 2004-6. Available at SSRN: http://ssrn.com/abstract=560067 (Retrieved 2010-07-29)

Clemens, Roxanne. *Meat Traceability in Japan.* Review Paper (IAR 9:4:4-5), November 2003. Center for Agricultural and Rural Development, Iowa State University, Ames IA 50011-1070. Available at http://www.agmrc.org/media/cms/meattraceability_A930CADCDD1B2.pdf (Retrieved 2010-07-29)

A number of interactive platforms have emerged to extend supply chain transparency to suppliers and the general public. In 2006, apparel-maker Patagonia disclosed some of the manufacturing practices, sites and environmental impacts of products through the *Footprint Chronicles* website.[38] This nuanced marketing effort tells the story of socially and environmentally responsible (SER) practices while detailing some of the challenges that lie ahead, such as non-recyclable materials and the persistence of toxic compounds. Public-facing brands are increasingly using the rich media platforms of the web to convey some aspect of their supply chain practices.[39]

Consumers can also obtain third-party reviews of products and practices. *Goodguide* is a mobile application that scans product bar codes (SKU's) to retrieve health, social and environmental ratings.[40] Goodguide's algorithms churn third-party data into three easy-to-read scores (on a scale of 1 to 10) to inform shopping decisions. For industrial consumers, web directory *Panjiva* generates in-depth reports on the economic, social and environmental performance of millions of suppliers.[41]

Supply chain transparency is being extended within supplier networks and to the general public to engage more participants in the verification of supplier practices. In a recent FDA workshop, executives from the Rx-360 consortium acknowledged the need to document supplier addresses with GPS so that auditors from different oversight groups could independently verify that they exist.[42] Since 2007, furniture maker IKEA has been using Geographic Information Systems (GIS) to verify sustainable sources of lumber.[43] In 2008, HP became the first electronics manufacturer to publish a list of most of its first-tier suppliers as a

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[38] Patagonia Footprint Chronicles Available at
http://www.patagonia.com/web/us/footprint/ (Retrieved 2010-07-29)
[39] Levi's has published a LCA for a pair of jeans:
http://www.levistrauss.com/sustainability/product/life-cycle-jean (Retrieved 2010-07-29)
  Ben and Jerry's describes its fair trade sourcing on an interactive map:
http://www.benjerry.com/activism/inside-the-pint/fair-trade/ (Retrieved 2010-07-29)
  Dole Organics has a website where consumers can trace bananas to their source:
http://www.doleorganic.com/ (Retrieved 2010-08-04)
[40] Goodguide available at http://goodguide.com/ (Retrieved 2010-07-29)
[41] Panjiva available at http://panjiva.com/ (Retrieved 2010-07-29)
[42] *U.S. FDA, Industry Aim to Further Strengthen Pharma Supply Chain Quality.*
Available at http://thegoldsheet.elsevierbi.com/cs/ (Retrieved 2010-07-17)
[43] Trubins, Renat. Introducing of [sic] GIS into IKEA's wood sourcing system: Aspects of forest resource data availablility and system functionality. Master Thesis no. 134, Swedish University of Agricultural Sciences, Souther Swedish Forest Research Centre, Alnarp 2009. Available at: http://stud.epsilon.slu.se/352/1/ Trubins_R_090702.pdf (Retrieved 2010-08-01)

way to "increase supplier accountability."[44] This move positions HP as a consumer and places responsibility for performance in the hands of its suppliers.

Crowd-Sourcing Verification

The practice of *radical transparency* –in which supply chain information is made available to the public– has the potential to revolutionize the relationship between buyers and sellers. The theory of "conscious consumerism" holds that once customers make purchasing choices based on environmental and social performance data, producers would be pressed to adopt more responsible practices.[45] But more short-term effects are already being felt within supplier networks. Wal-mart has introduced a system for scoring the packaging used by its suppliers as a way to apply direct pressure to reduce material consumption.[46] The manual work required to fill these 'scorecards' limits their effectiveness unless more people can be involved in the auditing process.

Automated approaches like Goodguide and Panjiva point towards the crowd-sourcing of supply chain transparency: their algorithms scour the work of hundreds of oversight groups to arrive at useful ratings. Crowd-sourcing is the engagement of a community in the completion of a task, usually facilitated by collaboration over the internet. It is a digital form of *collective intelligence:* "people and computers...connected so that –collectively– they act more intelligently than any person, group, or computer has ever done before."[47] Considering the widespread nature of supplier networks, only a large group of geographically dispersed individuals could audit all of the sites involved. These include oversight groups (governments, unions, NGO's) as well as students, journalists and nearby residents who have a stake in the economic, social and environmental sustainability of the region. A public forum could allow diverse groups to participate in supply chain documentation at the scale necessary to tackle the complexity of global sustainability.[48]

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[44] HP News Release: HP Becomes First in Technology Sector to Release List of Top Suppliers. Available at http://www.hp.com/hpinfo/newsroom/press/2008/080403b.html (Retrieved 2010-07-18)
[45] Goleman, Daniel. Ecological Intelligence: How Knowing the Hidden Impacts of What We Buy Can Change Everything. New York: Broadway Books, 2009.
[46] Walmart packaging scorecard:
http://walmartstores.com/pressroom/news/6039.aspx (Retrieved 2010-08-04)
[47] MIT Center for Collective Intelligence available at: http://cci.mit.edu/ (Retrieved 2010-08-04)
[48] Malone, Thomas and Klein, Mark. Harnessing Collective Intelligence to Addess Global Climate Change. Innovations. Summer 2007, Vol. 2, No. 3, Pages 15-26 Posted Online 18 October 2007. (doi:10.1162/itgg.2007.2.3.15) Available at http://www.mitpressjournals.org/doi/abs/10.1162/itgg.2007.2.3.15 (Retrieved 2010-08-04)

Related Work | Civic Media

Industry groups are converging towards supply chain transparency to elevate standards and to distribute the task of auditing suppliers. New communication platforms are needed to share sustainability data between supply chain stakeholders. The enterprise-scale software traditionally for supply chain management centralized while most public-facing media is the product of marketing departments. LCA programs are also stand-alone and refer to privately-held databases. Private, centrally-controlled software keeps valuable sustainability resources out of the hands of many potential users, putting the fidelity and the accuracy of the data at risk. A *Civic Media* approach, which allows communities to represent their interests through broadly accessible communications channels, could be applied to create a trustworthy platform for supply chain transparency.

Civic Media is defined as "any use of any technology for the purposes of increasing civic engagement and public participation, enabling the exchange of meaningful information, fostering social connectivity, constructing critical perspectives, insuring transparency and accountability, or strengthening citizen agency."[49] One historic example is the newspaper, a technology that allowed towns and cities to represent their individual interests cheaply and independently.[50] A contemporary analogue is *citizen journalism* through blogs, video- and photo-sharing websites, which lowers barriers for communities to share their interests. A civic media approach to supply chain transparency would allow multiple stakeholders to represent their own interests, whether they are consumers, producers, suppliers, or among the hundreds of thousands of people involved in the extraction, manufacture, use and disposal of a product.

Civic Media is embodied by web-based tools that put useful resources into the hands of communities. Free web platforms like Youtube, Craigslist, and Wikipedia have become channels through which citizen groups share resources. Open data –information that can be freely used and distributed– makes it possible for individuals to advocate around relevant issues. Through the US government's data.gov initiative, in-

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[49] Civic Media: A Syllabus. Henry Jenkins. Available at http://henryjenkins.org/2010/07/civic_media_a_syllabus.html (Retrieved 2010-07-17)
[50] Ewen, Stuart. Pr! A Social History of Spin. Basic Books 1998.

formation is made publicly available about a myriad of civic issues: pollution, crime, infrastructure...[51] Application Programming Interfaces (API's) are a powerful means for individual groups to leverage enterprise-scale applications, even when these are proprietary. The 2005 release of the Google Maps API enabled individuals and organizations to create spin-offs ranging from business directories to maps of environmental and social disasters.[52] Data visualization tools have been made available to a wide audience through API's: the website *Many Eyes* allows anyone to upload and visualize sets of information ranging from experimental data to baby names.[53] The environmental social network *Wattzon* lets users calculate their energy footprint and compare it to individual and regional benchmarks.[54] Free and Open Source Software (FOSS) further lowers the barriers to access so that digital media can be customized by its users. FOSS can be especially useful to niche groups for whom software is seldom designed and for governments and NGO's who need control over their own tools. When Google Maps was unable to map one of Africa's largest slums, an open source/open data alternative called OpenStreetMaps was employed and the information about geography was crowd-sourced.[55]

In these critical early days of supply chain transparency, open access to tools and data is essential to evaluating industry practices and developing sustainable ones. A civic media approach built on open access to transparent tools and information can engage more, diverse groups of participants in monitoring and innovating for sustainability.

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[51] Data.gov: http://data.gov/ (Retrieved 2010-08-04)
[52] Google Maps API available at http://code.google.com/apis/maps/index.html (Retrieved 2010-08-05)
   The US Holocaust Memorial Museum's mapping initiatives are available at http://www.ushmm.org/maps/ (Retrieved 2010-08-04)
[53] Many Eyes available at http://manyeyes.alphaworks.ibm.com/manyeyes/ (Retrieved 2010-08-04)
[54] Wattzon available at http://wattzon.org/ (Retrieved 2010-08-04)
[55] Map Kibera available at http://mapkibera.org/ (Retrieved 2010-08-04)

Sourcemap | Collective Engagement in
                 Sustainable Design

It is becoming increasingly important to adopt sustainable practices. But how do we know what is sustainable? A number of factors need to be considered: civil rights, health and safety, resource use, pollution, damage to ecosystems... There are established methods of measuring these impacts: environmental *Life-Cycle Assessment* and social *Monitoring*. These approaches rely on an understanding of where things come from and what they are made of. Answers to these questions make it possible to estimate carbon footprint, water- and energy-use, and other pollutants, as well as the social and economic impacts of production. But only a limited number of industrial processes are evaluated for sustainability, and the results are usually kept private. Many of the decisions we make on a daily basis –what groceries to buy, where to travel, what projects to take on– have significant impacts on society and the environment. Publicly accessible information and tools could inform these choices and speed the adoption of sustainable practices.

A Sustainability Calculator

The sustainability communications platform Sourcemap was built to empower people to understand the impacts of goods and services in order to make sustainable decisions.[56] Many individuals have the potential to engage in *sustainable design*: the invention of sustainable alternatives. They include consumers, product designers, and business proprietors –anyone who can impact the types of goods and services that are made available to others. The primary goal of Sourcemap is to provide these decision-makers with tools and information to make sustainable choices between existing offerings and to inform the design of new products and services. A calculator built from publicly available databases and using a simplified form of Life-Cycle Assessment makes it possible to gauge the environmental impacts of goods and services over the five phases of life: extraction, manufacturing, shipping, use and end-of-life. A map-based visualization enables the geo-location of industrial processes so that the sites can be evaluated for social and economic conditions.

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[56] Sourcemap is available at http://sourcemap.org/ (Retrieved 2010-08-04)

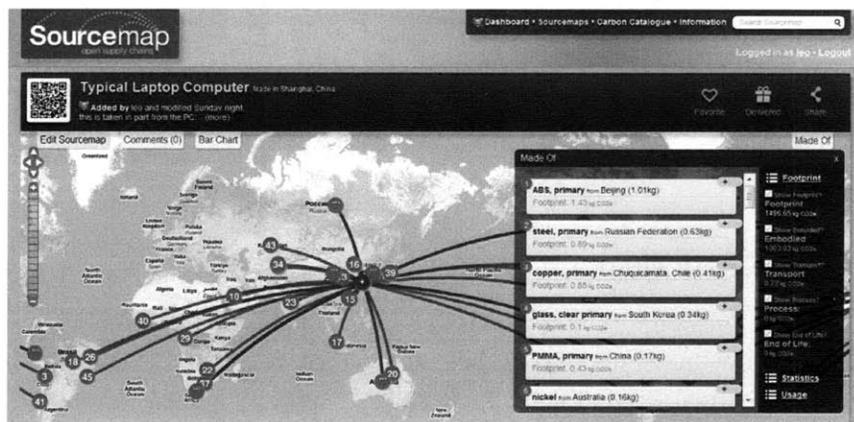## A Catalogue of Sustainable Products and Services

By opening access to the data generated through a sustainability calculator, Sourcemap can take advantage of the collective intelligence from many discrete calculations of environmental and social impact. Simulations carried out by different groups can be gathered into a crowd-sourced catalogue of the impacts goods and services. This directory approach benefits from the involvement of diverse communities: producers seeking to advertize their sustainability practices, journalists and researchers deconstructing opaque supply chains, and the general public, whose curiosity about goods and services may ultimately drive top-down disclosure of industry practices. With sufficient entries, a catalogue of sustainable products and services makes it possible to choose sources based on location and social and environmental criteria suited to each buyer.

A Platform for Distributed Verification

Sourcemap facilitates the disclosure of supply chain information to enable the distributed verification of environmental and social performance. Supply chains are formally audited by major brands and by NGO's working on their behalf, and informally by academic and journalist groups. These approaches can be patchy, as major brands are only able to consider high-level suppliers while researchers are motivated to find anomalies. A transparent approach to environmental and social impact calculations including access to tools and raw data makes it possible to verify the numeric assessments. Disclosing production practices and plants would enable NGO's and researchers to more effectively monitor suspicious sites. A more comprehensive sustainability audit would involve individuals involved with all phases of life cycle, including manufacturing workers, consumers and recyclers as well as nearby residents. Crowd-sourced verification of supply chain practices will never replace auditing by official groups, but the practice of supply chain transparency ensures that anyone *can* verify practices, an important part of building trust between brands and consumers.

Sourcemap | Implementation

Sourcemap was born as a tool to help industrial design students calculate the social and environmental impacts of consumer products.[57] The first prototype had two components: an open LCA calculator and map-based supply chain visualization. Case studies with small businesses led to the development of additional communications and customization features. Finally, a case study with a major retailer influenced longer-term functionality as a scalable system for supply chain transparency.
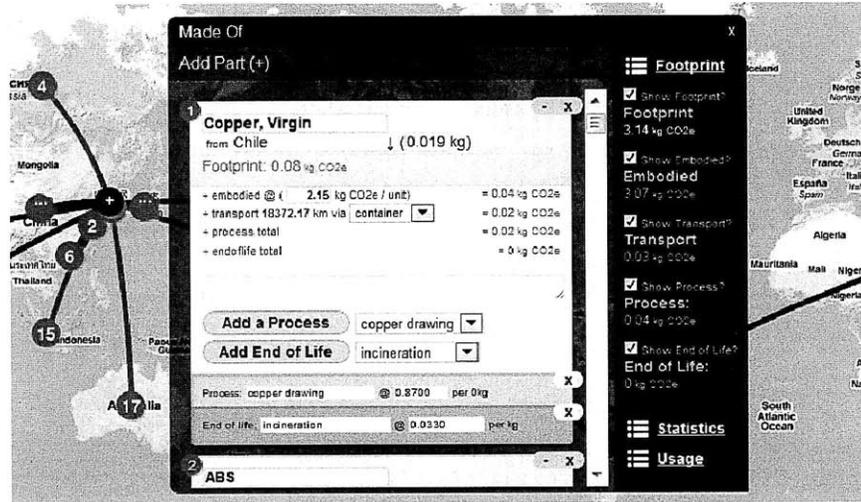

Sourcemap 0.8 default view: a supply chain map and overlaid bill of materials

A user creates a Sourcemap entry (hereafter called a sourcemap) by deconstructing a product into its BOM: a list of constituent parts and their provenance. For each part, a user can specify the weight, the type of material, its assembly origin and means of transport. If applicable, he or she can also enter the lifetime energy consumption of the product and its planned end-of-life scenario (recycling, reuse, incineration or landfill). Sourcemap adopts a simplified approach inspired by the *Okala* method, which assigns normalized impact values to commodity materials and common industrial processes.[58] The calculator computes a carbon footprint for each phase of the product's life, and geo-coding serves to calculate the carbon footprint of shipping. A *Receipt* is continuously updated with the impact of each phase of a product's life: extraction, manufacturing, shipping, use, and end-of-life. A *Bar Chart* can be used to

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57 Bonanni, L., Parkes, A., and Ishii, H. 2008. Future craft: how digital media is transforming product design. In *CHI '08 Extended Abstracts on Human Factors inComputing Systems* (Florence, Italy, April 05 - 10, 2008). CHI '08. ACM, New York, NY, 2553-2564. DOI= http://doi.acm.org/10.1145/1358628.1358712.
58 Okala LCA approach available at http://www.idsa.org/ (Retrieved 2010-08-04)

compare the life-cycle contributions from each part and life-cycle phase at a glance.

The 'Made of' dialog box acts as a Bill of Materials for each sourcemap: for every part, a user specifies the type of material, its provenance, weight, mode of transportation, processes and end-of-life strategy. The cumulative 'Receipt' is seen on the right.

Supply Chain Map

An interactive supply chain map is generated alongside the bill of materials to show the whole supply chain at a glance. Each source appears as a numbered marker on the map; clicking it brings up a balloon containing text, photo or video descriptions. Sources are connected to the assembly hub by an arc in the style of an airline route map. This is only for legibility: actual shipping lines would involve multiple stops and a combination of land, sea and/or air.

While Sourcemap does not yet provide numeric measures of social sustainability, the supply chain map gives an intuitive measure of the number of parts in a product, the distance between them, and the "localness" of a supply chain: the boundaries shift as more of the world is involved, so a locally-sourced product has a very different map than a globally-sourced one has.

Data

At its core, Sourcemap provides a free and open directory of carbon footprints, material provenance and shipping methods derived from publicly-available sources. A database of carbon footprints for manufacturing commodity materials is offered as part of the *Carbon Catalogue*. There is a growing amount of information available on-line about the sources of parts and materials, including the locations of many known

mines.[59] Commodity materials undergo standard refining and manufacturing processes, most of which have been evaluated for impact according to producer, industry, region or material.[60] Shipping routes and the impacts of various modes of transportation are well-documented.[61] The impact of using a product, whether because it relies on electricity, fuel, or passes through periodic processing (like washing) can be measured according to power generation types by locality.[62] The impact and likelihood of various end-of-life treatments can be estimated based on locality and material type.[63]

Directory

As visitors to Sourcemap generate supply chain maps and bills of materials, they contribute to a publicly-accessible catalogue of sustainable products and practices. This growing database makes more sustainability measures available to the general public; it also doubles as a directory of transparent suppliers. Sourcemap was designed to attract contributions to this directory from different stakeholders, especially producers who can benefit from supply chain transparency as a form of marketing. Careful consideration has been taken to providing an alternative to traditional advertising without "greenwashing" or presenting a false image of sustainability. The site respects the integrity of authors and provides a number of features to help tell a rich, customized story about their products and practices; at the same time the open source structure of the underlying software makes it impossible to modify the supply chain reporting templates without leaving a public record.

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[59] World Mineral Production, 2004-2008. British Geological Survey, Natural Environment Research Council, 2010. Available at:
http://www.bgs.ac.uk/downloads/start.cfm?id=1574 (Retrieved 2010-08-04)
    US Geological Survey Mineral Resources Spatial Data available at
http://mrdata.usgs.gov/website/MRData-World/viewer.htm (Retrieved 2010-08-04)
[60] European Life Cycle Core Database is available at
http://lca.jrc.ec.europa.eu/lcainfohub/datasetArea.vm (Retrieved 2010-08-04)
    Canadian Raw Materials Database is available at http://crmd.uwaterloo.ca/ (Retrieved 2010-08-04)
    Inventory of Carbon and Energy (ICE) is available at http://www.bath.ac.uk/mech-eng/sert/embodied/ (Retrieved 2010-08-04)
    A list of LCA databases is available at
http://www.pre.nl/simapro/inventory_databases.htm (Retrieved 2010-08-04)
[61] Maersk shipping routes available at
http://www.maerskline.com/link/?page=brochure&path=/routemaps (Retrieved 2010-08-04)
[62] US Energy Information Administration Electric Power Annual 2008 is available at
http://www.eia.doe.gov/cneaf/electricity/epa/epa_sum.html (Retrieved 2010-08-04)
[63] Recycling rates for selected OECD countries. (2004). In *UNEP/GRID-Arendal Maps and Graphics Library*. Available at http://maps.grida.no/go/graphic/recycling-rates-for-selected-oecd-countries (Retrieved 2010-08-04)

Catalogue

Every new sourcemap joins the underlying databases of sustainability and geographic data, creating opportunities for ad-hoc directories of materials sources, carbon footprints, and sustainable or transparent suppliers. Each entry joins the catalogue of existing products and materials so that it can be nested into a new supply chain: for example, a hard drive can be added to a computer or a dish can be added to a meal. This *nesting* is the principal way that the Sourcemap database grows; it also supports the realistic depiction of multi-tiered supply chains.

Over time, the growth of a geographic and environmental supply chain catalogue will provide increasingly useful resources. A consumer guide could provoke direct engagement between consumers, retailers and manufacturers to promote issues of sustainability and transparency. Organizational purchasing could be guided by information supplied to the site, especially for products which rely on a traceable history. Designers would be able to understand at a glance which materials are more easily suited to certain regions. Logistics providers will be able to analyze densities of demand and create new efficiencies in routing. Strategists may be able to discover potential risks in the dependence on particular materials, routes and suppliers. Policy decisions can also be informed by the economic, environmental and social implications of the aggregate of supply chains in a particular region.

Authorship

Attracting such diverse groups of stakeholders depends on providing a trustworthy platform for businesses and individuals to express their interests. Sourcemaps are sovereign: only the creator(s) can edit them, although everyone else is free to duplicate them. Author roles are inspired by social media platforms like Youtube: individual and group *users* have administrative *dashboards* and the ability to *comment* on and *favorite* other users' entries. Organizations can form groups or sub-domains (mycompany.sourcemap.org) to present their products as collections as part of cohesive marketing and sales campaigns.

Privacy

The decision to adopt supply chain transparency takes careful deliberation within organizations and supplier networks. Sourcemap can be used as a stand-alone application for use in private networks; entries on the site can be published only to pre-defined groups, and drafts can be saved without publishing to the web.

Customization

Sourcemap has been developed over time to suit specific application domains, including food, travel and traceability –each with its unique measures of sustainability. The receipt can be customized to show only those measures relevant to a particular entry. Industry-specific templates are designed to ease adoption by specific sectors, especially consumer products, food and drink, travel and general traceability.
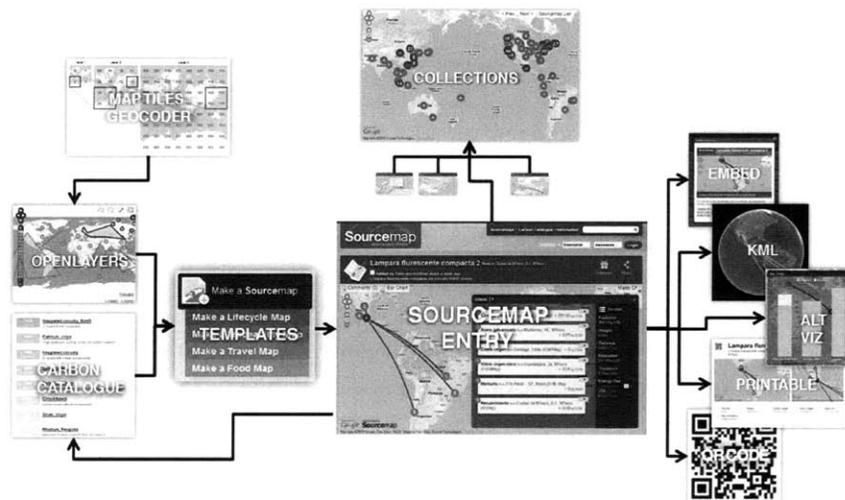
Channels

Sourcemap offers a number of ways to export information for marketing as well as to engage in larger discussions between producers, consumers and sustainability experts. Small interactive sourcemaps can be embedded into external websites (like Youtube movies) and act as viral advertisements. Each embedded map links to the complete supply chain description on Sourcemap.org. Simplified maps can be printed onto product packaging and documentation. Two dimensional bar codes (QR codes) are automatically generated for each entry on the site; these 1" (3cm) square stickers are meant to be affixed to products so that consumers who photograph them with a camera phone can retrieve environmental, social and traceability data at the point of sale. In the future, optical markers on products could be used to track and optimize many phases of product life-cycle, especially traceability, shipping, retail, use, and proper re-use and re-cycling.
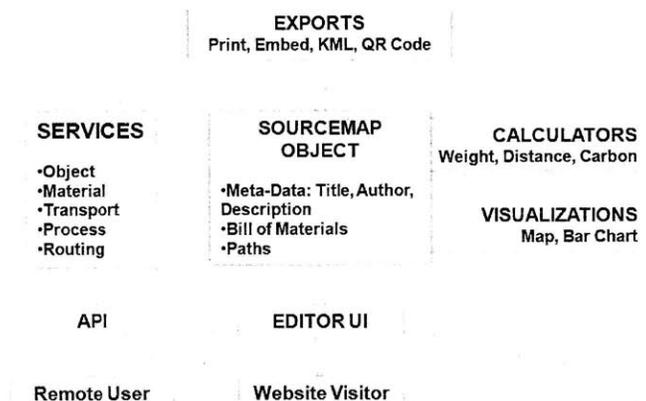
Sourcemap | System Description

User Perspective

The Sourcemap system stores supply chain and sustainability data in a modular social networking structure. The site is centered on source-maps (Sourcemap Entries/Sourcemap Objects). From a user point of view, sourcemaps combine a map (made of map tiles and an OpenLay-ers drawing) with a bill of materials from the Carbon Catalogue.[64] Users select templates to customize the type of options presented to them before creating a sourcemap. Once the entry is created, it can join other sourcemaps in a Collection and it can be exported to different formats: as an embedded map, a Google Earth file, a bar graph, a printable map, or a QR code. Published sourcemaps also join the Carbon Catalogue so that they can be incorporated into future multi-tiered supply chains.

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[64] OpenLayers is available at http://openlayers.org/ (Retrieved 2010-08-02)
   Sourcemap Carbon Catalogue available at http://www.sourcemap.org/parts
(Retrieved 2010-08-05)

System Perspective


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                              EXPORTS
                        Print, Embed, KML, QR Code


    SERVICES            SOURCEMAP              CALCULATORS
                         OBJECT           Weight, Distance, Carbon
    •Object
    •Material           •Meta-Data: Title, Author,
    •Transport          Description             VISUALIZATIONS
    •Process            •Bill of Materials       Map, Bar Chart
    •Routing            •Paths


        API              EDITOR UI


    Remote User       Website Visitor
```

Sourcemap provides a RESTful interface through standard HTTP (Get/Post/Put) to affect the attributes of a Sourcemap Entry: materials, transportation options, processes, and routes. These services are accessed through an API (for remote users) or through the website UI.[65] Sourcemap objects contain meta-data descriptions, a bill of materials with geographic routes and calculators and visualizations that can be expanded to include future impact categories. Objects can also be interpreted in different formats for export (Print, Embed, KML, QR Code).

Sourcemap Services are written in PHP; the UI Editor is written in Javascript; the OpenLayers library is used for map drawing and Google Geocoder for geocoding.[66] Map tiles are switchable between Google maps, Cloudmade and Openstreetmaps.[67] In addition, a number of social API's are used to provide sharing functionality: Facebook, Twitter, OpenID, and Topsy.[68]

Sourcemap is open source software licensed under the Affero General Public License (AGPL)[69] which is designed to protect software distributed as web services.

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[65] Sourcemap API available at http://www.sourcemap.org/api (Retrieved 2010-08-05)

[66] Google Geocoding API available at http://code.google.com/apis/maps/documentation/geocoding/ (Retrieved 2010-08-05)

[67] Cloudmade available at http://cloudmade.com/ (Retrieved 2010-08-05)
    Openstreetmaps available at http://www.openstreetmap.org/ (Retrieved 2010-08-05)

[68] Facebook API available at http://developers.facebook.com/ (Retrieved 2010-08-05)
    Twitter API available at http://apiwiki.twitter.com/ (Retrieved 2010-08-05)
    OpenID API available at http://wiki.openid.net/Libraries (Retrieved 2010-08-05)
    Topsy API available at http://labs.topsy.com/ (Retrieved 2010-08-05)

[69] Affero General Public License available at http://www.gnu.org/licenses/agpl-3.0.html (Retrieved 2010-08-05)

Sourcemap | **Verification**

Industry groups are converging on a collective approach to account for the diverse measures of sustainability: social, environmental, and economic. Open communication channels could engage contributors from new professional and geographic communities. Sourcemap is a transparent communications platform that makes tools and information widely available so that solutions to the problems of sustainability can be crowd-sourced. This collective engagement occurs at three levels: in validating calculations, verifying supply chains, and developing the open source software itself.

Math

The proprietary nature of LCA tools and information limits widespread adoption of sustainability measures. Despite the fact that ISO reporting requires disclosure of references and methods, most LCA's are based on proprietary industry data so the resulting assessments can be difficult to validate. Life-Cycle Assessments are based on a mix of facility-specific data (for example, water use at a supplier factory) and industry averages (such as the energy mix in the US). The validity of a final assessment fluctuates widely based on the accuracy of these base values. Without disclosing the latter, it can be impossible to verify the data or to update it as better information becomes available.

An open approach broadens access to environmental assessments while increasing their transparency and accuracy. LCA practitioners largely work for industry, academia and as private consultants, relying on stand-alone software and proprietary databases costing thousands of dollars.[70] Environmental assessment is out of reach for many small businesses, independent designers and decision-makers at various levels of industry and government. Sourcemap makes free LCA tools and information available so that anyone with access to the internet can be informed of the sustainability impacts of their choices. The underlying calculations and data are open to scrutiny and debate: users can comment on or submit alternatives to any of the values in the underlying

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Sourcemap source code is publicly available at
https://sourcemap.codebasehq.com/ (Retrieved 2010-08-04)
[70] Cooper, Joyce Smith, and Fava, James A. Life-Cycle Assessment Practitioner Survey: Summary of Results. Journal of Industrial Ecology, Vol. 10 No. 4 pp. 12-14, 2006. Available at http://dx.doi.org/10.1162/jiec.2006.10.4.12 (Retrieved 2010-08-04)

Carbon Catalogue. Aggregating methods and values on an open forum could form the basis for standard approaches to environmental assessment, extending the reach of sustainability accounting far beyond where it is today.

Supply Chains

Sourcemap adopts an *Open Data* standard so that supply chain information published to the site can be freely exported and verified, like the underlying database of environmental information. Each map is built with collective intelligence as prior entries join the library of materials from which new supply chains can be generated. After that, users can publish their entries publicly to gather attention and feedback. Sourcemaps can be visualized using alternate views, and raw data is easily exported for use on other platforms.

Today, sourcemaps can be directly critiqued and rated, or they can be cloned and modified to present alternative hypotheses. Over time, the viral distribution of supply chain estimates will empower field verification at different points along the supply chain by on-site contributors in real time.

Software

A pluralistic definition of sustainability is based on representation from diverse geographic, cultural and professional communities. As an open source project, Sourcemap software can be copied and modified to represent different perspectives. This is intended to allow the development of alternate databases, calculators and visualizations, including measures of cultural and social sustainability that represent local interests. For example, in the UK the measure of "Food miles" is used to describe the cumulative distance traveled by a meal, whereas the French have a concept of "terroir" to describe the flavors of food and drink in specific territories. An open source platform is intended to reflect these multiple priorities, enabling different groups to create unique versions of Sourcemap to express the resources and the measures unique to them. This mechanism is intended to act as a sort of sustainability federalism to prevent the dominance of a global standard.

Discussion

Any collective project runs the risk of being misused or abused, corrupting the very data it was made to collect. In the short term, the open sharing of supply chain data expands on the ability of individuals to make sustainable choices and verify industrial practices. If successful, these tools and information could attract manipulation to favor certain products, industries and geographic regions. The mechanisms of Open

Data and Open Source have been put in place so that all data, software and content are transparent and open to public record and scrutiny. But it is hoped that competition will continue to elevate standards in supply chain transparency as a means for businesses to differentiate themselves along sustainability grounds.

Field Research | Deploying Sourcemap

Sourcemap development was informed by field research with small businesses in the Scottish Highlands and in the northeastern United States over 14 months, followed by pilot studies with a regional organization and a major US retailer. The aim of the research is to identify sustainability-related practices and to tailor the site to support those practices across the Sourcemap user base. The research sought to observe the following shifts in behavior:
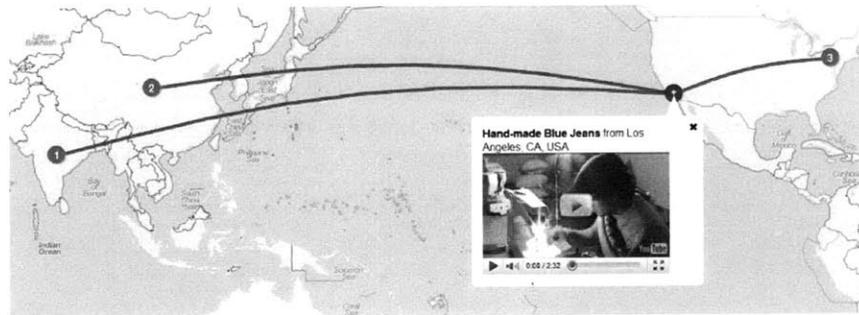
Communicating sustainability practices
Auditing actionable issues of sustainability
Streamlining operations
Reorganizing industry practices

The small business case studies involved highly motivated and web-savvy proprietors concerned with sustainability. Small businesses tend to have simple, relatively static supply chains under their direct control. They also tend to have smaller geographic footprints and to be invested in the growth of surrounding communities where many of their customers live. The combination of economic, environmental and social motivations made these businesses ideally-suited for early Sourcemap development across multiple sustainability measures.

Case Study | The Product Designer

The Product Designer runs an ethically and environmentally conscious studio producing hand-crafted specialty electronics and toys in the Highlands of Scotland. Her products are "locally, ethically and environmentally crafted." She is interested in demonstrating her efforts on the company's principal sales channel, its online store. Not all raw materials are locally available, however, so she needs a way to demonstrate that distant labor is necessary and ethical. She has traveled to India to document weavers working with traditional techniques, and wants to invest in preserving these endangered skills. The Product Designer suggested that rich media be included to describe each part of a Sourcemap entry, so that photographs and videos of the manufacture of every piece could be seen on the interactive map. It became apparent that a sustainable business strategy relies on documentation, and that a business can self-document practices as part of its presentation to consumers.

Photos, videos and text descriptions can be embedded at any point along a supply chain.
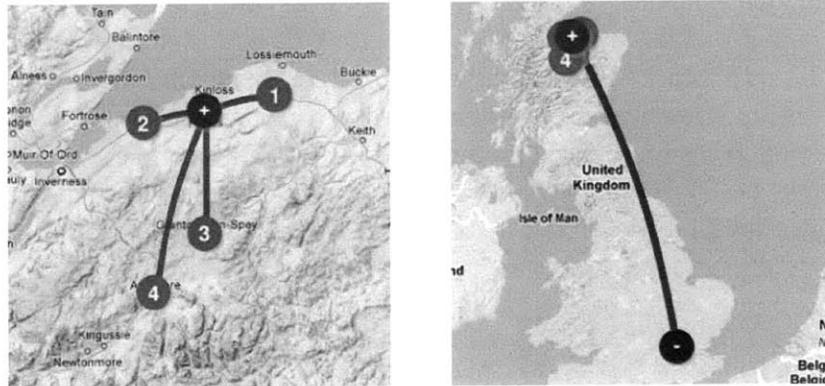
The Product Designer is expanding into retail sales, and she suggested that a printable version of the map be added to product packaging. This desire reveals a need for extensions to the calculators and visualizations of Sourcemap so that more designers can adopt the tool as an extension of their visual language.

As part of the study, the Product Designer created a sourcemap for each product she manufactures. She reported a hurdle: some of the materials that she sources are hard to find, and this gives her a potential competitive advantage. The transparency imposed by geolocating parts poses a problem. One potential solution is to locate the supplier approximately so that competitors cannot track it down while the shipping estimate remains accurate. As sourcing information becomes less sensitive over

time, these locations could be revealed in detail. This brings up a nearly universal need to phase-in supply chain transparency by temporarily firewalling sensitive information while ensuring that the impact estimates remain accurate.

Case Study | The Butcher

The Butcher grows native breeds of cattle on his family farm, selling the beef along with pork, lamb and game at his small-town shop in the Scottish Highlands. Online sales represent the fastest-growing portion of the business, and he spends considerable time creating content for the website and the accompanying social networks. The Butcher has a very small geographic footprint: all of his products are made within 50 km of his shop; he knows all of his suppliers personally. Many of his customers –both online and in person– buy his products because of his assurance of localized production and his verifiable supply chain.

The Butcher uses a local map (left) to show his supply chain, and the geolocating function (right) to calculate the impact of shipping to consumers.

Though the Butcher is fond of telling his story to walk-in customers, he is looking for ways to extend a social dialogue to his growing base of online consumers. The business has a rich website that includes recipes, news, and a presence on *Facebook* where he seeks to communicate more actively with customers.

The Butcher is using Sourcemap to show the geographic reach of his operation and to account for the carbon footprint of his product. The first step was to create a map of his operations without any environmental data. This revealed the need to include customization features that allowed maps to be created for supply chain transparency separate from measuring carbon footprint. Next, the Butcher proposed embedding an interactive supply chain map in his online store to account for the footprint of specific products. Most of his web sales occur in the south of England, so he suggested that this embedded map also show the footprint of shipping the product to the end-consumer. Finally, he proposed
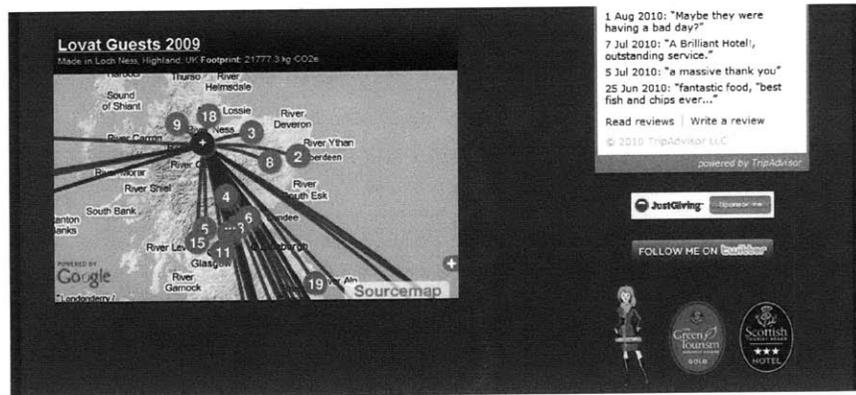
that the Sourcemap data be exported to *Facebook* to foster a conversation with his fans.

As we worked together to start accounting for the footprint of the meat sold in the store, the Butcher was surprised to find that the impact of producing meat is much greater than the impact from transporting it. The Sourcemap LCA makes it clear which portions of a supply chain have the largest footprint, so that users can direct improvements where they will be most effective. Despite being disappointed in this finding, the Butcher continues to account for carbon footprint because he sees it as a necessary part of an open dialogue with his consumers; and he believes that it will improve the image of his business and raise the standards of his industry.

The Butcher brought up a potential problem, however, with locating his suppliers on a map: the farm "is, in effect, where they live." It is unlikely that publishing their address will have negative effects in terms of compromised privacy, this makes an interesting case for devising approximate map locations while still providing enough supplier information to ensure traceability. This reinforced a common concern with the Product Designer: the need to carefully phase in information to be presented on Sourcemap to protect suppliers and intellectual property while conveying an accurate and engaging story.

Case Study | The Hotelier

The Hotelier owns and operates a three-star vacation hotel and restaurant on the banks of Loch Ness. Much of the tourism to the area is driven by its scenic landscapes, and her approach reflects an investment in the area's natural wealth. In recent years she has taken steps to increase the environmental sustainability of the hotel, installing a wood chip heating system fueled with local lumber and participating in national and international green initiatives. She sources produce from local and organic farms whenever possible. She goes so far as to track how far guests have traveled to reach the hotel and offsets their carbon footprint by planting trees in nearby forests. The hotel's philosophy and sustainability efforts are documented on its website, which she updates daily, along with a number of accompanying social networks. The hotel website includes embedded *Tripadvisor* widget showing unbiased (but largely positive) reviews from her guests; she is also considering a *Facebook* presence.[71]

An embedded sourcemap joins other social media badges on the Hotelier's website

When the Hotelier first heard of Sourcemap, she suggested using it to visualize the paths traveled by her visitors, and to use the map on her website as a way of illustrating her efforts to offset carbon footprint. This led us to refine an embeddable widget and to develop a template specifically for visualizing travel. She includes an embedded sourcemap of yearly travel footprint on the hotel's website, along with a description
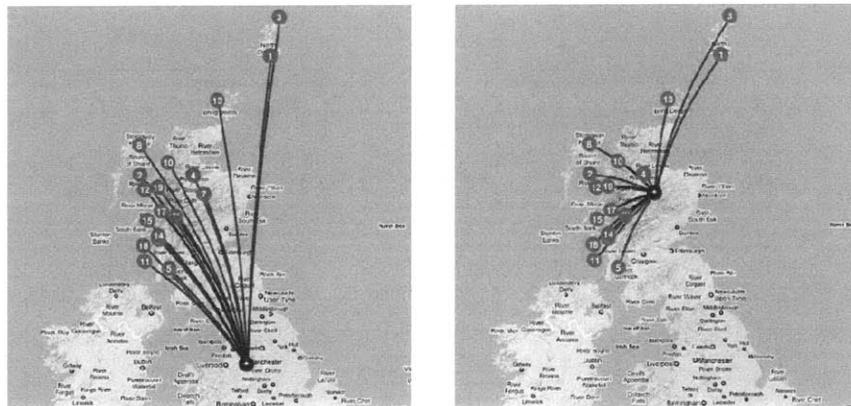
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[71] Tripadvisor available at http://www.tripadvisor.com/ (Retrieved 2010-08-04)
Facebook available at http://facebook.com/ (Retrieved 2010-08-04)

of the carbon offsets she has chosen to purchase. Her hotel now represents a carbon-neutral travel destination for all of her guests.

Later, the Hotelier proposed that the map could be used to assist in strategic planning for the hospitality industry of the region. Visualizing where guests originate from, where food is sourced, and which sites are visited could assist the region in overall development. Finally, she requested a streamlined input method whereby information could be directly exported from her existing database of guests to Sourcemap. These expanded functions further motivated the development of an extensible architecture with multiple points of entry to the Sourcemap calculators and visualizations.

Case Study | The Brewer

The Brewer manages an independent cask ale brewery located within a national park in the Scottish Highlands. Like the Hotelier and the Butcher, the Brewer believes that practicing business sustainably reinforces the image of the region and its products. Because the brewery operates within the confines of a park, minimizing waste and pollution is of the utmost importance. The Brewer has installed specialized machinery to re-use packaging materials and hot water, and she uses the social network *Freecycle* to find people that can re-use some of the brewery's by-products.[72] Some beers are named for local interests, and a portion of profits is earmarked for issues such as wildlife preservation.

The bottling plant under construction could reduce the cumulative distance to bottling for all of the brewers in the region from 9,300km to 3,100km.

The brewery's location in a national park puts it close to many of its customers, but quite far from the nearest bottling plant. After speaking with several brewers in the Highlands it became apparent that operations are inefficient due to the lack of bottling plants in the region. As a result, all 18 breweries in the Scottish Highlands ship their products to central England for bottling and back to northern Scotland to be distributed. A short-term approach would push production south, stripping already fragile areas of employment. The Brewer's long-term outlook is leading her to invest in a bottling plant on-site where her product and her competitors' products could one day be bottled. This plant will eliminate the brewery's footprint from shipping to the bottling plant,
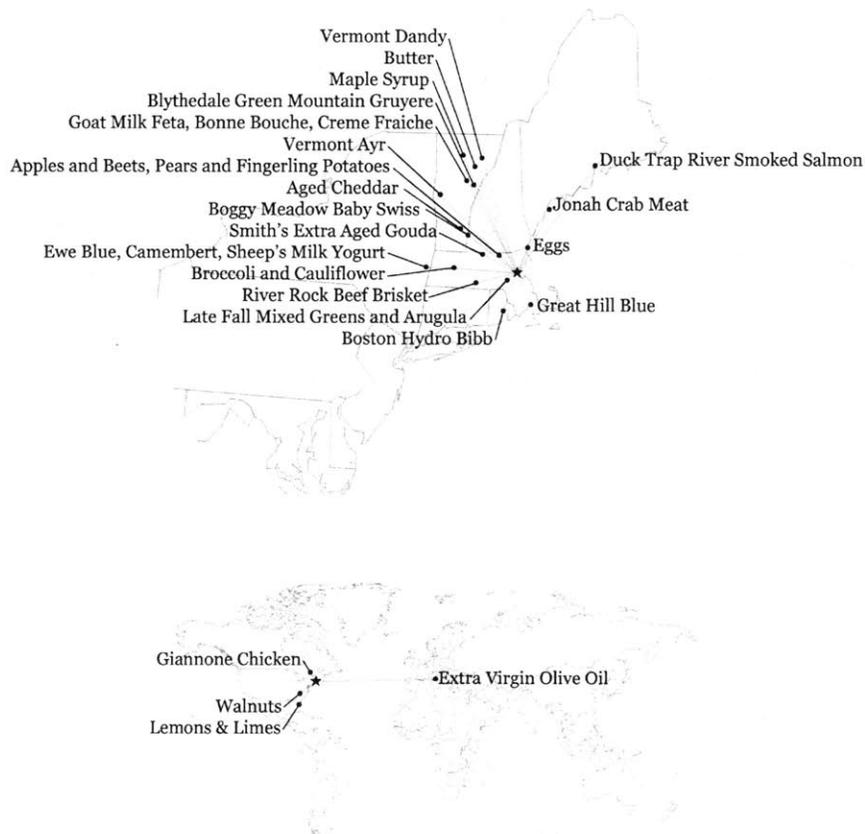
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[72] Freecycle available at: http://www.freecycle.org/ (Retrieved 2010-08-04)

and it could halve the distance to a bottling plant for other brewers in the region.

The Brewer is not only motivated to reduce her carbon footprint: her underlying desire is to grow the community of these rural parts of Scotland. The decisions to eliminate waste and to invest in a bottling plant add important costs to her business, but they also represent nature conservation and employment opportunities. Her priority is *social sustainability* – investing in the communities of the region for long-term economic and cultural development. After mapping her operations on Sourcemap, she sought to source more ingredients locally. Barley, the principal farmed ingredient of beer, is not grown in the Highlands; now the Brewer is working with local farmers to develop varieties that could one day be grown locally.

Case Study | The Caterer

The Caterer owns and operates a gourmet catering business dedicated to direct and local sourcing in the Boston metropolitan area. He takes care to source as many ingredients as possible from farms that are less than 250 miles (400 km) away; this limits his operation to the New England growing season, which runs from April to November. Thanks to a personal network of dozens of farms and farmers' markets, he is able to source nearly all of his ingredients locally during peak season. He explains his concern for local food with four arguments: he needs to ensure a safe and healthy source of ingredients; he wants to keep costs low; he believes in supporting ethical labor; and most importantly, he wants to make the best-tasting food possible. Nearly half of his clientele hires him because of his focus on locally-sourced ingredients.

This printable map prepared by the caterer demonstrates a transparency approach: locally-sourced ingredients are mapped (top) as well as globally-sourced ones (bottom)

Like the Brewer, the Caterer has a long-term strategy to reduce the footprint of his business and of his industry. He has invested in a fixed location for his kitchen in order to cut his travel footprint and he is installing a distribution hub for locally farmed produce at this location during off-hours. This has the potential to benefit his suppliers, to reduce his and his competitors' dependence on industrially farmed ingredients, and to create a carbon sink that can be reflected in his net environmental impact. He is also building a root cellar and canning operation at his kitchen so that he can extend the season for locally grown produce.

The Caterer initially suggested the idea of printing maps on the menus distributed at his catering events, and three generations of printable designs were subsequently used. The first efforts –which were manually generated– showed that two maps are needed to document his sourcing. A local map illustrates the source of most ingredients with enough detail for customers to recognize the farm names, in case they want to buy the produce themselves. A global map locates those ingredients that cannot be sourced locally (e.g., olive oil, herbs and spices, and some fruits). The Caterer insists on showing both maps so as not to mislead his customers, and to highlight the relatively large number of ingredients he is able to source locally.

The Caterer has used Sourcemap several times, noting a few changes in his behavior as a result. First, the map visualization revealed that several of his base ingredients –without which it would be difficult to make *any* meal– are sourced from distant and less-than-ideal locations. As a result, he is actively pursuing alternative sources for his grains and oils. Second, his team has begun to devise creative solutions to avoid ingredients that cannot be sourced locally; for example they are considering replacing cane sugar sourced from Latin America with maple syrup from New England. Third, using Sourcemap inspired him to provide custom maps on receipts as part of a new small-scale 'pick-up' catering business. The Caterer uses Sourcemap as a strategic design tool and as a marketing tool in printed menus and on his website.

Although revealing his sourcing strategy makes it easier for his competitors to imitate him, the Caterer believes that the relative benefits he will garner from publicity, bolstering his suppliers' businesses, and being an early adopter outweigh the risks posed by imitators. In fact, he uses Sourcemap in part to stand out from the growing crowd of restaurateurs claiming to source locally without specifying which ingredients are sourced where. Like many of the other participants in the field re-

search, the Caterer believes that an open dialogue –in which both the positive and the negative are revealed– is fundamental to gaining trust from his clients and elevating the state of his industry in general.

Field Research Findings

The five entrepreneurs used Sourcemap as a **communication** platform: they found ways to express their particular sustainability approaches through the visualization, calculators and marketing features of the site. The Designer sought to express cultural traditions; the Butcher prioritized quality and traceability; the Hotelier advertized a carbon neutral approach; the Brewer shared concerns about her industry; and the Caterer communicated a combination of quality, traceability, and innovation in ingredients. Communications functionality was a strong motivation for the business owners to try Sourcemap. Viral media channels are already popular with small businesses as an inexpensive way to enrich their websites. One unexpected discovery was that supply chain transparency could be applied in such diverse ways to convey the nuanced sustainability strategies of the entrepreneurs.

Beyond this, three of the business owners carried out an **audit** of some aspect of their sustainability strategy (the Butcher, the Hotelier, and the Brewer) and three used it to determine how to **streamline** their operations (the Hotelier, the Brewer and the Caterer). Small business entrepreneurs have a choice of worksheets to measure environmental performance; and professional consulting can bring about more thorough assessments and action plans. None of the entrepreneurs favored these approaches, however, as they can be resource-intensive and the results opaque. In conversations with the entrepreneurs, the transparency of Sourcemap was seen as a differentiator: the open calculations and math make it easy to test different scenarios and understand the relative importance of certain choices. Sourcemap supports the sustainable design decisions of the business proprietors by simulating the impacts of different hypothetical scenarios. Beyond that, publishing assessments on the site is a way to avoid *grenwashing* – the risk that visitors interpret sustainability claims as empty rhetoric – since the underlying impact calculations are plain for all to see.
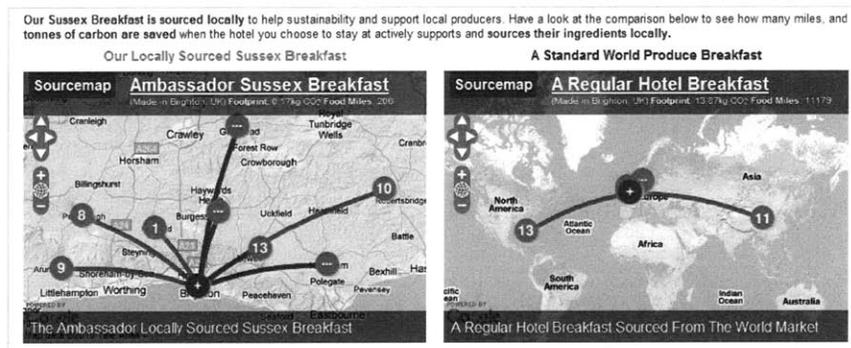
Two of the participants have been actively **reorganizing** their regional industries: the brewer, by relocating bottling operations to a new factory, and the caterer, by investing in a root cellar and canning operation and a local produce distribution hub. These regional infrastructure developments reflect ideas and priorities already held by the business owners, with Sourcemap serving to communicate the results. Sourcemap is able to support this type of sustainable design that extends

beyond the interests of a single business to include the industry and the region. These entrepreneurs sought to differentiate themselves, as well as to raise the standards of their respective industries. This reinforces the need for a sustainability communications platform where multiple stakeholders can participate –including suppliers, competitors, investors and regulators– to trace the impacts of sustainability decisions on the economy, society and the environment.

Communications functionality motivated the use of Sourcemap and made it possible to account for larger-scale social, environmental and economic sustainability. The field studies also highlighted a need for sustainable design tools that are accessible by decision-makers outside the environmental domain. While the model of simplified LCA and supply chain mapping employed by Sourcemap proved to be widely applicable to different design strategies, there has yet to be a robust mechanism for valuing social impacts. Social sustainability initiatives will need to be better illustrated to reflect the benefits of small business supplier networks.

Pilot Studies | Scaling Sourcemap

The field research points towards large-scale applications of a social network for supply chain stakeholders. Two pilot studies were carried out to test transparency in large supply chains: one with a regional development group and another with a major retailer. These exploratory studies point to future directions in the development of collective tools for sustainable design.

This badge is included on the website of businesses participating in a campaign to promote local foods, showing the business' actual sources (left) as compared with a globally-source meal (right).

Regional Development Group

Two of the small business entrepreneurs defined a regional strategy through their use of Sourcemap: the Brewer, in her plans for a regional bottling hub, and the Caterer, in his creation of a local farm stand. To arrive at these strategic decisions, each had to be conscious of the needs of their respective industries, needs that extend beyond the day-to-day concerns of running a business. What if a real-time assessment of regional sourcing could be aggregated from all of the sourcemaps of individual businesses in a region? A tourism organization in the South of England created its own version of Sourcemap to promote local industry and culture. Hotels and restaurants that source a proportion of ingredients from local farms are asked to disclose their sources in exchange for being featured on the umbrella organization's website. Sourcemap is used as a reporting and certification tool: any business can join the group if it is transparent about its sourcing and meets community standards. A *branch* of Sourcemap was created by local developers; a cultu-
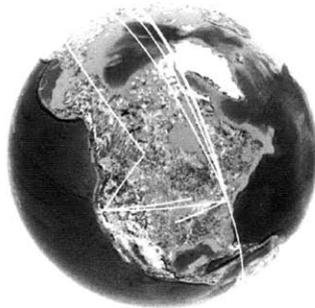
rally relevant measure has been introduced (food miles) as well as locally specific means of shipping (diesel van, lorry).

Five hospitality businesses have mapped their regional food supply chains, and these maps were embedded in their respective websites and on the umbrella organization's site. These five supply chains touch sixty supplier farms who are also being promoted indirectly through the sourcemaps. Over time, an ad-hoc directory of suppliers and buyers will form, providing the region with a valuable tool for development. Work is under way to visualize this aggregation of supply chains on a single regional map which could be used as a shopping portal to further stimulate local business.

Major US Retailer

Two months after public release the Sourcemap team was contacted by representatives from a major US retailer to create map-based visualizations of product supply chains for internal and external communications. This experience highlighted some of the short-term benefits and long-term challenges of supply chain transparency in large organizations.

This case study consisted in researching a single supply chain –a can of tomatoes – to produce visualizations used in internal and external presentations. The canner supplied information about the provenance of all of the ingredients and packaging, while expressing concern that this information could be used by the retailer –his client– to push for changes to his practices. The 8 oz. can of tomatoes contains eight edible ingredients from seven countries in North and South America and Asia (more edible ingredients may be used in quantities small enough to fall below the threshold for reporting).[73] The packaging is made from five materials sourced in three countries in North America and in Asia. Even though some of the industrial packaging (eg. pallets and pallet wrap) do not appear in the finished product, they can have substantial impacts to the overall safety and sustainability of the product.[74] In short, this relatively simple product – sold as 'Tomatoes' is made of (at least) 13 materials from 9 countries without considering secondary inputs like fuel, fertilizer or chemicals.

Two of the visualizations used to present the supply chain: Google Earth (left) and a still from a video of production practices at a supplier factory (right)

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[73] Hydrolyzed vegetable protein recall available at http://www.accessdata.fda.gov/scripts/hvpcp/ (Retrieved 2010-07-21)
[74] US Food & Drug Adminstration , "Johnson and Johnson's Recall of Children's Tylenol and Other Children's Medicines." Available at http://www.fda.gov/ NewsEvents/Testimony/ucm213640.htm (Retrieved 2010-07-15)

Visually depicting the supply chain of a simple product can be challenging. After numerous calls and emails, enough information was gathered to make four Sourcemaps: three second-tier suppliers and one first-tier supplier (the cannery). The second-tier suppliers' maps are nested at the extremities the cannery's supply chain. Videos prepared by the supplier were added to production sites on the map. A two-minute movie was ultimately produced from animated screen captures of Sourcemap and Google Earth. It was presented to executives within the company, and stills were shown at the TED 2010 conference by a company executive.[75] Executives were surprised by the number and provenance of ingredients sold as California tomatoes, suggesting that involving more people in sourcing decisions might shift practices. The pilot study was considered successful, and additional supply chains are being mapped as part of a larger strategy to phase-in supply chain transparency within the organization.

The retailer case study underscores the need for platforms with multiple points of entry for spreading an understanding of supply chain practices. The map-based visualizations of Sourcemap served as a communications link between suppliers, sustainability professionals, retail executives and the general public. Considerable hands-on work was required to gather the supply chain information; more automated methods would be ideal. Suppliers could one day publish information about their practices directly to Sourcemap; it would join information from other suppliers, at which point the retailer could incorporate all of the supply chain data for internal or public-facing presentations. Motivating suppliers and consumers to make use of the data is another challenge. Creating a sustainability 'score' could drive suppliers to monitor and report on their performance over time. Consumers could be provided with in-store and mobile applications for viewing information about the story behind products; they could also be engaged to provide user-generated content in an online social network.
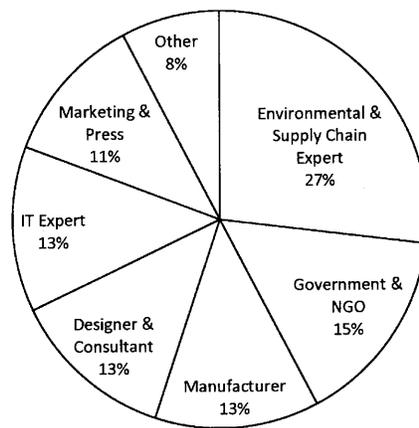
Early discussions of Sourcemap suggested that major industries could be reluctant to adopt supply chain transparency because of concerns over disclosing supplier identities or proprietary formulas. This study showed that suppliers could present a more significant opposition. Conversations with a number of major industries suggest that a phased-in approach is being favored, where transparency migrates from within an organization to its larger supplier network and finally into the public realm.

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[75] TED conference available at http://www.ted.com/ (Retrieved 2010-08-04)

Hands-on evaluations show that a communications platform for sustainable design can shift attitudes and practices. But what happens when the platform is released to the public? Collective engagement depends on the collaboration of different supply chain stakeholders: consumers, producers, designers, environmental experts and oversight groups. The open source approach also depends on contributions to the project and to the underlying software. Sourcemap.org was released to the public on September 1st, 2009. In the ten months since, engagement has been observed through user-generated content on the website and direct contributions to the project's development by a growing community of environmental, logistics, software and business experts.

Professional affiliations of 78 users who sent emails through the Sourcemap.org contact page between November 2009 and July 2010[76]

A cross-section of participants can be glimpsed from those who sent messages sent to the development team (above). This sampling suggests that Sourcemap.org engages the communities it was designed for: environmental and supply chain experts (27%), manufacturers, designers and consultants (26%), oversight groups (15%), and IT experts (13%). The manufacturers, designers and consultants (who have a direct influence on product offerings) include one or two representatives from each of these sectors: architecture, apparel, beverage, consumer

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[76] Sourcemap contact page: http://www.sourcemap.org/info/contact-us/ (Retrieved 2010-08-03)

electronics, engineering, furniture, household goods, pet products, polymers, product design, recycling, retail fixtures, and urban planning. Outside the target groups, journalists and marketing professionals also contacted us to write about the project or to use Sourcemap as a resource for stories about sustainability and supply chains. As influencers of mainstream media, they could play an important role in spreading the expectation of transparency within industry and to the general public.
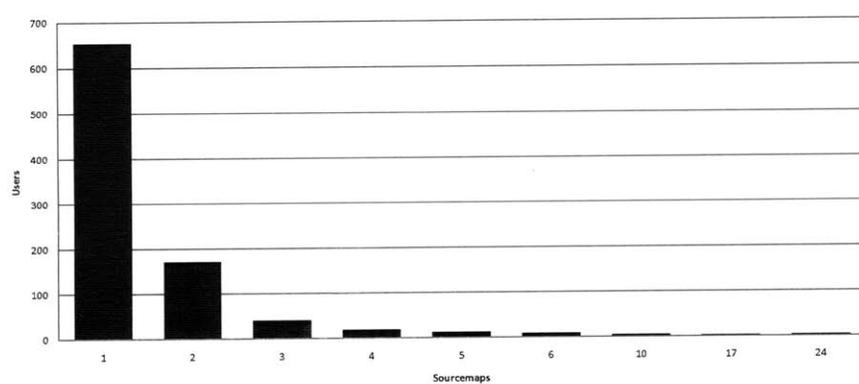
Engagement is evaluated through user-generated content and contributions to the technical development. These early results paint an optimistic picture of the need for forums where supply chains can be shared between diverse stakeholders. At the same time, there is a clear need for a uniform quality and depth of information about supply chains. A code of conduct for transparency reporting could bring more specificity to the public discussion of sustainability.

Registered users and sourcemaps created September 2009 – July 2010

The largest and most diverse group of contributors to Sourcemap is made up of visitors to the website. In the ten months since it went public, sourcemap.org was visited by 170,000 people from 182 countries and territories.[77] Nearly 2% (3,200) registered as members, enabling them to rank, comment on and create sourcemaps. 28% (913) of users created at least one entry and about 200 super-users are responsible for more than half of the 1,650 maps on the site.[78]

Number of sourcemaps created per user: 39% of users create 1 map; 35% create 2-5 maps, 12% create 6-20 maps and 14% create more than 20 maps each.

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[77] As of 2010-07-25: 3,200 registered users, 171,685 unique visits and 515,142 page views.
[78] As of 2010-07-25: 1,672 sourcemaps have been created excluding entries without a title, an assembly location or parts. 421 sourcemaps are publicly visible.

As the first open supply chain visualization platform, Sourcemap offers a glimpse into the kind of supply chains that the web-surfing public knows about and is interested in. Industry-specific templates, which were inspired by field research, do pigeonhole entries into four pre-defined categories: traceability, life-cycle assessment, food and travel. A survey of all public entries reveals the nuances within those categories as well as some of the gaps in common knowledge:

The type of entries on Sourcemap.org as observed from 327 unsolicited public submissions as of July 25th, 2010.

Direct observation of unsolicited entries on the site reveals a strong emphasis on food mapping, with more than a third of all maps depicting food and beverage (34%). Users also document a variety of consumer products (41%), trips (8%) and construction projects (3%). But an important number of entries (14%) represent users testing sustainability scenarios without leaving a coherent BOM or map behind. This suggests demand for a publicly-accessible environmental calculator to inform day-to-day decisions.

A survey of sourcemaps reveals several types of environmental assessment maps: life-cycle assessments, supply chain networks, shipping and travel maps. There also exist multiple kinds of traceability maps serving to express professionally, culturally or personally relevant supply chains.
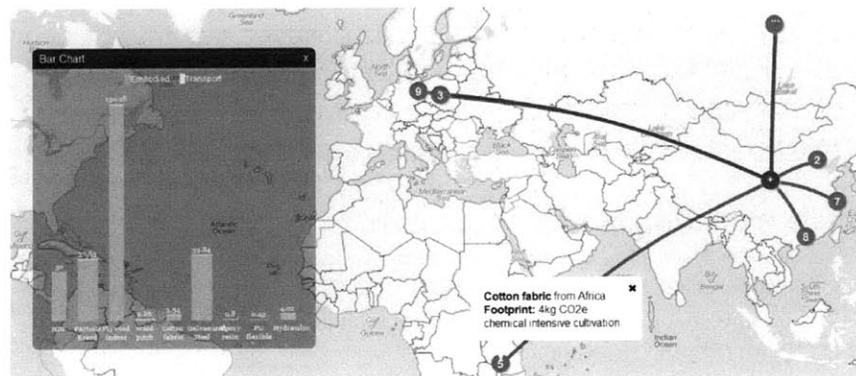
Life-Cycle Assessments

Environmental assessments serve to calculate the likely life-cycle impact of products and are characterized by a complete and realistic listing of parts, their weights, origins and the impacts of more than one life-cycle phase. These maps often compress multiple tiers of a supply chain into a single tier so that all of the relevant parts are easy to identify.

Làmpara Fluorescente 2 by Kalia [79]

> This map is one of four different interpretations by user Kalia of the life-cycle impacts of Compact Fluorescent Lamps (CFL's), a product synonymous with "green" because of its high operating efficiency.

IKEA Sultan Alsarp bed by jeremyjih [80]

> This environmental assessment by jeremyjih is based on an investigation of a specific bed by a well-known furniture manufacturer informed by online source materials. Its completeness and the reference to a specific product helped make it one of the sourcemaps most cited in the press.[81]
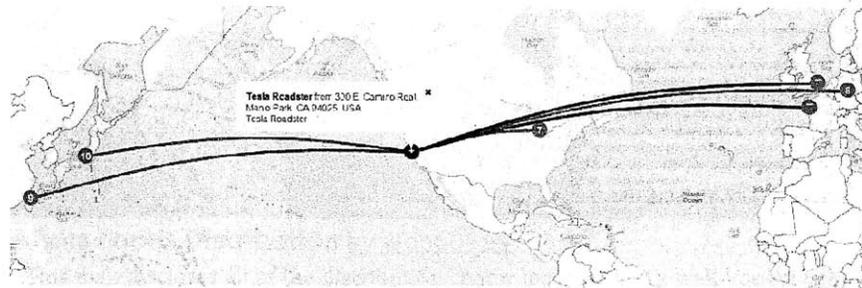
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[79] Available at http://www.sourcemap.org/object/lmpara-flurescente-compacta-2 (Retrieved 2010-07-30)

[80] Available at http://www.sourcemap.org/object/ikea-sultan-alsarp-bed (Retrieved 2010-07-30 Jeremy produced this map as part of an assignment in my Fall 2009 class at the MIT Media Lab.

[81] "Checking the Tag." Report on Business, The Globe and Mail, April 2010, pp. 7. Available at http://ebooks.dmdigital1.com/april2010rob/ (Retrieved 2010-08-04)
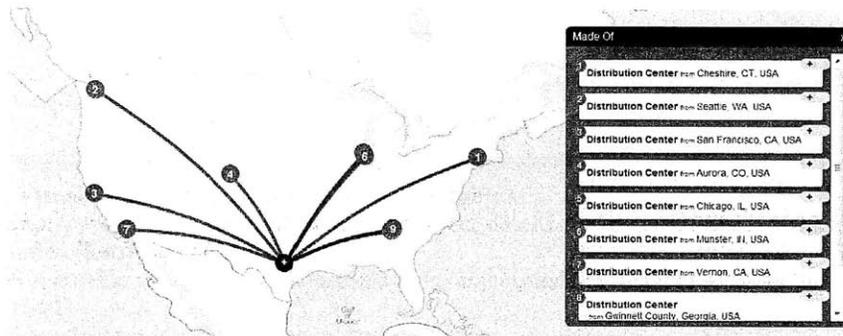
Supply Chain Networks

Network maps describe one tier of logistics in a supply chain, either up-stream (source, manufacturing) or downstream (distribution, retail), and they are characterized by precise locations of sites although they may be lacking information about quantities and impacts.

Tesla Roadster by nshanken [82]

This first-tier supply chain of a pioneering electric car includes precise street addresses and supplier names, indicating that the creator has some familiarity with the manufacturer's practices.

Whole Foods Distribution by wood0444 [83]

This map discloses all of the distribution center locations for a well-known health food grocery chain. In this case Sourcemap's hub-and-spoke routing model is unlikely to represent the shipping connections faithfully.
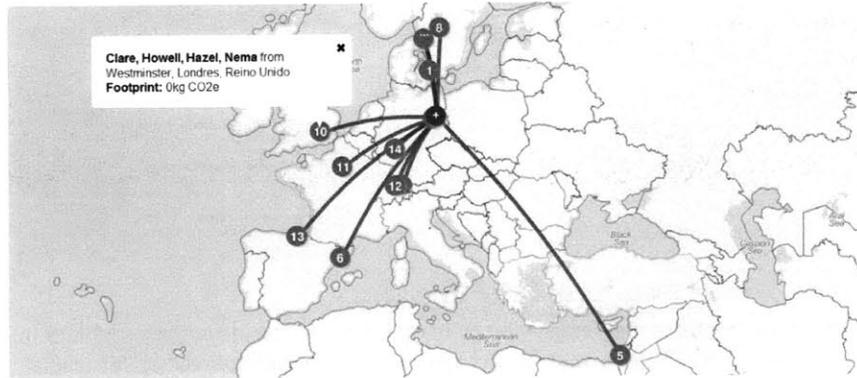

Visual Complexity post on Sourcemap available at:
http://www.visualcomplexity.com/vc/project_details.cfm?index=708&id=708&domain= (Retrieved 2010-08-04)

[82] Available at http://www.sourcemap.org/object/tesla-roadster (Retrieved 2010-08-01)

[83] Available at http://www.sourcemap.org/trace/whole-foods-distribution (Retrieved 2010-08-01)
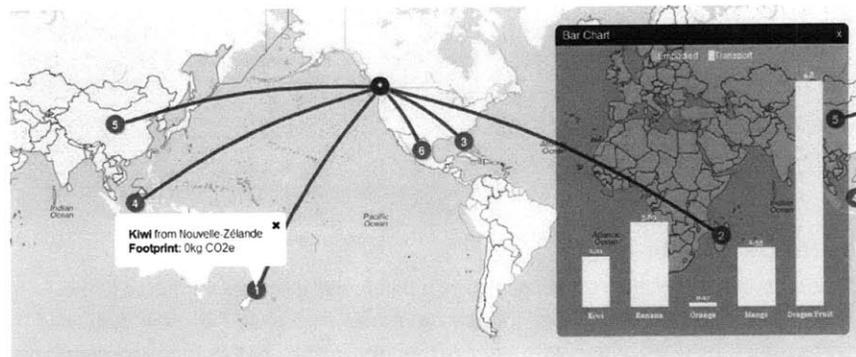
Shipping and Travel Maps

Shipping and travel maps account for the movement of multiple people or things to a meeting point or hub, specifying the weights and modes of transportation used.

artful research workshop by borjiz[84]

This is a traditional use of the travel template that represents a proxy calculation: it shows participants traveling to a meeting place, but the notes reveal that the map was used to calculate the carbon footprint avoided by using tele-presence instead of actually traveling.
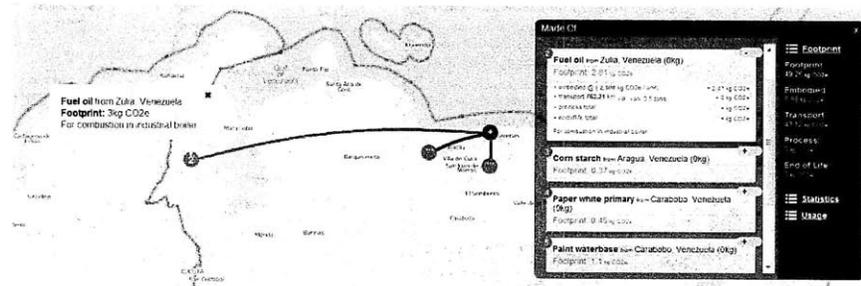

Tropical Smoothie by eap15sadu [85]

This is a worst-case scenario of the distances traveled by ingredients in a fruit drink prepared in Canada. The user accounts only for shipping footprint and assumes that ingredients originate as far as possible from their destination.

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[84] Available at http://www.sourcemap.org/travel/artful-research-workshop (Retrieved 2010-08-01)
[85] Available at http://www.sourcemap.org/food/tropical-smoothie (Retrieved 2010-08-01)
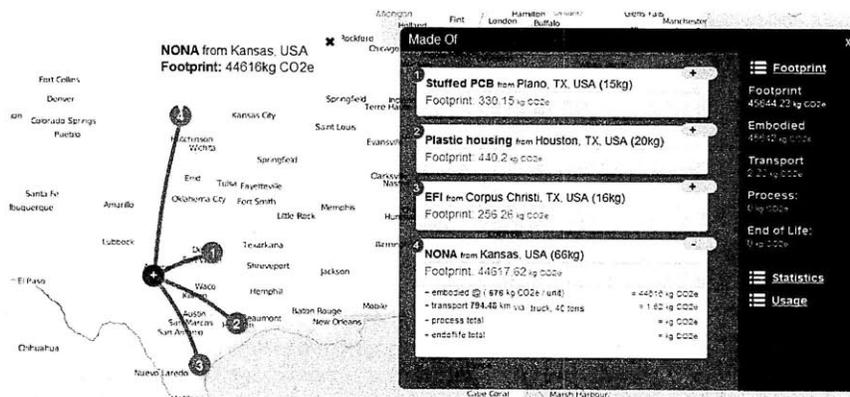
Artifacts

Artifacts are objects of cultural significance; in Sourcemap this refers to products that represent special interest groups: individuals, cultural or professional communities.

Arepa. Harina PAN. Corn Flour by helenahv [86]

This map describes the Venezuelan culinary staple Arepa, including secondary ingredients such as heating oil and packaging, which are also sourced in Venezuela.

Secure Detonator by mooney5 [87]

This map describes an artifact specific to a particular industry, in this case the type of explosive used by the oil industry to perforate a well. Two new materials were added included, along with their carbon footprints: NONA (an explosive) and EFI (a detonator).

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[86] Available at http://www.sourcemap.org/object/arepa--harina-pan--corn-flour (Retrieved 2010-08-01)
[87] Available at http://www.sourcemap.org/object/secure-detonator (Retrieved 2010-08-01)
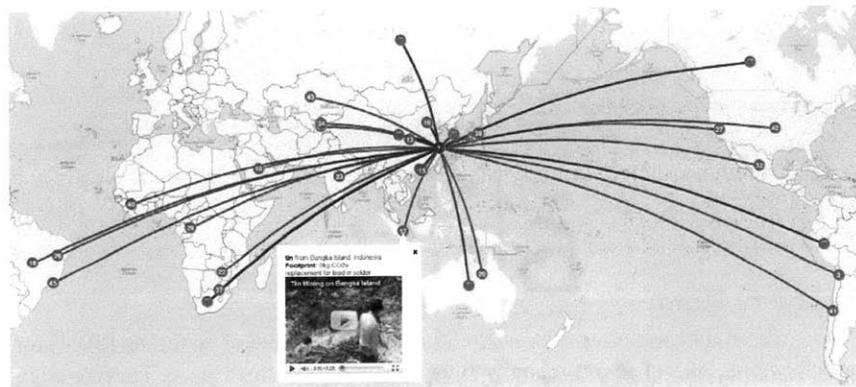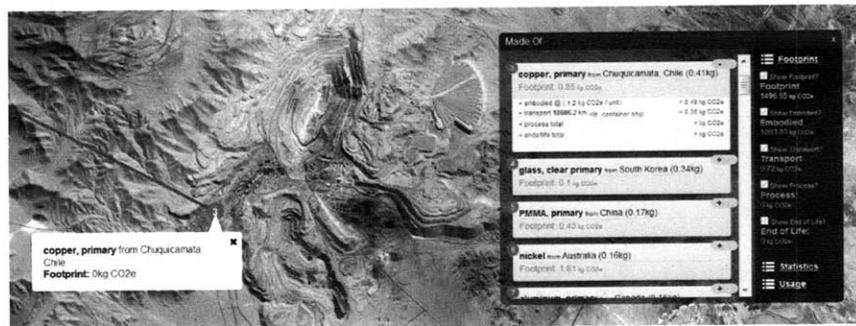
Solicited Sourcemaps

Some Sourcemap types have only been created by contributors to the project. These include narratives, regional industries, product tear-downs, and financial maps.

Narratives

Sustainability strategies often touch on the minutiae of running a business. Rich storytelling features are included with Sourcemap so that these important but seldom communicated strategies can be part of a transparent corporate communications strategy. While no publicly visible user-generated maps include this type of content, it is favored by professionals using Sourcemap to present sustainability strategies within a company or a supplier network.
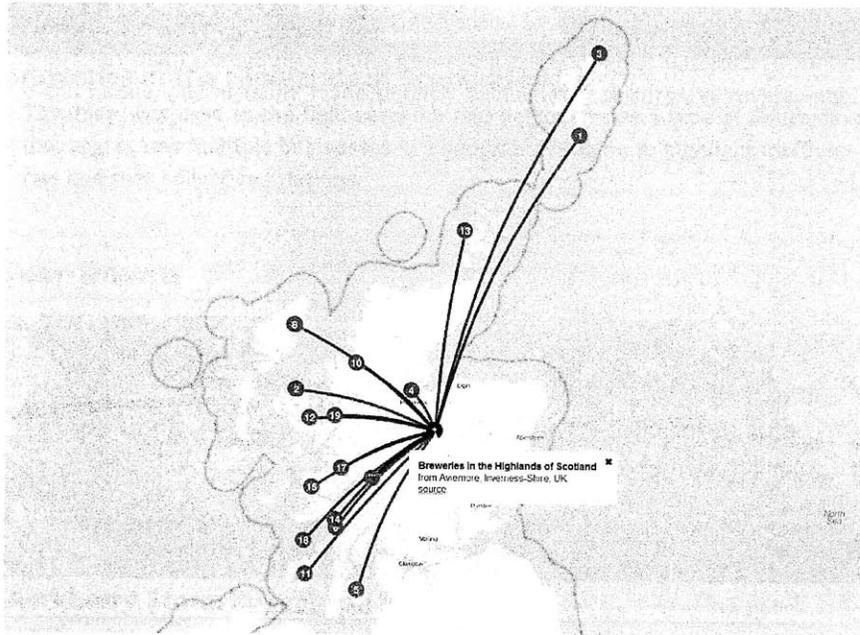

Typical Laptop Computer by leo [88]

The prototype for Sourcemap showcases the system's storytelling capacity: facilities such as a copper mine can be located via satellite (top) and rich media like photos and videos can be embedded at points along supply chains (bottom).

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[88] Available at http://www.sourcemap.org/object/typical-laptop-computer
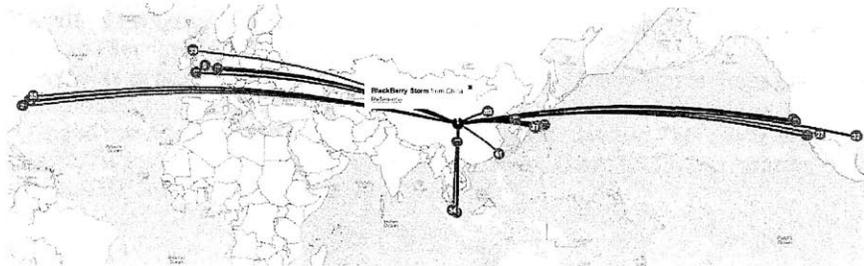(Retrieved 2010-08-01)

Regional Industries

Breweries in the Highlands of Scotland by leo [89]

This map was used in the field research and demonstrates a type of Sourcemap that aggregates multiple businesses in a geographic region to highlight inefficiencies and seek collective solutions.

Tear-Downs

Blackberry Storm by geng_tan [90]

This sourcemap containing 52 parts refers to a detailed Bill of Materials (BOM) for a cell phone, one of many made publicly available by third party reverse-engineering services.[91]

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[89] Available at http://www.sourcemap.org/object/breweries-in-the-highlands-of-scotland (Retrieved 2010-08-01)

[90] Available at http://www.sourcemap.org/object/blackberry-storm (Retrieved 2010-08-01)

[91] iSuppli provides detailed 'teardown' lists for popular devices. This one is available at http://www2.electronicproducts.com/Blackberry_Storm_9530_Smartphone_-whatsinside_text-76.aspx (Retrieved 2010-08-01)

Financials

Apple Ipod Video 30GB Profit Distribution by <u>leo</u> [92]

This map describes the flows of capital to different countries based on the sale of a $399 iPod, with the bulk of profits ending up in the US ($163) while suppliers in Japan($43), Korea($1) and Taiwan($1) end up with the rest.[93]

Findings

This preliminary analysis of user-generated sourcemaps reveals the tendency to map familiar, simple products, especially "good" ones (electric cars, efficient light bulbs, health food), suggesting that users or their companies are sustainability-conscious. There is variety in the type of products being mapped, but relatively little inventiveness outside the templates provided – only those Sourcemaps created by the development team use the hub-and-spoke model to describe flows of money, for example. Many maps focus on major ingredients and neglect the small but sometimes important secondary ingredients and processes. Establishing and enforcing standards for reporting could help achieve more complete entries.

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[92] Available at http://www.sourcemap.org/object/apple-ipod-video-30gb-profit-distribution (Retrieved 2010-08-01)
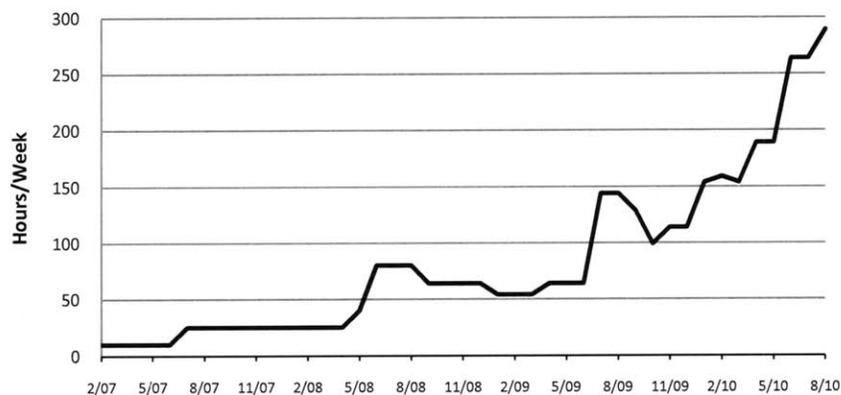
[93] Varian, Hal R. An iPod Has Global Value. Ask the (Many) Countries That Make It. The New York Times, June 28, 2007. Retreived 2010-4-15: Available at http://www.nytimes.com/2007/06/28/business/worldbusiness/28scene.html?_r=2 (Retrieved 2010-08-01)

The Sourcemap project is developed through contributions from experts in open-source software development, GIS, sustainability and logistics. At the time of this writing there are twenty contributors to the project: eleven academics from five universities in the US and Canada, four software developers based in the US, three business experts, a graphic designer and a writer. The largely volunteer team members are motivated by the social (and especially environmental) mission of the project. Academic and technical challenges also drive development, especially since the open source and open data licenses make it possible for anyone to collaborate. This section describes expert contributions to the ongoing research challenges of the project.

Weekly hours devoted to the Sourcemap project February 2007 - August 2010

Sustainability Assessment

The proprietary nature of Life-Cycle Assessment tools and information limits the widespread adoption of sustainability measures. As we have seen with Sourcemap, an open and transparent resource can extend the practice of environmental assessment to underserved communities including SME's and the general public. Beyond carrying out single assessments, it can be difficult to reconcile the myriad measures and approaches used. One problem is scope: some assessments describe entire industries, supplier networks and brands while others reflect individual products and sub-components. The scope problem also applies to life-cycle: whereas some assessments include manufacturing, use and end-

of-life impacts, others consider only a single phase like shipping. A web-based tool called *Earthster* is proposed for manufacturers to conduct Life-Cycle Assessments and report them to their clients so that an impact assessment of every product, producer and industry can be compiled.[94] Alongside Earthster, a *Linked Data* approach is presented to standardize environmental reporting so that any two processes, products or industries can be compared.[95] Linked Data attaches semantic meaning to discrete bits of information so that they can be independently interpreted and compared. As an example, every product could be associated with its bar code number (SKU) so that an ethical shopping website could independently match products to their sourcemaps.

Inspired by the Earthster, a linked open data system is being developed to increase the transparency and accuracy of environmental assessments on Sourcemap and elsewhere. The linked data format has been designed so that sourcemaps can be combined with other sources of information along an open standard compliant with ISO 14048 reporting.[96] This could help to reconcile the different scopes of information, both in terms of industrial scale and life-cycle approach. Entries on Sourcemap could be confronted with output from LCA software packages, product catalogue information and enterprise-scale supply chain software. Compiling assessments from different authors and platforms would make it possible to arrive at representative values for social, environmental and economic impact.

Another hurdle to widespread sustainability assessment is the proprietary nature of existing software and consulting services. An open approach to sustainability assessment based on linked data and open source software could create alternative business models for environmental, social and supply chain experts. API's are being developed so that rich third-party software applications can take advantage of the free sustainability data and calculators underlying Sourcemap. These

[94] Earthster: http://www.earthster.org/ (Retrieved 2010-08-03)
[95] Norris, Gregory A. Social Impacts in Product Life Cycles: Towards Life Cycle Attribute Assessment. International Journal of Life Cycle Assessment #11, Special Issue 1(2006), pp. 97-104. Available at: http://www.springerlink.com/content/360656144202524p/ (Retrieved 2010-08-03)
  Earthster Core Ontology: http://code.google.com/p/earthster/ (Retrieved 2010-08-03)
[96] Linked Data - Connect Distributed Data across the Web. Retrieved from http://linkeddata.org (Retrieved 2010-08-02)
  Carlson, Raul., Tivander, Johan. (2001) Data Definition and File Syntax for ISO/TS 14048 Data Exchange: with Data Storage Format Based on ISO/TS 14048 CPM - Centre for Environmental Assessment of Product and Material Systems. CHALMERS UNIVERSITY OF TECHNOLOGY. Göteborg, Sweden.
  International Organization of Standardization. (2001). ISO/TS 14048 Environmental management – Life Cycle Assessment – Data documentation format. ISO/TC 207/SC 5/WG 2/TG N 20, SIS

sustainable design tools will be available through a linked data "App Store" where developers and consultants can sell software and services to support sustainability across a broad range of application domains.[97]

Social Media

Tackling the complexity of global supply networks requires partnerships between industries, governments and NGOs. By extending this collective approach to various professional domains, Sourcemap seeks to help assess and optimize the functioning of industrial ecosystems. But there are important cultural barriers to supply chain transparency, a fundamental step towards sustainable design. The erosion of trust between consumers and producers resulting from the numerous ethics, quality and safety scandals in recent years has been exacerbated by 'greenwashing' in the popular media. In conversations with a number of Social and Environmental Responsibility (SER) and Corporate Social Responsibility (CSR) representatives, it is often noted that these scandals have made it harder to practice supply chain transparency because it might be interpreted as a marketing effort. There is also a reluctance to make any public or industry-wide sustainability claims without a plan to remediate problems, even though supply chain transparency would have to be in place before some of the most important problems present themselves. These hurdles only compound existing impediments to transparency like trade secrets, which have made it commonplace to negotiate with suppliers without knowing exactly what is being bought.

Business culture will need to transform as consumers come to expect information about where things come from and what they're made of. Transparency –especially with regards to social media– is often against company policy. Despite the success of online viral media as a channel for marketing, sales and support, many corporate networks are closed to online social media.[98] The new generation of transparency and traceability tools –like Sourcemap– depends on remote data resources hosted in the 'cloud' of distributed data servers. Real-time data on suppliers and shipping will come from many stakeholders, including producers. Avoiding the back-room deals that plague semiconductor supply chains will rely on traceability software that can be accessed using any kind of media in the field (computer, tablet, cell phone, paper, etc...).

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[97] Markoff, John and Holson, Laura M. Apple's Latest Opens a Developers' Playground. The New York Times, July 10, 2008. Available at http://www.nytimes.com/2008/07/10/technology/personaltech/10apps.html?_r=1&scp=3&sq=%22app+store&st=nyt (Retrieved 2010-08-04)

[98] Alboher, Marci. Blogging's a Low-Cost, High Return Marketing Tool. The New York Times, 27 December 2007. Available at: http://www.nytimes.com/2007/12/27/business/smallbusiness/27sbiz.html (Retrieved 2010-08-03)

Representative media platforms can be refined through field research with the communities being targeted: in this case producers, governments and NGOs. Identifying and working in partnership with specific user groups can help to target individual needs with unique software features. Three communities are being studied as part of ongoing field research: a national group of large companies, the industrial eco-system of a large city and a social network of farmers and restaurateurs. Case studies with these groups will help to identify benefits to economic, social and environmental sustainability that can be used to motivate broader engagement in supply chain transparency.
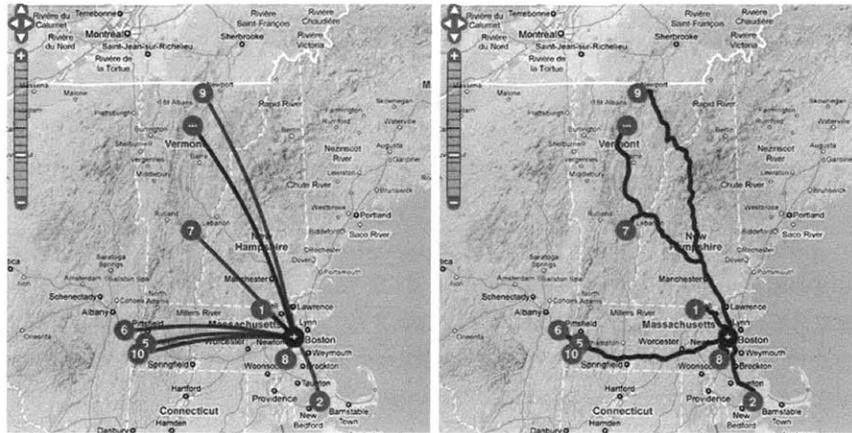
GIS

Geographic Information Systems (GIS) are digital mapping tools easily customized to reflect the needs of different user groups. Web-based maps have gained prominence as a form of Civic Media because their accessibility makes it possible for small communities to research and represent their geographic interests. Web maps have low barriers to entry; unfortunately existing systems were inadequate to use for Sourcemap. As an example, the Google Maps API only supported mapping ten points at once, while the open source map library *OpenLayers* could not be used to draw paths across the Pacific Ocean, linking America and Asia through the Greenwich Meridian instead.[99] The first Sourcemap volunteer is a GIS expert who was able to tweak the OpenLayers library to enable lines to be drawn across the Pacific.[100]

Web-based maps have been used since the first prototype of Sourcemap as a way to simultaneously calculate and visualize distances traveled. Stylized arcs are drawn on the map for legibility while "Great Circle" distances are calculated as if parts traveled the shorted possible distance between any two points. More realistic routing calculations and visualizations are being developed; the concept sketch below reveals how they may look. In global supply chains these more realistic shipping lines will include multiple modes (land/air/sea) with major ports as way stations along multi-stop paths.

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[99] OpenLayers is available at http://openlayers.org/ (Retrieved 2010-08-02)
[100] David Zwarg fixed the so-called *date line bug* in OpenLayers. To read about his fix see http://openlayers.org/pipermail/users/2009-June/012505.html (Retrieved 2010-08-03)

Stylized drawing of a supply chain (left) as compared with the actual routes taken (right). More realistic routing is being developed to accurately reflect distances, modes of transport and their relative environmental impacts.

This detailed routing impact calculator –the first of its kind– will require significant computation on the part of the client (the computer running the browser). Adding another challenge to the mix, GIS experts will investigate ways to leverage the computer's graphics hardware to take on these additional calculations.[101] With the ability to make highly precise route calculations on client computers, a world of applications opens up. The choice of locations and shipping lines will be informed by fuel, time and environmental costs – all of which are related. One potential application is an optimizer that takes into account a group of people and determines the greenest, cheapest and nearest location for them to meet.

Logistics

Now that sustainability experts are converging on supply chains to reduce social and environmental risks, logistics professionals will play an increasingly important role in sustainable design. Supply Chain Management is concerned with reconciling supply and demand across networks of companies. Product demand is met through a network of distribution centers, warehouses, manufacturing plants and suppliers. A Bill of Materials (BOM) describes each product to be manufactured in terms of its constituent parts. Parts are sourced, assembled into finished products and distributed to consumers in response to shifting demands while avoiding excessive costs. The scale and complexity of these systems can make them difficult to optimize, but novel interfaces have been applied to making supply chain modeling a more intuitive
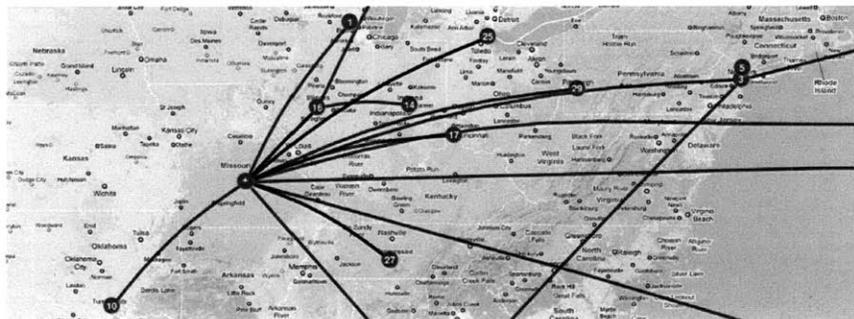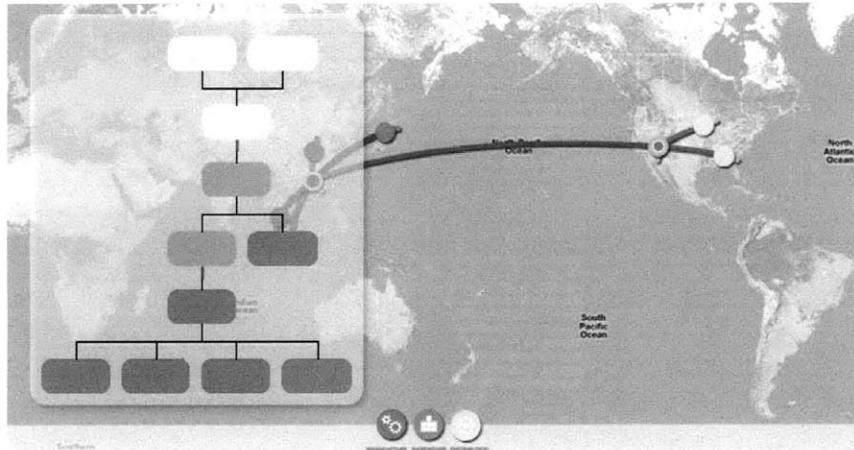
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[101] For more information on GPU computing for GIS visit http://www.azavea.com/blogs/labs/2010/06/what-the-heck-is-gpgpu/ (Retrieved 2010-08-03)

and collaborative activity.[102] In a simulation modeling approach called *Construction by Replacement*, links in a supply chain can be directly manipulated and the effects on supply and demand gauged in real-time. Until recently all of this work was conducted through spreadsheets or abstract diagrams; with Sourcemap supply networks can be mapped using familiar visual metaphors. This creates the opportunity to optimize plant locations and shipping lines or to plan for parameters including time zones, weather and natural disasters. The underlying calculators are modular so that they can account for carbon footprint as well as for fuel cost, time to delivery and product volumes, which are all proportional to weight, distance and speed.

A large touch-screen version of the Sourcemap platform is being developed in collaboration with logistics experts to support collaborative design of supply chains informed by environmental and social parameters. The software is being expanded to support traditional BOM's, often expressed in the form of *recipes* and *tree diagrams*, different kinds of 'stops' to describe sources, manufacturing locations, distribution centers and clients, and multi-stop paths that more accurately reflect complex shipping logistics. This new supply chain management platform could become useful for multi-stakeholder initiatives where groups present their respective concerns –whether social, environmental, or economic– and try to reconcile them through a common approach. The large touch screen suited to group presentations would remain based on a web infrastructure so that remote participants can contribute at the same time.

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[102] Hines, James H, Malone, Thomas W, Herman, George, Quimby, John, Hoye, Mary Murphy, Rice, James, Goncalves, Paulo, Patten, James and Ishii, Hiroshi. Construction by Replacement: A New Approach to Simulation Modeling. System Dynamics Review 2010. DOI: 10.1002/sdr.437 Available at: US: http://dx.doi.org/10.1002/sdr.437 (Retrieved 2010-08-03)

Prototypes of new Sourcemap features targeted at logistics professionals: a BOM is displayed as a tree diagram on a large touch-screen map (top); a drag-and-drop supply chain map supports multi-stop paths for individual parts (bottom)

New Directions

Sourcemap resulted from a participatory design process with dozens of people over two years: students, entrepreneurs, environmental and software experts, and users from many walks of life. Working with new groups informs the development of features to engage them as stakeholders in sustainable design. This section identifies new target groups and entry points for participation.

I. Students

a. Primary and Secondary

A pilot study in Fall 2010 will explore the integration of source mapping with sustainability, history and science curricula while imparting web research skills. Special attention will be taken to respect the privacy of students.

b. Design and Engineering

Two graduate product design classes will be taught in Fall 2010: a fashion design class with special focus on ethical issues in garment supply chains and a product design class concentrated on appropriate technology. Web documentation including sourcemaps will be used to present strategies for technology integration, design, marketing and sustainability.

c. Business

i. Entrepreneurship

Entrepreneurial development students will collaborate with the Sourcemap team to find ways to pitch their business plans through self-documentation of ethical and environmental impacts.

ii. Marketing

Pilot studies are under way to investigate the application of Sourcemap to websites of socially and environmentally sustainable companies as part of marketing and traceability.

iii. Operations

The logistics version of Sourcemap is being piloted with two classes of graduate students as a way to graphically document supply chain practices to determine potential costs, risks and alternatives.

II. Journalists and NGOs

Investigative research is under way to integrate the Sourcemap forum with the work of journalists and NGO's who have historically played an essential role in identifying neglected aspects of supply chains. The site can be used to make basic assumptions about provenance of materials and their environmental impact, which could help identify potential conflicts. A class of journalism students will use the platform as a forum for documenting the impacts of industry practices.

III. Enterprise

a. CSR/SER

Corporate Social Responsibility/Social and Environmental Responsibility professionals introduce sustainability practices within organizations through a form of internal activism. While pilot studies focused on preparing presentation materials, further studies will consider large industrial ecosystems of suppliers and global companies to identify short-term benefits from supply chain transparency.

b. Logistics

As part of the industrial ecology study, a group of companies will disclose sourcing geography so that collective strategies can be identified to minimize costs, delays and environmental impacts in logistics.

c. Quality & Compliance

Proposals are being drafted to assist large-scale quality assurance through public-facing traceability, including single-unit labeling with optical bar codes that would allow product to be 'checked in' at any point along the supply chain, use and end-of-life.

Conclusions

The Right to Be Informed

The Consumer Bill of Rights advocates for "the right to be informed: to be protected against fraudulent, deceitful, or grossly misleading information, advertising, labeling, or other practices, and *to be given the facts needed to make informed choices.*"[103] As the social and environmental impacts of industrialization become increasingly evident, consumers need to understand the sustainability of their actions. The need to *make informed choices* grows more important with every step up-stream in a supply chain: retail consumers have influence over their personal footprint, but manufacturers determine the footprint of every product they supply. How can industrial and end-consumers become informed of the impacts of their choices? Sustainability is a complex measure that varies by time and place; products that are sustainable for one consumer may not be for another. Fortunately, these impacts can be estimated from the supply chains underlying mass production. Total transparency about supply chain practices enables consumers at every step to make informed choices about the products –or components, or sub-components– that they are buying. The *Right to Be Informed* should to be amended to reflect the importance of sustainability: we have the right to know where things come from and what they are made of so that we can make informed choices about the social and environmental impacts of what we buy.

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[103] Consumer Bill of Rights, available at
http://www.mass.gov/?pageID=ocamodulechunk&L=5&L0=Home&L1=Governmen
t&L2=Our+Agencies+and+Divisions&L3=Division+of+Professional+Licensure&L4=
Consumer+Fact+Sheets&sid=Eoca&b=terminalcontent&f=dpl_consumer_consumer_
bill_of_rights&csid=Eoca (Retrieved 2010-08-04)

An Open Approach to Sustainability

Sustainable design relies on assessments of goods and services –information that can only be amassed through the combined efforts of many people familiar with supply chains. The disclosure of suppliers and processes is a reality for many industries where it serves to ensure quality and bolster consumer confidence. In others, competitors work together to prevent quality and dependability problems by auditing shared suppliers. Communicating supply chain practices can push for quality improvements and help identify efficiencies in the sourcing, shipping and reuse of materials. Certification and eco-labeling are useful in establishing best practices, but they work through a closed system, so it is impossible to verify or disseminate successful strategies. An open communications platform can gather the contributions of diverse groups, including environmental and supply chain experts, governments, NGO's, producers and other communities affected by industrial production. The multi-stakeholder approach has the potential to scale up monitoring and verification to account for more steps in supply chains. But the more powerful open approach depends on supply chain transparency: only once companies begin to hare the information behind their supply chains will sustainable practices become the new standard for excellence.

Verification

This thesis takes a democratic approach to sustainability assessment where individuals put forward their interpretations of impacts based on what they know about industrial supply chains. How can we know if individual assessments are accurate? A crowd-sourced approach –like Wikipedia– is at risk of information vandalism. But the problem of "Garbage in, garbage out" –that data is only as good as its source– also plagues private, industry-funded sustainability assessments. Unlike proprietary studies, an open source and open data approach makes it possible for the underlying raw data to be verified by third parties. In Wikipedia, every change to an article is documented so that it's possible to revert to an accurate revision and block the offending user. In Sourcemap, every bill of materials can be specified down to the address of supplier sites and the impact of each process so that it's possible to verify every aspect of a supply chain. Base values are linked to a reference library of peer-reviewed publications. The underlying code is itself transparent, including the life-cycle assessment calculations. The transparent approach fosters good faith contributions and vandals can be easily identified and discredited. As more data is compiled, new algorithms and ratings will need to be introduced to assign confidence ratings for user-generated content. Contributors who have established a good reputation will be sought after to help correct and complete other assessments. By extending the domain of sustainable design to many new participants, it should be possible to map industrial ecosystems at a scale and accuracy that no proprietary system can achieve.

A Transparency Code of Conduct

Supply chain transparency is a question of probability: once commodities are mixed from a number of sources, it can be impossible to distinguish where they came from. With no way to decode the exact supply chain of a product, there needs to be a code of conduct for supply chain transparency to ensure completeness without misrepresentation. In brief, transparent disclosure needs to account for both the *knowns* and the *unknowns* of supply chains. Precise values should be described in enough detail to be independently verified. Unknown (or unknowable) aspects of a supply chain should be accompanied by a description of due diligence sufficient to identify the individuals or groups capable of filling in the blanks. Beyond that, the crowd-sourced approach may be able to contribute the missing details and bring up parameters ignored by the author. By understanding which aspects of a supply chain are precise, which are approximate, and which are unknown, it will be possible for an automated system to derive confidence ratings useful for comprehensive comparisons of goods and services.

Source Mapping

How can source mapping –a collective answer to *where things come from*– be applied to other domains? Supply chain maps depict inheritance, a process which is central to fields ranging from biology to art history. Like sourcemaps, inheritance maps benefit from collaboration: every link that gets added to the chain gives a more complete picture of the whole. Over the course of this research, I re-discovered a fascination with origin stories; judging from the reception this work has received, it is a fascination shared by many. And for good reason: if understanding where things come from is essential to knowing their impacts –on society, economy, and the environment– for generations to come; then understanding where things come from is a necessary step in the process of finding out where we are going.

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