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Reducing Environmental Impact in Procurement by Integrating Material Parameters in Information Systems: The Example of Apple Sourcing

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ABSTRACT

Legislation, customer pressure, and energy costs are increasing the interest of enterprises in environmental performance indicators such as greenhouse gas emissions and energy usage. Currently, business users take decisions across the value chain, from product design to disposal, without the ability to compare the environmental impact of alternatives within their information systems, thus limiting the optimization potential. In this paper we consider procurement as an example business operation and show how capturing previously-unknown material parameters in the respective information system can significantly increase the achievable optimizations. We use apple procurement into the U.K. to illustrate the paper's idea, and conduct Monte Carlo analysis to quantify the realizable impact reductions as each additional life cycle parameter is tracked. The results show that taking into account the production country alone achieves a decrease in energy consumption of around 1250MJ per ton of apples, equivalent to 28% reduction from the base case.

Keywords

Environmental purchasing, green procurement, material footprint, apple sourcing, Green IS.

INTRODUCTION

Companies across various industries are increasingly monitoring the environmental impact of their products and operations, focusing on energy and carbon as prominent environmental performance indicators (Carbon Trust, 2006). They typically use home-grown spreadsheet-based tools or special-purpose carbon accounting software to create their emission inventories and assess their product footprints (Matt, 2010). Prominent solutions include Carbon Impact, Carbon View, Carbonetworks, SimaPro, and GaBi. However, the current environmental accounting practices are still typically an annual exercise separate from daily enterprise operations (Ranganathan, Corbier, Bhatia, Schmitz, Gage and Oren, 2004). Specifically, business information systems do not show decision-makers across the product value chain the environmental impact of their decisions, let alone provide the capability to evaluate alternatives with respect to these impacts. This latter shortcoming has direct consequences on concealing environmental optimization opportunities because the user is not presented with the impact of each alternative. Even though this is generally the case for several business operations e.g. product design, logistics, and even people mobility, this paper will focus on material procurement as a particular application area with high economic and environmental leverage (Chien and Shih, 2007).

Companies procure the materials they need for manufacturing – including raw materials and semi-finished components – from available suppliers, and rely on logistic service providers for inbound delivery into the production plants. Because of many variations in the material life cycle (e.g. country of origin), distinct "instances" of the material generally have significantly different carbon and energy footprints (Blanke and Burdick, 2005; Milà i Canals, Burnip and Cowell, 2006; Milà i Canals, Cowell, Sim and Basson, 2007). If procurement information systems can provide the differences in environmental impact among material instances, the business user would be able to select, say, the less carbon-intensive alternative (assuming all other criteria are equal). However, these differences cannot be currently presented because they are due to variations in material parameters that aren't captured by the procuring company's information systems, e.g. supplier's

production location. Once the differentiating parameters are tracked in information systems, the reductions could be discovered and leveraged by the implementing companies. This paper illustrates this by taking the procurement of apples (as an example of seasonal produce) for a food company in the U.K. that in turn uses them as part of its recipes, e.g. apple juice, apple pie, etc. We deduce from literature the parameters that need to be captured and then quantify, using a Monte Carlo study, the realizable reduction in lifecycle energy as each additional parameter is tracked: country of production, month of production, and cultivation orchard. The results show that tracking the country of production alone reduced the impact by 28% from the base case.

First, we provide a review of state of the art carbon accounting pilots in addition to business and information systems literature that deals with "green" procurement. An overview of papers dealing with apple life cycle variations is then presented and used to build a model showing the dependency between life cycle parameters and different impact stages. We present the simulation study and discuss its results, before concluding with a summary and an outlook to future research.

LITERATURE REVIEW

Product-level Carbon Accounting: Methodologies, Pilots, and Solutions

The carbon footprint pilots and methodologies that we will summarize here are mostly based on life cycle assessment (LCA), a methodology that quantifies the environmental impacts of products. Usually, the entire product lifecycle is considered, from resource extraction over production and use until disposal. In an LCA, an inventory of energy and material flows related to the product is built. In a next step, resources and emissions are related to impacts such as pollution or resource depletion, and are typically expressed in the form of indicators, e.g. CO_2-equivalents for climate change.

The Carbon Trust developed the Publicly Available Specification 2050, an LCA-based methodology for estimating the carbon footprint of products (Carbon Trust and DEFRA, 2008). Currently the most prominent methodology for this purpose, the PAS2050 suggests a five-step approach to calculate carbon emissions. (1) A process map is built that includes all the emission-causing activities in the product's life cycle (2) The system boundaries, which determine what to be included in the study, are then defined. (3) The next step is to collect the required data from different partners or LCA databases. (4) Emissions are calculated for each process as an activity data multiplied by an emission factor, and then added up into the total product footprint. (5) An optional last step is an uncertainty analysis. In addition to the PAS2050, two ongoing standardization efforts are worth mentioning: the "Product and supply chain greenhouse gas protocol" (by the World Resource Institute & the World Business Council for Sustainable Development) and the ISO 14067 - TC207/SC7 working groups, both of which are expected to be concluded by the end of 2010 or early 2011.

The above-mentioned efforts aim to meet the increasing industry demand for such methodologies. Companies, especially from the consumer goods industry, are conducting pilot projects to assess the life cycle impact of sample products. For example, the Carbon Trust is applying its methodology in with several companies, including Coca-Cola, Cadbury Schweppes, Kimberly-Clark, and Tesco (Carbon Trust, 2008). The Product Carbon Footprint project in Germany also included several consumer goods companies who calculated the impact of pilot products on climate change (Thema1, 2008). Legislation is providing a strong driver for carbon labeling in France where companies are requested to label products with a carbon indicator. For example, Casino, the French retailer, is working to put a carbon label on 3000 of the products it sells.

Companies generally follow one of four solution approaches to perform their carbon accounting. First, spreadsheet-based home grown solutions are widely used, especially when companies are still in an early learning phase. Second, special purpose, stand-alone carbon accounting tools are gaining in popularity, e.g. SAP Carbon Impact, Carbon View, and Carbonetworks. Third, some companies are customizing traditional enterprising costing tools, e.g. SAP Performance and Cost Management and Oracle Hyperion to fit the new need of environmental accounting. Finally, specialized LCA tools such as SimaPro and GaBi are widely used for detailed product-level impact analyses (Matt, 2010). Fulfilling an environmental accounting task is the common end of all these approaches, however what the state of the art lacks is allowing traditional business solutions – where the end is to fulfill a business need, e.g. purchasing – to compare the environmental impact of different alternatives.

Environmental Purchasing

Environmental purchasing (EP) "is the set of purchasing policies held, actions taken, and relationships formed in response to concerns associated with the natural environment" (Zsidisin and Siferd, 2001). We provide in this section an overview of this field, showing that while management research has pointed to the importance of considering environmental criteria in purchasing, 'Green IS' is still lagging in concrete systems approaches with quantifiable benefit.

The EP literature falls under one of three research themes. First, authors studied the conditions and drivers that lead companies to adopt EP. Some of the most important factors that were seen as influencing companies in this direction were strong supplier integration (Carter and Carter, 1998; Bowen, Cousins, Lamming and Faruk, 2001), corporate-level endorsement (Bowen et al., 2001), and stricter regulations (Min and Galle, 2001). The second theme of EP literature mostly comprises case studies show how companies actually integrate supplier's environmental performance in their purchasing decisions (Handfield, Sroufe and Walton, 2005; Koplin, Seuring and Mesterharm, 2007), in addition to conceptual models and frameworks to guide firms in future EP practices (Handfield, Walton, Sroufe and Melnyk, 2002; Humphreys, McIvor and Chan, 2003). Most of these works focused on supplier-level environmental performance rather than material-level considerations. The third research theme we identified is that of discussing the benefits (Green, Morton and New, 1998) and evaluating the economic and environmental impact of EP practices on the adopting firm (Chien and Shih, 2007). Product-level environmental indicators such as the carbon footprint haven't been a focal part of EP literature and practices until now.

As opposed with the significant body of EP business research, there is only very few IS papers that aim to address the issue with concrete applications in this area. This is due to a bigger emphasis on Green IT (decreasing the environmental impact of IS) rather than Green IS (employing new IS applications to decrease environmental impact across industries) (Boudreau, Watson and Chen, 2008). Only recently are authors investigating the latter, especially via papers that map out an IS research agenda to address the environmental sustainability challenges (Melville, 2010; Watson, Boudreau and Chen, 2010). These works provide a good start for Green IS research but are still not comprehensive enough to address many of the important business areas. This paper contributes to filling the gap in Green IS research, specifically in the domain of environmentally-aware procurement. We address the previously-mentioned shortcoming in current information systems: the apparent lack of capability in comparing different supply options of a particular material with respect to their environmental impacts. This can be mitigated once the necessary material lifecycle parameters are captured, and this paper quantifies the realizable optimizations with a concrete example.

LIFE CYCLE PARAMETER ANALYSIS: EXAMPLE OF APPLE SOURCING

Variations in environmental impacts (among instances of the same material) occur because of seasonal changes in agricultural produce, sourcing of materials from different suppliers, transport and storage of products during upstream logistics, etc. When these variations become transparent, companies can take informed decisions, e.g. from which supplier to source a particular material or component, resulting in significant reductions of the total impact. However, this is difficult in practice because the variations are due to parameters which are not captured in the sourcing company's information systems. For example, a company producing orange juice purchases oranges (among other ingredients) from different suppliers. The information systems of the orange juice producer identify oranges as a material with a unique identifier, but they don't track any life cycle parameters that cause significant variations in life cycle environmental indicators. Such parameters include the country of origin, production season, transport route, storage duration, etc. Technically, several of these parameters can be tracked, either at the batch-level or using more sophisticated track & trace infrastructures. Since tracking each additional parameter will incur an overhead, we should investigate which parameters will lead to the most reduced impact. This section takes apple sourcing as an example to illustrate which parameters could be tracked to reduce carbon emissions and energy usage. We first review the literature that deals with environmental impact variations of apples.

Life cycle environmental impacts of apples

This subsection provides an overview of the studies that dealt with energy usage and/or carbon footprint of apples, in particular those that compare different scenarios showing the variability in the respective environmental indicators. Based on the findings from literature, we will derive a model in the next subsection that explains the dependency between life cycle parameters and the environmental indicator variability.

Mason, Simons, Peckham and Wakeman (2002) calculate the carbon emissions due to transport of the three possible sources of apples to be consumed in the UK: local, Europe, and New Zealand. The results were 31, 85, and 167 gCO_2/kg apples. Jones (2002) analyzed different transportation systems for apples consumed in Brixton and Denbigh, UK. The energy consumed ranged from 0 up to 17.75 MJ, while carbon emissions ranged from 0 up to 1000 g CO_2/kg. Both research works emphasized the importance of origin of apples in determining the transport energy, but didn't include other life cycle burdens in the analysis, e.g. cultivation or storage energy.

Blanke and Burdick (2005) went beyond transport and included the cultivation and storage energy required for apples sold in Germany. They compared the energy needed to import apples from New Zealand (7 MJ/kg apples) with that of storing German apples until March (5.9 MJ/kg). Saunders, Barber and Taylor (2006) confirmed that relying on food miles only is

over simplistic: New Zealand apples compared favorably to UK ones, mainly due to less energy-intensive production in the former and six month storage in the latter. Neither paper considered various consumption season scenarios.

Milà i Canals et al. (2006) showed significant variations in the environmental impact of apple cultivation among different sites in New Zealand. Sim, Barry, Clift and Cowell (2007) studied imported and local (UK) food systems to determine the relative significance of transport. For the case of apples, transport contributed 72% and 90% of the carbon footprint of imports from Chile and Brazil as compared to 30% for Italian apples and 6-21% for UK ones. Also cultivation impacts were noted to be country-dependent.

Milà i Canals et al. (2007) took the broadest view so far in considering different scenarios for variations in apple life cycle environmental impacts, focusing on energy consumption. The authors considered four possible origins of apples to be consumed in a particular European country: local, European, New Zealand, and a different southern hemisphere country. They also considered four different months of consumption, thus determining the seasonality of the apples. While the country of origin determined the range of possible transport energy, the seasonality determined the duration of storage and the wastage in apple produce incurred. Figure 1 shows the range of variations in the total energy usage for each of the resulting cases.

This subsection provided a literature summary of the variations between apple sourcing options. The insights provided regarding which factors contribute to which emission sources will be used to build a model of the interdependencies between the parameters and the impact areas.

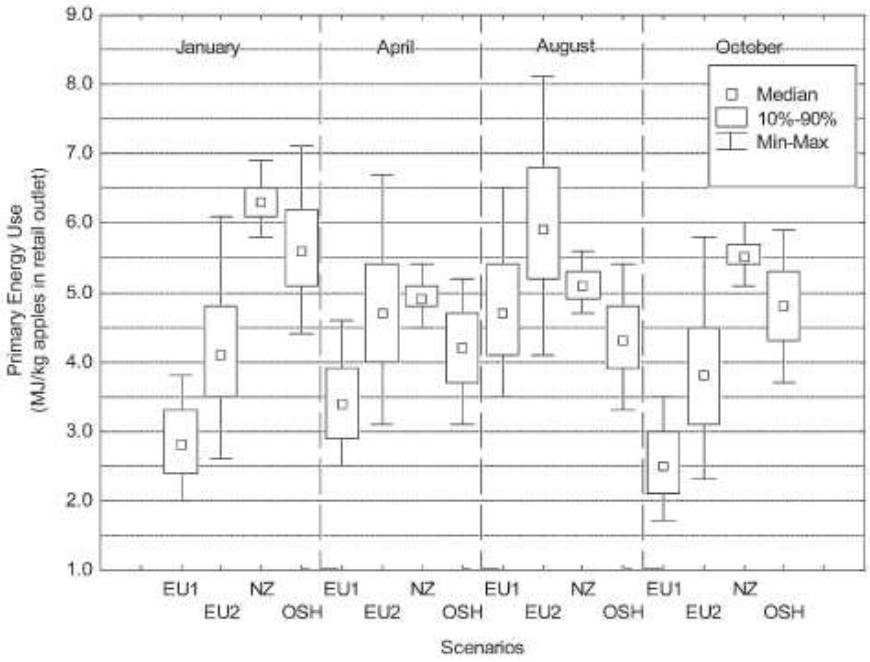


Figure 1. Ranges of apple energy requirements in different scenarios (Milà i Canals et al., 2007)

Parameter-dependency model

Based on the insights provided by the literature review, we derive the model shown in Figure 2 that shows which apple parameters influence what parts of the environmental impacts. The model comprises emissions resulting from four stages of the apple lifecycle, namely cultivation, transport, storage, and additional production due to wastage. The latter was modeled by Milà i Canals et al. (2007) who explained that longer storage periods that aim to extend the apple season result in wastage which in turn results in a higher produced quantity to reach, after wastage, the required quantity to be consumed. The model neglects the environmental impact due to packaging because of its limited variations (Milà i Canals et al., 2007). The literature review showed that the energy used and greenhouse gases emitted during apple cultivation vary depending on the country of production (Blanke and Burdick, 2005, Saunders et al., 2006, Sim et al., 2007) and even in the same country depending on the orchard (Milà i Canals et al., 2006). Transport emissions were shown to depend mostly on the combination of country of production and country of consumption. This is expected as food transport between two countries is typically done using the same mode (e.g. road vs. ship vs. air) which, together with the distance, are the two most influential

parameters in determining transport emissions (Hickman, Hassel, Joumard, Samaras and Sorenson, 1999). Storage emissions are mostly determined by the time during which apples need to be stored in a controlled atmosphere before consumption. This period varies depending on the season during which the apples were produced in the country of origin and the consumption date. Since the seasons depend on the production country and time of the year, the storage emissions will be mostly a result of the three parameters shown as shown in the model: production country, production date, and consumption date. Finally, the wastage is mostly a result of the storage duration. Wastage results in more produce to satisfy the same apple output, thus indirectly contributing to the total impact per kg of apples consumed.

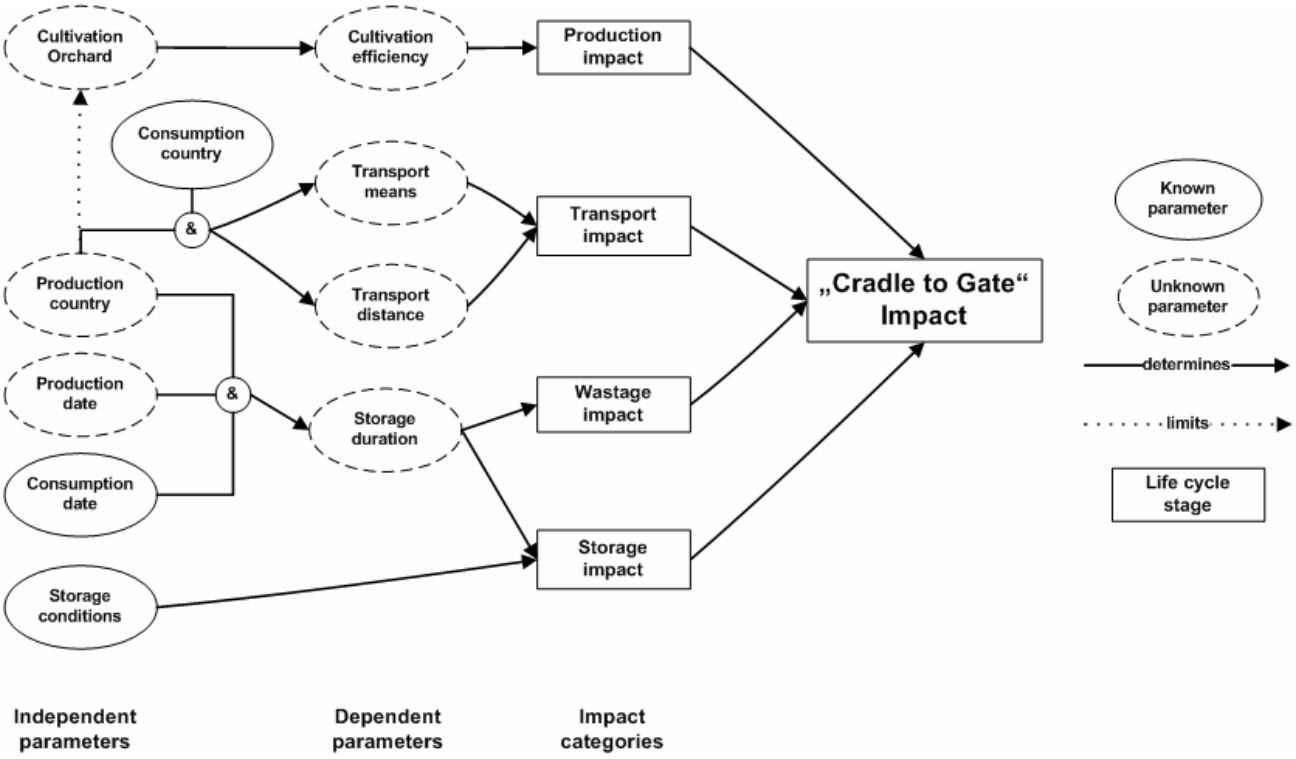


Figure 2. Dependency model between apple production parameters and energy/carbon impacts

In our scenario, a consumer goods company sources apples to use them in several of their recipes, e.g. apple juice, apple pie, etc. Since the company is aware of the country where it is using the apples and the procurement period, the respective parameters in the model are marked as "known parameters". However, if these are the only two known parameters, the model shows that none of the four emission sources is determined, i.e. the variability associated to each one of them, and thus to the total impact, is maximum. This reflects the current situation facing consumer goods companies, even from a system's perspective: since there is no need until now to capture such product parameters, all (apple) instances are treated uniformly with a single unique identifier. To make the variations visible and thus discover impact-reduction opportunities, such parameters should be captured. The model in Figure 2 marked three such independent parameters that are currently not tracked and that affect different life cycle impacts: production country, production date, and cultivation orchard. These can be treated as batch-level data by information systems. For example, if a company wants to track the production date of apples, it would ask its suppliers to identify the produce of each month with a different batch number (we don't need a granularity finer than one month to identify the season). That way, apples produced in January and those produced in June would be uniquely identifiable to the consumer goods company. The next section will present a Monte Carlo study that quantifies the reduction in energy consumption as each additional one of the parameters identified is captured.

MONTE CARLO ANALYSIS

This section presents a simulation study that aims to answer the question "how much reduction can companies achieve in energy usage of apples when they track (1) their country of origin, (2), date of production, and (3) cultivation orchard". We first describe the experiment and then provide the results and comment on them.

Experiment description and results

Each simulation run starts by picking a random sourcing date of the year, thus fixing the "consumption month" parameter in the model. Then, alternative apple batches are generated which have different values for the independent parameters. We adopt the example apple production countries used by Milà i Canals et al. (2007), the latest and – to our knowledge – most comprehensive paper on apple environmental impact data:

- EU1: the European country where the apples are used
- EU2: a different European country
- NZ: New Zealand
- OSH: other southern hemisphere country

We also adopt the paper's representative, minimum, and maximum values regarding apple cultivation energy in these countries, transport energies per km, distances, and storage energy per day. For each generated apple batch we first select one of the production countries, and then we sample values for the other parameters depending on their probability distribution pertaining to that country. The result is a realistic "basket" of sourcing alternatives with known energy consumption. The company must pick one of the alternatives available in each simulation run. The company decision-making process depends on the information available to it. To quantify the added value of each tracked parameter in terms of reduced impact, we considered four scenarios:

- S1: Base case scenario that reflects the current situation: none of the three unknown parameters being tracked. The company chooses randomly among the alternatives.
- S2: Country of origin being tracked. The company knows the country each alternative came from, which allows them to estimate the impact due to transport. Also, knowing the time of sourcing and the country of origin provides a rough estimate of the storage duration (time since apple season in production country). The company uses this input to make estimates of the energy consumption of each alternative. For the unknown parameters, it uses the mean values. Based on these refined estimates, the company will make a significantly more informed choice than in the previous scenario.
- S3: Production date being tracked (in addition to the country of origin). Tracking the production date gives companies an accurate view of the storage period which is better than the rough estimate they deduced in S2. They use this additional information and calculate the impact of each alternative according to their knowledge, also using mean values for the untracked parameters (cultivation impact).
- S4: Production orchard being tracked (in addition to the production month and country). Finally, we simulate that companies also know the production orchard and can thus make a fully informed decision simply by picking the alternative from the initial "basket" with the minimum impact.

Each scenario results in a decision taken based on the information known about the life cycle parameters. The (actual) impacts of the chosen alternatives in each scenario are added up across all simulation runs. We ran the simulation 10,000 times, accumulating the impacts from each scenario. Further runs didn't show significant changes to the results. The simulation was written in Python. Figure 3 shows the result of the analysis, expressed for each scenario as energy consumed in MJ per ton of apples. The graph shows that tracking the production country alone has the potential to reduce the energy consumption by 28% from the base case. The remaining two improvements are only marginal because most of the information is gained from the first parameter.

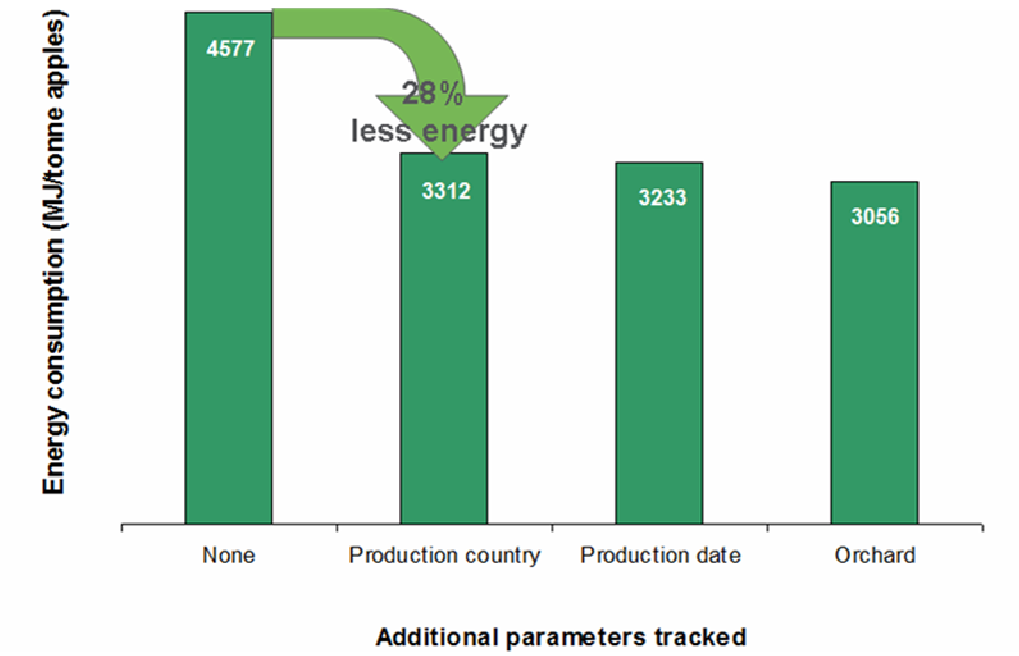


Figure 3. Energy consumption according to different tracking scenarios

Discussion and Green IS Implications

As expected, the more life cycle parameters we track, the more the variations become transparent and the easier it becomes for companies to make informed, ecology-minded decisions. The results show that although companies know very little about the life cycle of materials and ingredients they purchase, it is enough to track a few parameters on the batch level to achieve significant environmental optimizations: in this case tracking only one parameter revealed energy reduction opportunities up to 28% of the base case. This translates to direct, quantifiable environmental improvements in the purchasing function. This paper showed that there are lots of white spaces for Green IS research to enable environmental impact reduction across the supply chain and in many industries: Our literature review showed that the business and systems solutions to carbon accounting don't aim to integrate the environment into the daily business operations such as sourcing and procurement, instead they are annual or one-off exercises. Integrating the environmental impact of materials into purchasing decisions would allow companies to opt for the less carbon-intensive alternatives, thus achieving optimizations in their daily operations. The Green IS research field can contribute by adapting the traditional enterprise systems, e.g. the supplier and material management components, to make the differences in environmental impacts visible. This "benchmarking" of different supply options requires more information from the material's life cycle stages which is currently not available in today's information systems. This paper is a first step in this direction with the ultimate goal of continuously reducing ecological impact of businesses via integrating the environment into traditional information systems.

A limitation or our work is that we don't consider the relative effort and additional complexity incurred by companies in order to track different life cycle parameters. For example, we expect that tracking the specific orchard is much more demanding (technically and organizationally) than tracking the country or month of origin, but in this paper we quantify the absolute decrease in impact and not the decrease relative to the needed effort.

SUMMARY AND OUTLOOK

This paper addresses the wide issue that enterprise users responsible for material procurement don't have the ability to compare the environmental impact of alternative supply sources within their information systems, thus limiting the optimization potential. The proposed solution is that companies capture certain material-dependant parameters in their information systems, thus making the variations of environmental impact visible and the resulting optimizations achievable. We take apples as an exemplary seasonal produce and use secondary data to derive the parameters that need to be captured: country of production, month of production, and cultivation orchard. Using a Monte Carlo analysis, we quantify the reduction in energy consumption as each additional parameter is tracked. The results showed that tracking the country of production has a potential to decrease consumed energy by 28% from the base case, where as tracking the month of production and cultivation orchard have minor additional value.

In our future work, we will investigate whether our results can be generalized to cover non-food materials from different industries. Also, we plan to implement a prototypical system that allows companies to compare the environmental impacts of different supply options, even providing interfaces for their suppliers and LSPs to enter the necessary material parameter values. The system will then be tested in a realistic business environment to quantify the optimizations in practice.

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