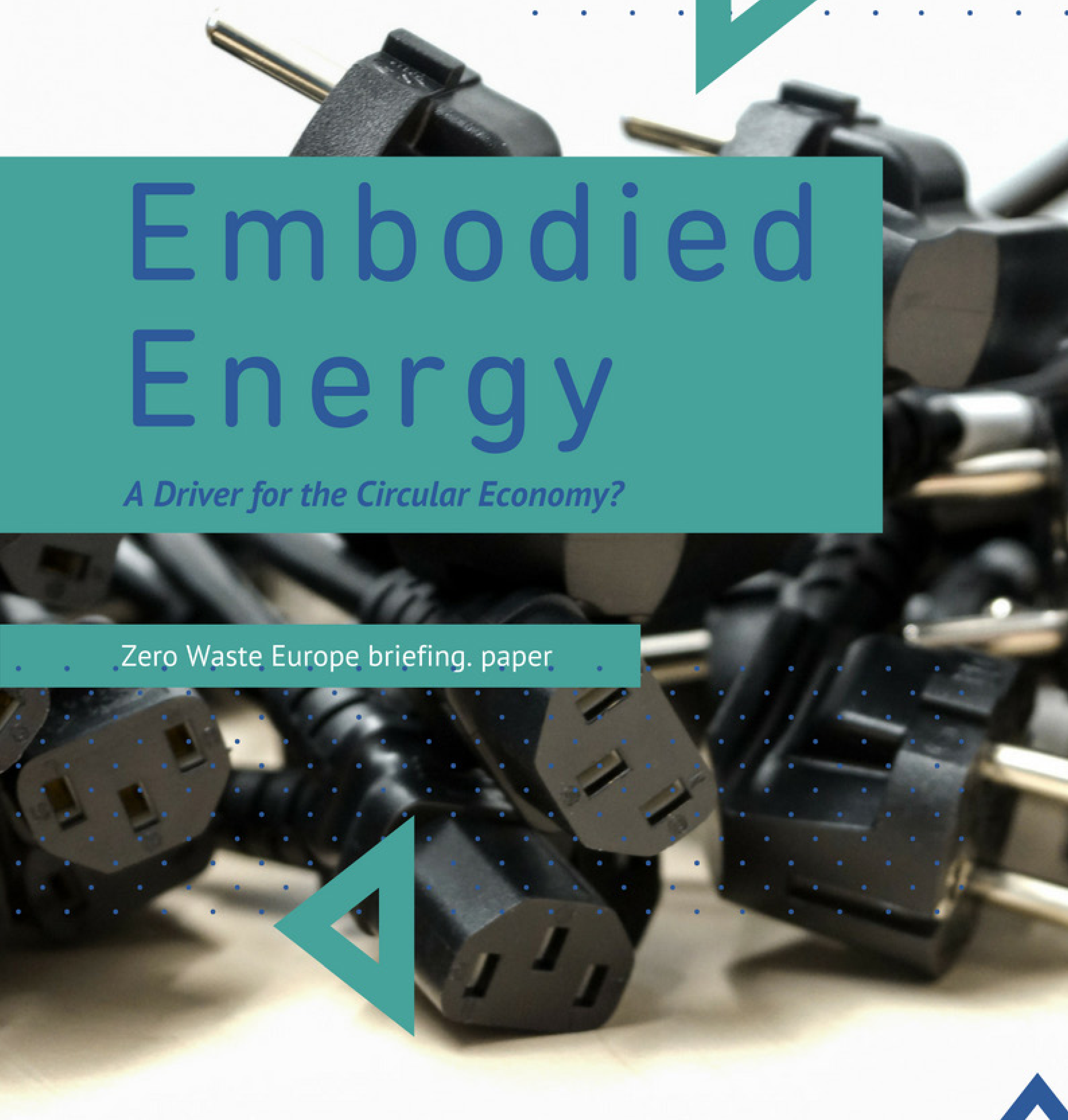
Embodied Energy

A Driver for the Circular Economy?



Zero Waste Europe briefing. paper

JULY 2017

Contents

This document was composed by Matthew Franklin, based on evidence produced by Eunomia Research & Consulting.

Contributors and authors include:

Dominic Hogg
Ann Ballinger
Simon Hann
George Cole
Matthew Franklin

Acknowledgements

Our thanks to the following reviewers for constructive comments and feedback made on draft versions of the document: Joan Marc Simon, Mariel Vilella, Delphine Lévi Alvarès, Ferran Rosa and Roberta Arbinolo.

Interior layout based on design by: Petra Jääskeläinen

Zero Waste Europe gratefully acknowledges financial assistance from the European Union. The sole responsibility for the content of this publication lies with Zero Waste Europe. It does not necessarily reflect the opinion of the funder. The funder cannot be held responsible for any use that may be made of the information contained therein.

WHAT IS EMBODIED ENERGY AND WHY DOES IT MATTER?

Why embodied energy?

The concept of energy efficiency is well developed and widely used as an indicator of the environmental impact of the products we use on a daily basis. Despite the clear value of measuring the energy efficiency of a product, there remain serious problems when accounting for the true environmental and climate change impact of a product. Embodied energy is a concept which could be greater used to fully account for the impact of a product on the environment and climate over its entire life-cycle.

When considering the environmental and climate change impacts of products we use, information such as tonnes of carbon dioxide emissions, or the direct effects of energy consumption, can be opaque and confusing. Even greater confusion is caused by the variety of different environmental impact measurements. By contrast, embodied energy can offer a relatively simple proxy for a product's environmental performance, as noted in a 2013 study by Alma García:

"Indicators based on energy flows are simple as in general they require a small amount of data compared to other indicators, and are also strongly linked with other environmental impacts (Huijbregts, Hellweg, et al. 2010)."

Recent European policy, including the Circular Economy Package, has increased the focus on the development of closed-loop systems where resources are kept in the system for as long as possible. This presents a clear opportunity for a new consideration of the energy embodied in materials and products, bringing together the policies in the fields of waste, product design, energy and climate.

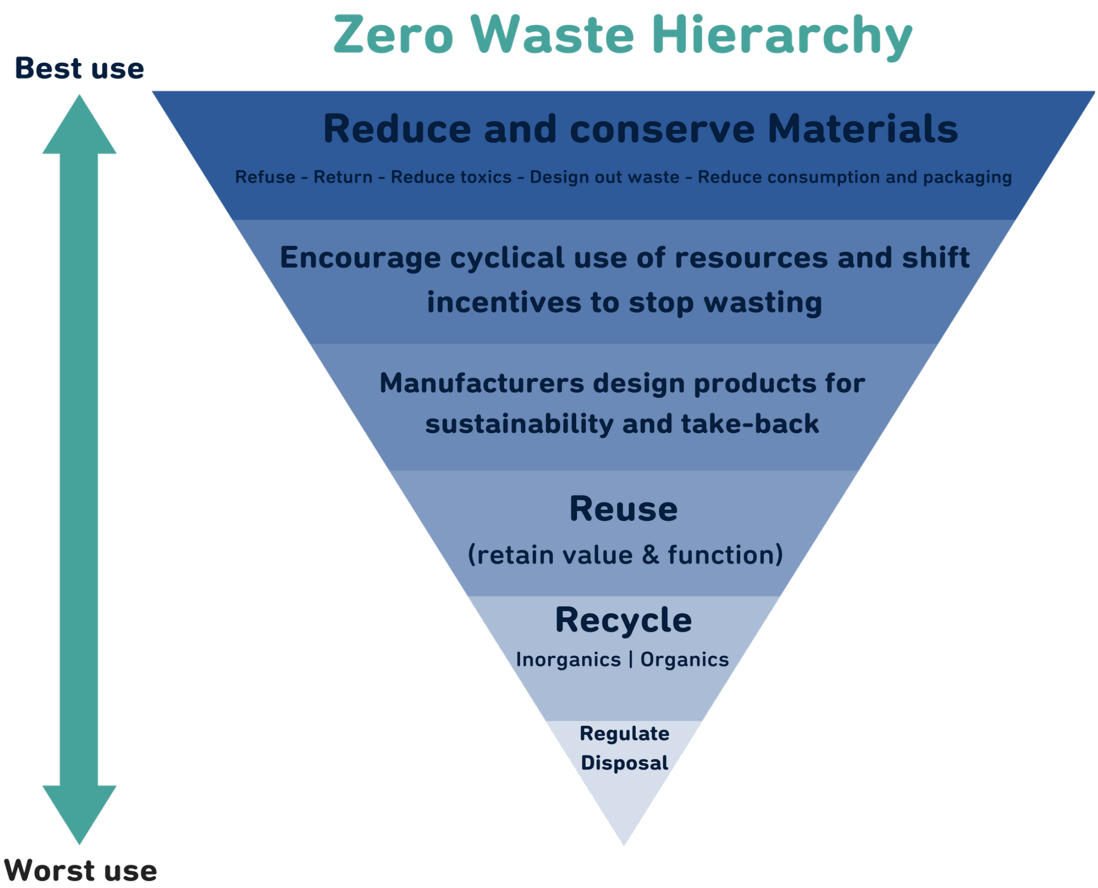
How to measure embodied energy?

The embodied energy of a product is the total energy required by that product over its life-cycle. This includes both energy from the manufacturing processes and the "embedded energy" which is present in the raw materials. Whilst many reports use the terms "embedded" and "embodied" interchangeably, there is a value in separating these components which make up embodied energy. By accounting for this total energy, it is easier to fully understand the significance of closed-loop processes and the movement towards a circular economy where materials and products are repaired, reused and recycled, rather than sent to landfill or otherwise sent for disposal.

"[Embodied energy is] the sum of energy requirements associated directly or indirectly with the delivery of a good or service"[2]

The best ways to retain embodied energy in the system correlate strongly to the upper tiers of the waste hierarchy, whereas lower tiers have a strong tendency towards a loss of the energy embodied in the product at the end of the first use cycle. It is clear that, in the majority of cases, having a product go through multiple cycles of use and reuse is going to retain far higher levels of embodied energy than the disposal or, in many cases, even the recycling of the product. In this regard, in lieu of the technical data for each product or product category, the waste hierarchy can act as a suitable substitute in deciding the best approach for dealing with the product.

1. Garcia, 2013. 'Resource Efficiency Indicators for EU Product Policy-Embedded Energy in Washing Machines' EEB.
2. https://www.ice.org.uk/disciplines-and-resources/briefing-sheet/embodied-energy-and-carbon



There are several methods for measuring embodied energy, which can produce different kinds of indicators. These different indicators can serve different purposes from a policy perspective, and offer different insights into the intrinsic characteristics of a product. Embodied energy is most simply calculated based on data from life-cycle assessment studies, using indicators such as cumulative energy demand. From this starting point, it is then possible to produce a number of different types of indicators, based on the type of energy that is included within the calculations. For example, it is common to focus solely on the fossil fuel energy sources, and to account for renewable energy separately. It is also necessary to convert different types of energy into equivalent forms, which is typically done by expressing the output in terms of the amount of primary energy.

Primary energy is the energy content in materials that are extracted from nature without changing the physical and chemical characteristics of the energy source, e.g energy from hard coal, natural gas and crude oil.[3] Secondary energy, on the other hand, is the energy that remains after the energy source has been subjected to anthropogenic transformations, e.g. energy in the form of electricity, heat, gasoline and diesel.

Whilst it is possible and often useful to use the information in life-cycle assessments to calculate the embodied energy of specific products and materials, in some cases it might be better to create a value for a category or group of products. Where a category of waste can be generalised such as food waste, this can help provide a clearer picture of embodied energy, than would be gained by looking at the embodied energy of a specific food product.

3. Øvergaard, S., 2008. Issue Paper: Definition of Primary and Secondary Energy. Statistics Norway, Oslo

How can we use embodied energy today?

The proposals in this policy paper offer a variety of key policy proposals which would allow embodied energy to be used effectively to influence consumer decisions as well as producer design and corporate responsibility. However, these proposals also require some currently unavailable data to be made open to have the biggest impact with the greatest accuracy. Despite this hurdle, there are key policy lessons which we can draw from embodied energy that should be considered immediately.

It is clear that a greater portion of the embodied energy in products is preserved when the product waste is managed in the upper tiers of the waste hierarchy (prevention, reuse, recycling) as opposed to lower tiers of 'recovery' (such as waste-to-energy incineration) and disposal. With this in mind, from an energy perspective subsidies for the lower tiers of the waste hierarchy and primes waste-to-energy generation in the Renewable Energy Directive should ceased immediately.

EMBODIED ENERGY AND ENERGY EFFICIENCY

When it comes to thinking about products and embodied energy, it is the life-cycle of a product which becomes important. The amount of time (and the number of use-cycles) between the manufacture of a product and it's final disposal, either through incineration or landfill, is the time during which the embodied energy is preserved. Furthermore, when product waste is recycled, a significant proportion of the embodied energy is also preserved.

Some of the products which we purchase can be expected to last for many years before we get rid of them, but others can be expected to be replaced within a relatively short period. This problem of short-lived products has been exacerbated in the past few decades, with accusations of some companies creating products with 'planned obsolescence'. This artificial limit on the life of a product often encourages it to be thrown away and replaced with its newest version. This way, many products end up being incinerated or sent to landfill, resulting in an almost total loss of the energy embodied within them.

Alternatively, products which are made either to last a long time, to be easily repairable or highly recyclable, are able to maintain their embodied energy over an extended period. This means that a significant amount of waste, energy use and greenhouse gas emissions can be prevented.

By using this method it is possible to gain a clearer view of a product's environmental impact than is often provided by other commonly used energy efficiency indicators.

It is important to consider the longevity, repairability or percentage of recycled content when it comes to embodied energy. For products which cannot be repaired, are short-lived, or do not allow for much recycling, the energy embodied in them will be lost very quickly, and with incineration (even if there is energy recovery) the entire energy embodied will be lost after only one use cycle.

Product Policy in Europe

When it comes to the environmental considerations that go into the design of products, the Ecodesign Directive[4] is the primary legislative tool in use in Europe. Revised in 2009 (after having been originally implemented in 2005) the Directive established a framework to set mandatory ecological requirements for energy-using and energy-related products sold across the EU. This Directive covers more than 40 different product categories (such as boilers, refrigerators and light bulbs) which are collectively responsible for over 40% of all EU greenhouse gas emissions.

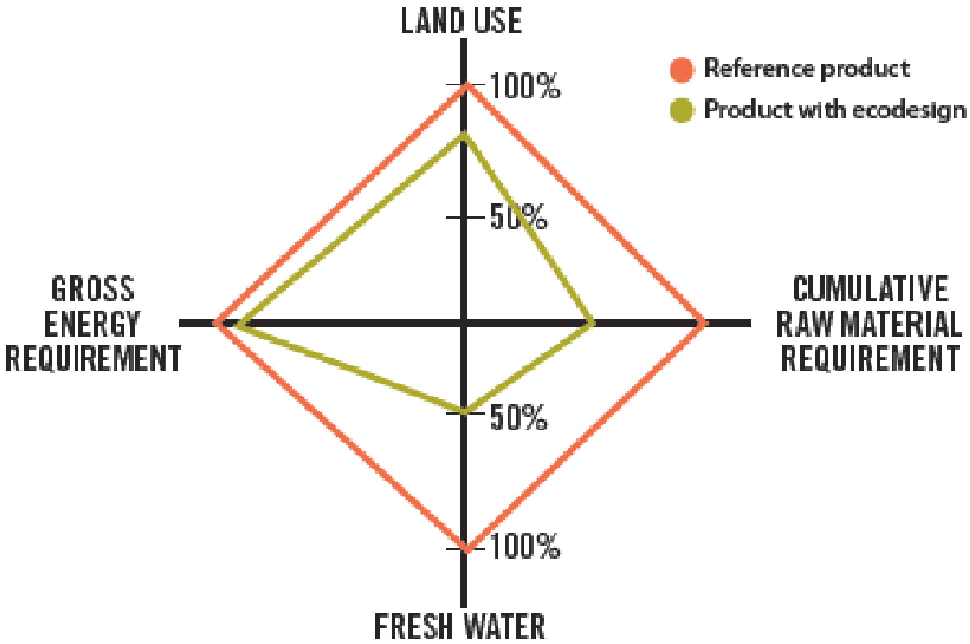
Whilst it has always been intended for this Directive to address resource efficiency through the life cycle of a product, in practice it has focused on energy related products (ErP)—products which use energy either directly or indirectly (this evolved from simply energy using products). The Directive has been implemented as a set of product-specific Regulations which cover computers,[5] televisions, vacuum cleaners and other, mainly domestic, products. The Regulation for computers, for example, focuses entirely on energy consumption during use (based on Energy Star requirements), including specifications for power usage during standby and sleep modes. The attention of the Eco Design Directive has therefore been on those products where energy consumption during use is expected to account for a significant part of the environmental impact over the life of the product. Several methods of incorporating environmental performance indicators into product design have been proposed over the years – a trend is to focus on simplicity without over simplifying to the detriment of providing spurious guidance. This is more difficult than it would first appear, and requires a significant amount of background data and analysis in order to distil a few simple metrics. Figure 4 from a report by the European Environmental Bureau (EEB) shows

4. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009L0125

5. http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0617&from=EN

one such approach using a 'multi-dimensional compass' to assess the relative environmental improvement of four indicators, including energy. Product performance is compared to a reference product, and the focus is on improving the impact indicators without detrimentally affecting the others. It does place equal importance on each indicator, however, and therefore limits technical solutions that would be acceptable. In practice, the reference product[6] could be the industry average (itself a moving target); such a model could be used to identify the worst products on the market for a possible ban.

In this case, four indicators were used to consider environmental performance. There is a need to consider whether, for specific products a focus on embodied energy would lead to detrimental performance in the other indicators.



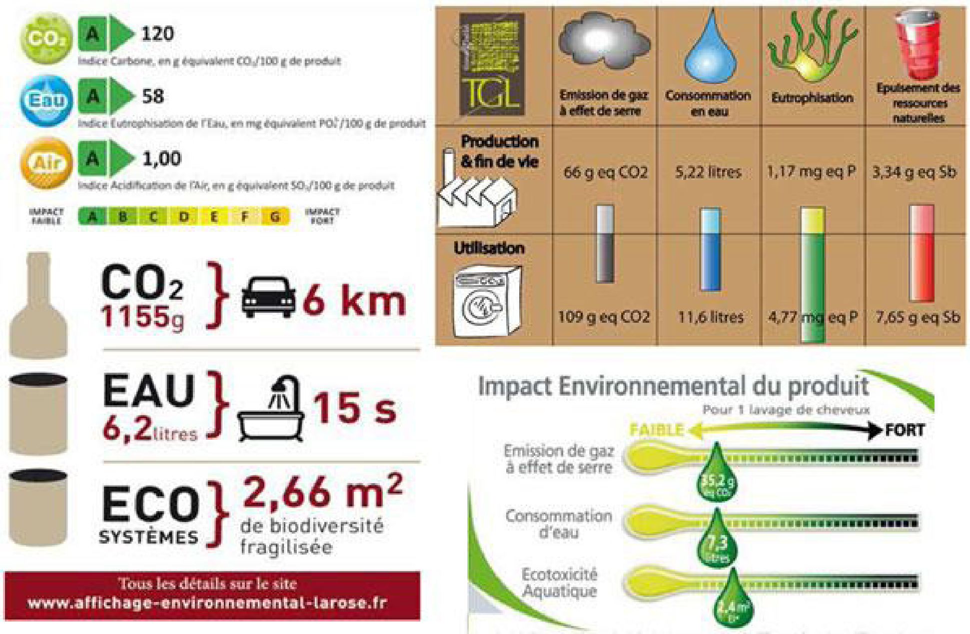
Multi-Dimensional Compass Assessment *Source: European Environmental Bureau*

6. Institut für Ökologie und Politik (2015) *DELIVERING RESOURCE-EFFICIENT PRODUCTS* - How Ecodesign can drive a circular economy in Europe, Report for European Environmental Bureau (EEB), March 2015

Is one dimension better? What can we learn from Product Environmental Footprint (PEF) Pilots?

A single indicator offers clear benefits if the aim is to create clear and informative advice for consumers. This is further reinforced in cases where the supporting data can be demonstrated to form a reasonable representation of the overall environmental impacts of a product. As we explored earlier, there is a strong case for embodied energy being an effective proxy for a variety of environmental impacts, meaning that it could form a simple and easily understandable product indicator.

The Product Environmental Footprint (PEF)[7] pilots built upon France's Grenelle II national product labelling experiment, which saw 168 companies with 1,000 products take part in a voluntary scheme during 2012. This pilot scheme allowed companies to experiment with different methods of communicating data from life-cycle assessment studies that were undertaken for their products. Figure 5 shows the results of some of the communication vehicles trialled. All of these examples includes multiple indicators (energy is not included but could easily be one of the indicators), but arguably, they do not provide a simple means for consumers to make quick, on the spot purchasing decisions based on comparisons across products.

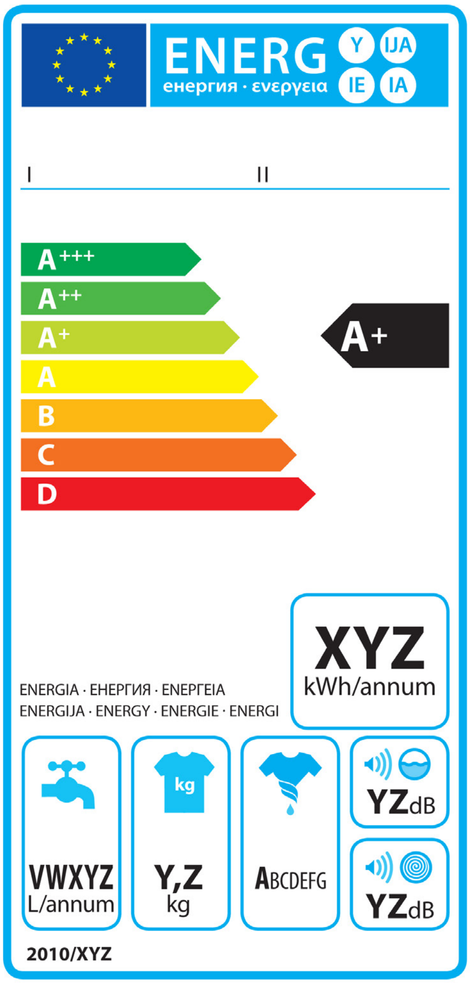


Grenelle II Communication Vehicle Examples

7. Ministry of Ecology, Sustainable Development, Transport and Housing (2010) *le Grenelle Environnement: Grenelle 2 law*, December 2010

Could embodied energy be incorporated into the Energy Labelling Directive?

Similar to the Ecodesign Directive, the Energy Labelling Directive is aimed at 'in use' energy consumption and does not consider the embodied energy in the materials that constitute the product. It is tailored towards consumers. And it is designed to help them to choose energy efficient products by providing more information on a scale from A++++ to D. The scheme was initially introduced in 1995 with a simple A-D scale, however due to the significant successive improvements stricter energy classes were added in 2010, so that there are now five 'A' classes. This more complicated new scale has somewhat undermined the original aims of the project, making it a victim of its own success. However, for some product groups most models of product now on the market are in these top classes. There is a current proposal[8] in place to 'rescale' the labels to A—G in order to help consumers understand the differences.



Example Energy Label *Source: European Commission*

A further consideration, therefore, is whether the existing Energy Label could be extended in some way to look at embedded energy. Expanding this to the whole life cycle provides additional challenges, but also interesting opportunities. It is important to recognise that, with some products where energy 'in-use' is thought to dominate embodied energy in manufacture, such as washing machines, focusing on the energy in use only can potentially lead to overlooking the negative impacts of manufacture. If more sophisticated electronics and materials are used in pursuit of a more energy efficient washing cycle, the embodied energy of the product itself may increase. It should be noted that, as the 'in use' energy declines, the embodied energy in manufacture may begin to acquire greater significance in the overall analysis.

Care would need to be exercised in developing energy based indicators that included embodied energy: washing machines, for example should be compared on a per washing cycle basis to ensure a fair product comparison, but different products are likely to have different lifetimes. This is where there may be an opportunity for an embodied energy indicator to be developed linked to product lifetimes. In principle, accelerated product testing could be used to understand how many cycles a given type of washing machine is likely to be able to deliver before breaking down. However, manufacturers have not always

8. http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1442564964643&uri=CELEX:52015PC0341

been keen to submit to such testing: in the absence of this, therefore, ratings could be linked to warranty periods that manufacturers are willing to offer to consumers.

In effect, the embodied energy and energy in use would be summed, and then divided over the time for which the warranty was offered, with this converted to an average number of cycles. The label would be based on energy per cycle, including in-use and embodied energy. Embedded energy would thus be distributed over a smaller number of cycles for the less durable products, thereby worsening their energy performance, and vice versa. This type of approach could help to incentivise durability in key products.

Six proposals for an embodied energy Indicator

Option 1: An embodied energy indicator could be set for municipal waste per household, on an absolute basis for European Member States.

This would be calculated on the basis of the life cycle assessment indicator cumulative energy demand. This would include all forms of energy generation (i.e., including renewable energy as well as the fossil energy demand).

The indicator figure would relate to the net impact per household from the management of the waste, thereby incentivising improved recycling, waste prevention, and energy generation from waste.

The indicator would sit alongside the existing (and proposed) tonnage based targets for the municipal waste stream. The embodied energy target would take into account materials managed as residual waste.

Option 2: Embodied energy indicators could be set for packaging waste for European Member States on the basis of cumulative energy demand.

Like the indicator in option one, this would be calculated to include all forms of energy generation. A single combined indicator could be set across all of the packaging waste streams. Although the figure could be set on a per household basis to account for waste prevention, the prevention might occur in various ways.

The suggestion here is that the indicator figure would relate to the proportion of the embodied energy in the packaging stream which is recouped by waste management. Reuse of packaging would be accounted for through appropriate reporting of the number of cycles over which packaging is reused before it becomes waste.

The indicator would sit alongside the existing (and proposed) tonnage based targets for the packaging streams. The embodied energy target should be set across all forms of packaging currently included within the Packaging Directive, to ensure there is some flexibility in meeting the target, and allowing for a focus on the higher impact materials. The indicator should take into account residual waste management.

Option 3: In addition to the above, the embodied energy indicators could also incorporate an appreciation of the level of recycled content within the packaging waste stream.

If this information (or a suitable proxy) was available, then the denominator in the equation (the embodied energy in the packaging waste stream) would be reduced accordingly, thereby enhancing the percentage performance achieved.

This would have the very important merit of increasing the incentive for the packaging supply chain to make use of secondary materials within the packaging used. This requires additional research on the feasibility of obtaining the type of data required from the European packaging industry (e.g. from the existing trades bodies).

There would also be a requirement for the development of specific datasets incorporating this data into existing measurements of embodied energy performance within the life cycle databases.

Option 4: An indicator considering climate change impacts in combination with the embodied energy impacts could be considered alongside the indicator in Option 1.

This should be considered particularly if the level of recycled content is taken into account, and assuming that benefits from energy from waste are included in within the indicator calculations. A separate indicator to that of Option 1 is required, as it is anticipated the embodied energy aspects would need to be considered on a relative basis, in order to allow the output from the two aspects to be combined. Such an approach would mean, however, that waste prevention impacts could not be properly accounted for within the indicator. The joint indicator should consider – where climate change impacts are concerned – the emissions from residual treatment, as well as benefits from recycling.

Option 5: Develop combined indicators covering embodied energy and energy in use for specific products, notably consumer electronic goods.

This would be related to the minimum warranty period which a manufacturer is willing to offer (with this converted to a standard number of 'uses', if required). The energy indicator would be designed to incentivise product durability as well as reduced energy in use, rather than focussing only on the energy consumed in the 'in-use' phase.

Option 6: Investigate the possibility of industry benchmarks on embodied energy for specific products. It might be possible to develop these with information from the Product Environmental Footprint (PEF) pilot studies which are being undertaken by the European Commission along with industry bodies.

The work on PEF (explored more in the product section of our briefing) aims to develop rules for undertaking environmental product comparisons. Current work is looking at aggregation methods for environmental impacts using the LCA methodology, but this could be expanded to consider embodied energy impacts. The work would help ensure fair comparisons are being made between products. This, in turn, would assist in the development of the industry average performance, which would be a necessary precursor to establishing product specific embodied energy performance targets.

Zero Waste Europe was created
to empower communities to rethink their
relationship with the resources. In a growing
number of regions, local groups of individuals,
businesses and city officials are taking
significant steps towards eliminating
waste in our society.
zerowasteeurope.eu