Supporting Information for

Greenhouse gas emissions from the consumption of electric and electronic equipment by Norwegian households

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Methods – details on own calculations with EuP tool

In our own calculations, a number of assumptions had to be made. "Big caps and coil" was used as a proxy for battery following the EuP study on computers, Cu winding wire was used as a proxy for cables, composite material were represented by epoxy, ferrous metals by stainless steel, glass/ceramics by glass for lamps, motor by ferrite (as in EuP study), non-ferrous metals by Al sheet, other by cardboard, plastics by a mix of 50%ABS, 25%PP and 25% PS, and printed circuit board by 90% big IC and 10% small IC. Results were compared with reference case extracted from EuP studies and there was less than 18% deviation with reference. Distribution was estimated to 5 kgCO_2e per product.

Discussion – data coverage

In four main categories of products, the lack of studies was a significant problem (Table S2): cooking appliances (1b the two products with ">1" are wet appliances), audio/video equipment (4b), small appliances (2) and electronic toys and games (8). For big cooking appliances and audio/video systems, some quite accurate average prices and good match with input-output sector enabled simulation with IO model using US2002 purchaser price model. The other items were estimated from a bill of materials, which implies that impacts connected to design and assembly are neglected. For electronic toys and games, no disaggregated sales data was available. It was not possible to evaluate how the amount in the EE-registeret was composed: plastic rich electric toys or electronic game console? The emissions vary by a factor of 3 between those categories.

Discussion – choice of electricity mix

There is a long-standing discussion in Norway about the emissions intensity of the electricity mix to use when evaluating climate mitigation measures. The Norwegian consumption mix reflects a situation where hydropower production is in excess of demand (this happens in wet years) and the Nordic mix reflects the market Norwegians buy electricity in. The argument for using a Central European or EU-average electricity mix is connected to that of consequential life cycle assessment [1]: Norwegian hydropower production or Swedish nuclear power production will not change in response to marginal changes in electricity demand from a shift in appliances. Energy saved will rather be sold to the Netherlands or Germany through one of the new sea cables. The results of our study are also more interesting when assessed with a more common electricity mix, as will be more similar to those of other countries. The Norwegian average household probably is similar in the consumption pattern of the wealthier half of the German or French population.

A reviewer suggested assessing life-cycle energy use instead of GHG emissions. This is unfortunately not possible as life-cycle energy use is less often reported in the underlying LCAs and EPDs than GHG emissions. In addition, there are problems with different accounting conventions for the primary energy equivalent of renewable electricity which make results difficult to compare.

Discussion of uncertainty

This assessment of greenhouse gas emissions of EEE consumption by Norwegian households is based on a wide range of disparate data sources. Electricity consumption data from measurement campaigns is taken to be fairly reliably, with an error margin of 25% or less for Norwegian data and 50% when EU average data was used. End-of-life carbon footprints are small. Use-phase uncertainty ranges provided relate to the emission intensity of electricity. The most important source for uncertainty is the production of the devices. Sales data can be assumed to be very robust, with less than 5% error margins, although there is some uncertainty connected to whether equipment is used by households or businesses.

Uncertainties in the life cycle inventory data for the production of EEE comes from a lack of studies for specific products (Table S2) and inconsistent results for same products resulting from different assumptions, different scope and boundaries, as further discussed below.

The wide span of LCA results for EEE production indicated by the high and low estimates in Table 2 and Table 3may reflect either real differences in the design and production of specific products and issues connected to assumptions and system boundaries. A careful literature review by Andrae and Andersen [2] suggests that it is indeed assumptions and system boundary issues that are responsible for most of the variation. It is well documented in the literature that incomplete system boundaries in many LCA studies lead to a systematic underestimation of the real environmental impacts [3]. Whether these problems exist with the LCA studies used here is not always easy to evaluate, as especially for the industry studies, because underlying data and method descriptions are not published. Based on these considerations, we would argue that the higher values are more credible. On the other hand, some of the highest values are based on production methods 10 years ago, for example an assessment of the impacts of monitor manufacturing [4], and may be outdated due to innovation. The true value of the life cycle emissions can only be revealed through verified and documented studies that have access to manufacturing data along global supply chains and employ hybrid LCA methods to avoid cut-off errors.

For several appliances, we estimated the lifecycle GHG emissions using several approaches, including material composition and material production data (neglecting assembly etc), the EuP tool, and input-output methods. For selected electronic products, estimates produced by the EuP tool were consistently and significantly below values from other assessments. The extreme case is the LCD monitor, where the EuP estimate is a factor of 10 below the value reported by Apple and a factor of 60 below [4]. For large appliances, EuP estimates are at the lower end of other studies. According to its creators [5], the EuP tool uses best and cutting edge technologies which justifies the consistently lower impact given to production. The focus of this tool is European technology in an optimistic and future related perspective. Given our LCA experience, we are sceptical about the feasibility of achieving such low emissions in the near future. EuP studies for electronic products are misleading European policy makers because they focus the attention on the wrong items, on operational energy use instead of production.

A particular item to notice is the emissions of NF_3 in the process of LCD manufacturing. NF_3 is a strong greenhouse gas (100-yr GWP=17,200) used in etching and vacuum cleaning processes, and its emission from these processes has received attention only recently [6, 7]. NF_3 constitutes about 30% of the GHG emissions from ICT products and 10% from audiovisual equipment. As NF_3 has only recently received a GWP, it is not yet included in many of the assessments. On the other hand, there has been a fair amount of attention on NF_3 and industry may already be addressing these emissions, as one reviewer suggested.

References

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Table S1: Ownership rates and data sources. For toys and games, one third in weight was assumed to be plastic rich toys, one third of hand held video games and one third of game console.

Ownership/ Household	Ownership rate	Acquisition rate, per household and year
Desktop	70%	0,052
Laptop	72%	0,47
Internet equipment	67% router 25% WLAN, 27% modem	(a)
Peripheral (printer)	67%	0,64
Scanner	37%	(b)
All in one printer	44%	(b)
Copier	25%	(b)
Total freezers	93%	0,076
Fridge freeze (combies)	66%	0,07
Refridgerators	52%	0,04
Total washingmachines	90%	0,107
Tumble dryers	45%	0,038
Dishwasher	74%	0,080
Electric Cookers/Ovens	96%	0,134
Cooker hoods	66%	0,056
Minikitchen	1%	0,001
Microwaveovens	67%	0,075
Personal care	200%	0,44
Food preparation (c)	300%	0,61
Vacuum cleaners, Iron	300%	0,55
Total color TV	200%	0,30
-hereof CRT 4:3	70%	0
-hereof LCD	100%	0,26
-hereof plasma	30%	0,058
Satellite tuners	39%	0,15
DVB-T tuners	36%	0,23
DVD players, excl. combinations	76%	0,15
Blu-ray	25%	0,014
Video cameras	32%	0,036
Digital still picture cameras	120%	0,26
Digital photo frames	23%	0,036
Hi-Fi	100%	0,10
Home cinema	30%	0,035
Separate units	70%	0,072
-Clock radios	20%	0,031
Portable sound products	120%	0,29
Total DVD/VHS/blu-ray	130%	0,23
TOTAL mobile phones	200%	1,1
Cordless phones	77%	0,12
Game console	25%	(a)

**NO/EU: REMODECE Norway, REMODECE Europe average*
****Norden: Nordic Council of Minister http://www.norden.org*
*****Own: (sales2008+sales2007+..+sales2008-lifetime)/average number of household*
(a) calculated in terms of mass of product sold
(b) included in peripheral
(c) kitchenmachines, coffemachines, espresso, waterboilers, waffelmakers etc

Table S2: Number of LCA studies available for different products, sorting according to the product categories used by the electric and electronic equipment register.

Category	Number of products	Number and % of product with more than one, one or none LCA studies					
		>1	%	1	%	0	%
1. Big appliances	13	5	38%	3	23%	5	38%
1a. Cold appliances	4	3	75%	0	0%	1	25%
1b. Other big appliances	9	2	22%	3	33%	4	44%
2. Small appliances	3	0	0%	1	33%	2	67%
3. ITC	6	5	83%	1	17%	0	0%
3a. Computer monitors	1	1	100%	0	0%	0	0%
3b. Other	5	3	60%	2	40%	0	0%
4. Consumer equipment	15		0%		0%		0%
4a. TV sets	2	2	100%		0%		0%
4b. Other	13	0	0%	5	38%	8	62%
8. Toys and games	3		0%	1	33%	2	67%
Total	40	10	25%	6	15%	9	23%

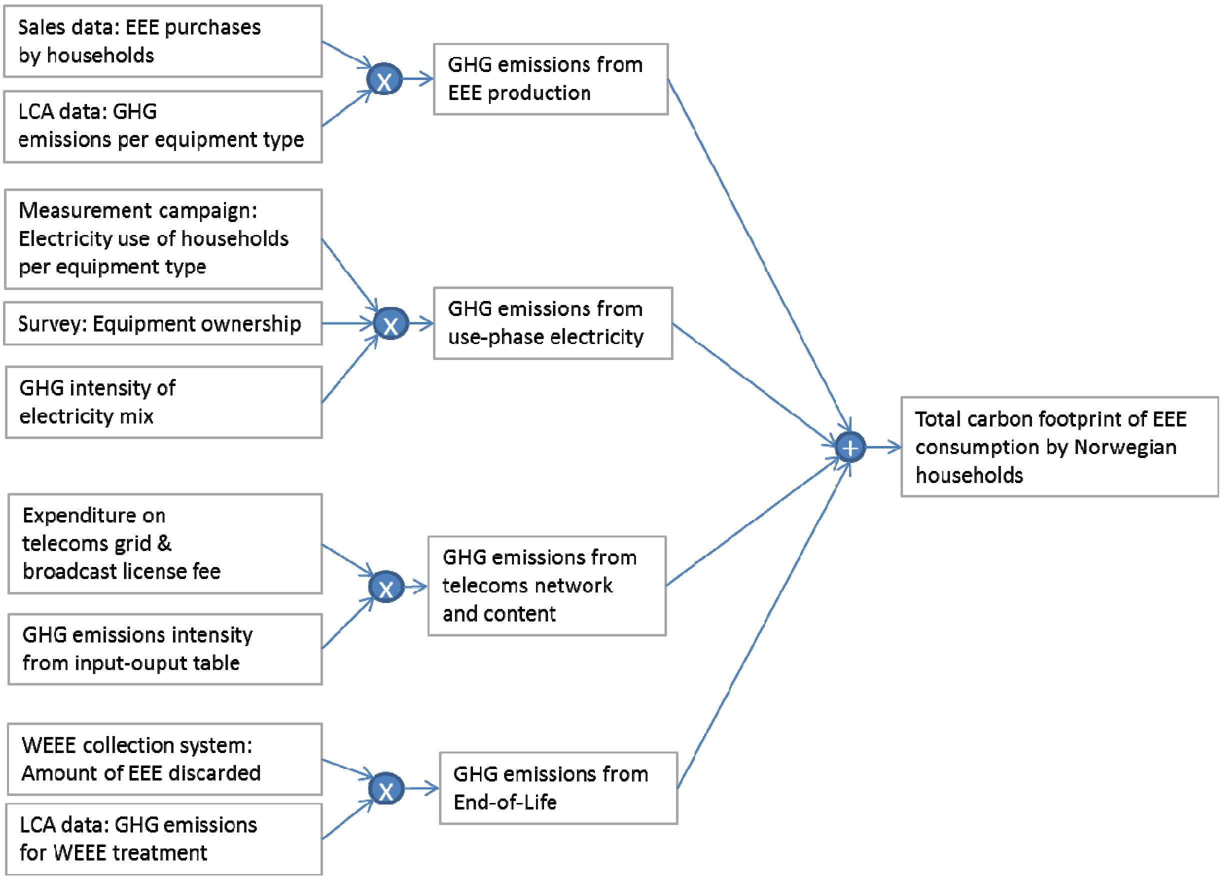

Figure S 1: Calculation scheme for the GHG emissions from the EEE consumption of Norwegian household. Note that the normalization step (dividing by number of households) is not shown.

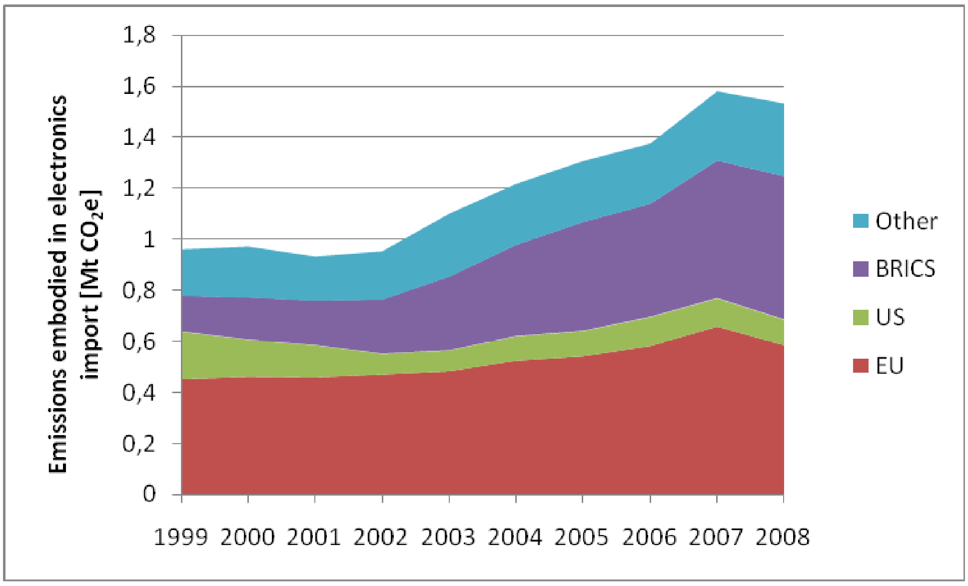

Figure S 2: GHG emissions embodied in the import of electronic products to Norway, as assessed by a multiregional input-output model, grouped by the world region where the emissions occur. The MRIO model is based on [8, 9], and the time series approach is documented in [10, 11]