# A comparative environmental assessment of electric hand dryers vs paper towels

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## Introduction

The aim of this research was to review the availability of sufficient data to determine conclusively the relative environmental impacts of electric hand dryers and paper hand towels.

Data that can be used for calculating the Global Warming Potential (GWP), or carbon footprint, of a product  is available through a number of global and regional databases. The use of generic database information is common practice (Dettling & Margni, 2009) due to the difficulty in obtaining primary data from manufacturers. But its relevance to a specific product or model, manufactured and used in a particular location or locations, is the subject of frequent interest (Gregory, 2013).

Significant variations exist across key variables which make a single certain end result difficult to obtain. Variability across model types further complicates the derivation of a single meaningful impact measure. Furthermore, the unavailability of meaningful data covering the full range of LCA impacts meant that the conclusions reached apply to the lifetime GWP alone.

To overcome these challenges, the present work sought to compare existing published data, by means of a literature review, with an environmental impact analysis following Life Cycle Assessment (LCA) principles. The scenario taken was of an electric dryer unit manufactured in China, delivered and used in the UK, and a higher performing unit manufactured in Spain (labelled Unit A and Unit B respectively). As will be seen, the greatest impact intensity is during the use phase which means that the location of production bears little overall relative impact.

The manufacture and use of paper towels in the UK is influenced by an extended supply chain network spanning several European countries (DEFRA, 2012). As will be seen, the manufacturing phase shows the greatest impact intensity.

Based on data found, this report also examines aspects of materiality in GWP indicators in the context of decision making. It focuses on global warming potential of emissions as a point of comparison and does not cover other factors which could influence user choice.

Conclusions confirm the lower GWP of high performing electric hand dryers when compared to the use of paper hand towels, while specific impact figures depend on the exact model type and use scenario.

## System boundary

### SCOPE

This work encompasses so far as possible LCA Scopes 1,2 and 3 as defined by ISO 14040 and PAS 2050. This is illustrated by the Value Chain Maps below.

Fig.1: Supply Chain Map showing systems boundary for electric dryer ex China

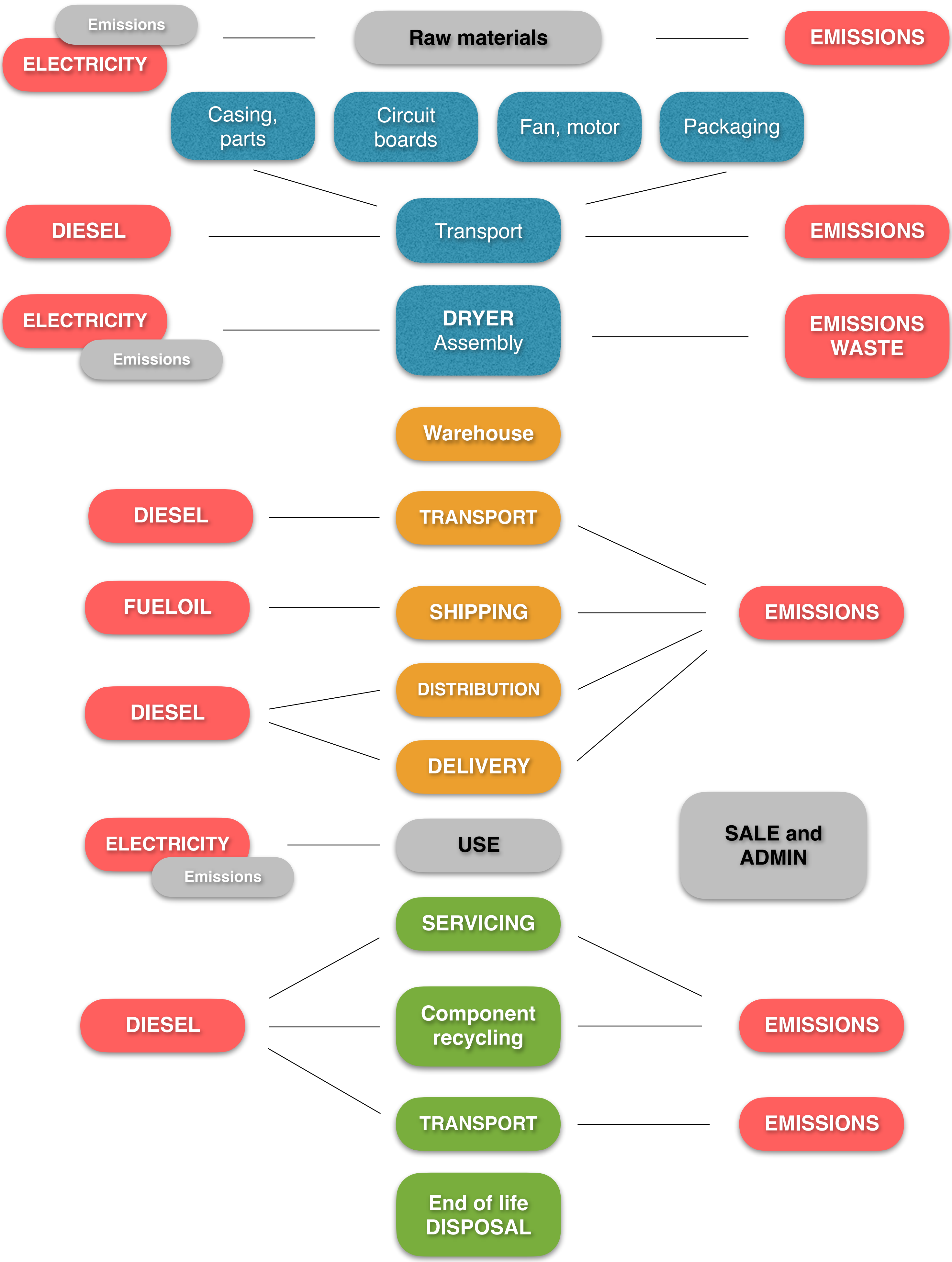
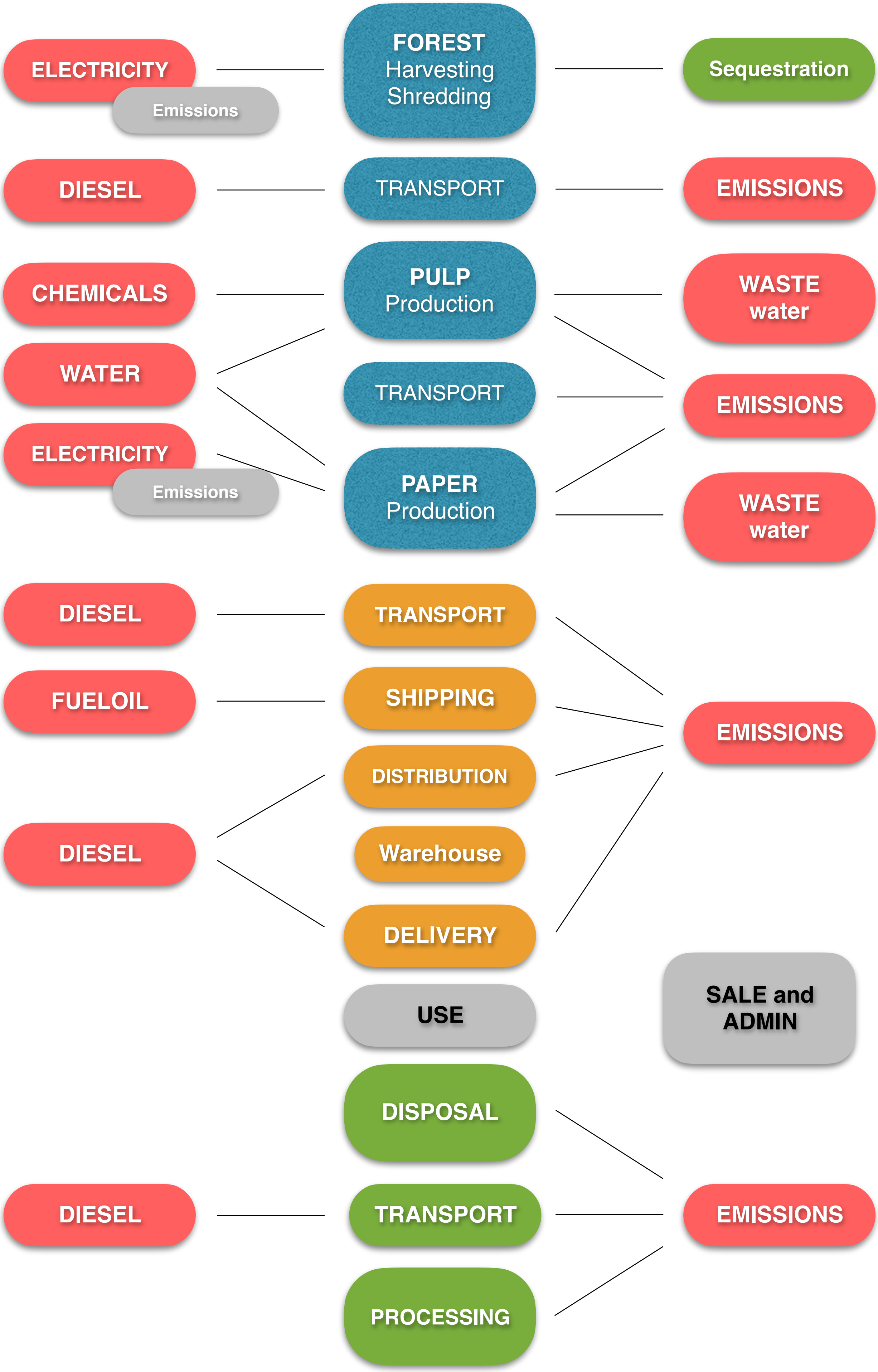


Fig.2: Supply Chain Map showing systems boundary for paper towels ex Sweden / Germany



ASSUMPTIONS AND VARIABLES

Gaps in the available data make it necessary to make some assumptions, while data obtained from the literature review allows an exploration of the effects of changing certain of these assumptions.

Functional unit (FU):

- data presented in the literature has been reduced to an FU of 'a single pair of dry hands', equivalent to one dry cycle of an electric dryer or two hand towels. Some reports use an FU of a full five years life or 260,000 dry cycles. Lifetime use varies from 200,000 to 350,000 dry cycles.

- for present purposes, we have taken a 5kg dryer including packaging as the functional unit while presenting data in a form that can be directly compared on a per dry basis.

The following assumptions apply to the present scenario:

- life span: < 17,000 hours

- use per day: 150, say 200,000 dry cycles over 5 years

Dry time: Unit A 18s Unit B 15s

Power: Unit A 4 wH/cycle Unit B 1.75 wH/cycle

Dryer weight: 4.5kg, say 5kg with packing

China grid mix for manufacture

UK grid mix for use

Key variables to be explored include the following:

- grid mix for manufacture and use phases
- dryer run time
- energy consumption per use
- location of manufacture and use
- type of dryer
- end of use disposal
- virgin or recycled content of paper towels.

## Literature review

PURPOSE AND APPROACH

The main purpose of the literature review is to establish to what extent previous authors have conducted research in topics that are directly relevant or closely related. It provides the ability to confirm the degree of agreement or otherwise between researchers and to provide a benchmark against our own work. The approach taken has been to conduct internet searches for key terms, identify the most cited authors and to carry out forward and backward searches from the various bibliographies and authors.

On this basis, it has been possible to discover a small number of directly relevant papers. However, they are few, mostly carried out for commercial clients, and to some extent share similar data sources.

If similar, the findings of these earlier reports may offer data and findings adequate for our present objectives. Their assessment of variables and identification of hotspots may enable a reasonable extrapolation to be made to the scenario under consideration.

Extant papers cover scenarios outside the UK, and their publication dates – and thus their data – are up to 13 years old.

**Dettling & Margni (2009)** present a comprehensive analysis of two dryer types – Excel 'Xlerator' and a standard electric dryer – in comparison with paper towels made from both virgin and 100% recycled pulp. The functional unit for this study is to dry 260,000 pairs of hands, which equates to a 10-year lifetime at 500 uses per week. The manufacturing phase takes place in the USA.

The paper options include the use of an electronic dispenser unit which is covered in the scope.

A sensitivity analysis shows that dryer run time has the greatest effect since intensity of use impacts increase in a nearly proportional fashion with the time the hand dryer is used. For both types of electric hand dryer, the impacts are significantly reduced under a scenario of renewable grid power (climate change score is reduced by between 80% and 95%), while for the paper towels, a reduction of about one-third is seen. For paper towels, the number used is the critical factor. End-of-life is important for the GWP score of towels, where methane emissions from landfill contributes as much as 20% of the total.

Using 100% renewable electricity would greatly reduce the use phase impacts of both types of dryer.

Recycled paper performs similarly in this study to the standard dryer, while the Xlerator – the primary subject of the study – shows only 45% of their emissions and performs best under all scenarios considered.

The authors have provided a detailed breakdown of their source data, which adds credibility to their results. They have broken down the entire value chain map into small discrete steps such as chrome electroplating. They have also taken into account of a wide range of variables such as geographic variations in grid mix and comparison of delivery distances. However, the conclusions presented might be considered as estimates of potential impacts, rather than as direct measurements of actual impacts, due to a lack of actual measurements of the products' use.

While much of the emphasis is on the Global Warming Potential from greenhouse gas emissions, a more complete LCA also presents findings on freshwater use, human health, ecosystem quality and resource depletion measures. These findings show similar patterns to that of GWP with the only exceptions being paper towels performing especially poorly on ecosystem quality, and – perhaps surprisingly – comparatively well, especially the recycled option, on freshwater use.

This paper provides a sufficient level of detail as to enable a manufacturer or user to identify specific areas for improvement under each of the LCA headings.

**Montalbo et al (2011)** have done for Dyson what the above researchers did for Excel, namely comparing a particular product – in this case a Dyson Airblade dryer – with the Xlerator (as above), standard dryer and paper towels. They have also included cotton roll towels which, for our present purposes, we have ignored. As with the above paper, this is a comprehensive full LCA carried out by professionals in this field. The paper notes design specification differences in their reference product which operates 'hands-in' while the Excel and standard dryers are described as 'hands-under'.

The reference unit is a single pair of dry hands and the study covers a cradle-to-grave scope in the USA with manufacture in China. Other geographies have been considered as part of a sensitivity analysis. Other variables include use intensity, grid mix, dry time, end of life, towel mass, manufacturing location, and use location. Most variables show little difference, especially in the location of manufacture, with an exception being France which has a mostly nuclear grid mix with a correspondingly low emissions factor.

Details are provided of the breakdown in materials used in dryer manufacture, noting differences in GWP between aluminium, steel and plastics. Based on this analysis, the authors observe that: "altering the assumptions related to the production, transportation, and end–of–life stages will have minimal affect on the total GWP".

The report's conclusion is that the environmental impact of high–speed hand dryers is generally lower than that of other hand–drying systems, although the exact rank order of the systems is sensitive to LCA methodology. The electricity grid mix and use intensity have the largest influence on the GWP outcomes for dryers. The paper towel system impact, by contrast, is driven by the production stage.

These authors emphasise that an LCA should "not provide the sole basis of comparative assertion intended to be disclosed to the public of overall environmental superiority or equivalence". Such assertions, they say, should also include other information about the relative performance of the products.

A two page certification document by Swiss consultancy **Climatop (2013)**, also for Dyson, compares four 'Airblade' models with a conventional hand dryer and paper and roller towels. No specification is given for the 'standard' dryer, which could, of course, be an older poorer performing model. While full data sources and assumptions are not provided, the results are presented for a European grid mix, which may be more relevant for our present purposes.

Findings are consistent with those from the reports above, with recycled paper towels shown as of lower impact than the standard electric dryer chosen. The report also confirms that the use phase is the most significant for dryers, with the manufacturing phase for paper towels.

One of the authors in **Gregory et al (2013)** is none other than the Montalbo mentioned above. This paper, also emanating from MIT, takes as its focus uncertainty factors in LCA for hand dryers. It appears to share some source data with the above study, and from Dettling (2009), but improves upon it by filling some of the earlier gaps and exploring in more detail the effect of variability in data which, say these authors, clouds many LCA calculations. Data is provided in sufficient level of detail to both confirm the accuracy of the findings and to extrapolate into our own scenario.

For the electric hand dryers, use phase impact is solely due to the production and distribution of electricity required for operation, which takes place in the USA. The manufacturing phase takes place in China. The system boundaries encompass all life cycle phases, from cradle to grave, along with transportation between and within each phase. At the end-of-life, all product types are transported to a waste facility where they are incinerated or sent to landfill. With the exception of the cardboard packaging, there is no clear evidence that any of these products are commonly recycled.

For hand dryers, environmental impact is driven by the use phase energy consumed in the active use of the hand dryer. Within the production phase (including materials and manufacturing), key contributors are the housing materials, electricity used in production, and the printed wiring boards for the controls. Dryer running time is the key factor.

For paper towels, the manufacturing phase makes up over half of the impact for global warming potential and water consumption, followed by materials (pulp) production. It is noteworthy that paper towels are the only product for which product end-of-life has any significant impact, specifically in global warming potential caused by degradation of paper towels in landfills.

The main conclusion is that high-speed dryers have lower GWPs than the other drying systems, but, due to the uncertainty factors considered in this report, it cannot be claimed that one type of dryer is clearly better than the others. To be valid, comparisons require identical scenarios and in the real world this is rarely the case.

**Joseph (2015)** compares the use of a conventional hand dryer (rated at 1800W and under a 30 s use intensity, ie an older 'standard' model) with using two 100% recycled paper towels issued from a roll dispenser. Material production and manufacturing phases take place in the USA, with the use phase in Canada.

This study concludes that the dryer system clearly offers a lesser environmental impact, but that this cannot be generalised for all warm air dryer use and paper towel use. The case-specific nature of the outcome of the comparative LCA is mainly influenced by the electric grid mix at the manufacturing and use locations of both the product systems.

End of life disposal and recycling scenarios are excluded under the scope of this study. However, these authors suggest that accounting for end-of-life will not affect the final outcome, which means that end-of-life for dryers is not significant enough to warrant further effort in recycling components based on GWP measures alone.

Comparisons with results of other assessment reports are attributed to differences in material and process data, the inventory data source for the unit processes, the manufacturing and use location, use intensity of product systems per functional unit, estimated reference flow, power rating of the hand dryer, grid mix for both the manufacturing and use stages, LCA and GWP calculation methodology adopted and chosen end of life disposal scenario (recycling, incineration, or landfilling). This researcher concludes that GWP metric values estimated for the dryer and dispenser product systems respectively are both within range of values derived in Montalbo et al.

The final paper discovered through our literature search is Budisulistiorini (2007) whose earlier study covered an older model of electric dryer (7kg cast iron, 30s dry time) in Australia, with a use phase based on a high coal grid mix with a proportionately high emissions factor. The study concludes that the electric hand dryer method of hand drying surpasses paper towel in environment sustainability performance, but that if end-of-life paper could be recycled, the dryer's advantage would disappear.

## Data analysis

SUMMARY OF PUBLISHED DATA

| TABLE 1 | Assumptions | Global Warming Potential, gCO2e per dry | | | |
|---|---|---|---|---|---|
| Source | | High speed dryer | Standard dryer | Paper towels | 100% recycled |
| Budisulistiorini, 2007 | 7kg dryer, 30s dry time, 5 yrs use, 130,000 dry cycles, Australian high coal grid mix | | 10.29 | 10.59 | |
| Dettling & Margni, 2009 | 10 year life, 500 uses per week, 260,000 dry cycles, US grid mix | 10.29 | 17.42 | 20.15 | 8.95 |
| Montalbo et al, 2011 | Dry times: Dyson 12s, Excel 20s, standard 31s. US grid mix | Dyson: 4.9<br>Excel: 8.0 | 17.80 | 15.40 | 15.70 |
| as above | Alternative LCA method | Dyson: 4.4<br>Excel: 7.85 | 17.2 | 14.6 | 14.8 |
| Gregory, 2013 | 350,000 uses over 5 years, US grid mix | Hands-in 4.5<br>Hands-under 8.0 | 17.80 | 15.40 | |
| Climatop, 2013 | 200 uses per day over 5 years | 3.0 | 10.0 | 8.9 | 4.6 |
| Joseph, 2015 | Canada grid mix | | 3.0 | | 9.4 |
| RANGE | | 3.0 -10.29 | 3.0 - 17.80 | 8.9 - 20.15 | 4.6 - 15.70 |
| AVERAGE | | 6.4 | 12.7 | 14.1 | 9.7 |

Specification comparison

| | Dyson | Excel | Standard | Unit A | Unit B |
|---|---|---|---|---|---|
| Power, w | 1400 | 1500 | 2300 | 800 | 420 |
| Run time, s | 12 | 20 | 31 | 18 | 15 |
| Energy per cycle wH | 4.67 | 8.33 | 19.8 | 4.0 | 1.75 |

Percentage use intensity

| | Dyson | Excel | Standard |
|---|---|---|---|
| Dettling | | 76% | 95% |
| Montalbo | 86% | 89% | 95% |
| Climatop | 90% | | 98% |
| Average | 88% | 83% | 96% |

If we ignore the outliers and rely on Dettling, Montalbo and Climatop from Table 1, then the applicable emissions/GWP figures from the published data are as follows, all figures gCO2e per dry.

| | Dettling | Montalbo | Climatop |
|---|---|---|---|
| Dyson | | 4.9 | 3.0 |
| Excel | 10.29 | 8.0 | |
| Standard | 17.42 | 17.80 | 10.0 |
| Paper towel | 20.15 | 15.40 | 8.9 |
| 100% recycled | 8.95 | 15.70 | 4.6 |

## DISCUSSION

The first question to consider is to what extent the above findings can sufficiently inform our own objectives, compared with running a full new assessment. Dettling & Margni (2009) provide a detailed breakdown of their source data, which together with additional information given in Montalbo et al (2011), may be considered to be a valid reference point for the present study since the assumptions would be largely the same. The primary difference is only that the the use phase takes place in the UK, as opposed to within the USA in these two earlier studies.

The effect of these variables can be calculated based on grid mix emissions factors as follows (from Carbon Footprint, June 2019):

| | |
|---|---|
| - China | 0.6236 kgCO2e/kWh |
| - USA | 0.4759 |
| - UK | 0.2773 |

Effect of manufacturing in China vs US:
(0.6236-0.4759) = 0.1477 x 5kg / 200000 = 0.0037 gCO2e per dry

Additional GWP from shipping to the UK from China:
22000km x 5kg x 0.012674 /te.km = 1.394 kgCO2e / 200000 dry cycles = 0.0070 gCO2e per dry

Effect of use in UK vs USA:
(0.4759-0.2773) x 4Wh dry cycle = 0.0008 gCO2e per dry

Taking a rounded median value from the chart above as 10 gCO2e per dry for a high performing dryer, we would ADD the China effect and SUBTRACT the UK effect to give a net effect of + 0.01 g, equivalent to 0.01%. This can be reasonably considered as insignificant.

Thus it is reasonable to conclude that the figures from the referenced reports are sufficiently valid for present purposes.

A second consideration would be the implications of the age of the published data. It would be reasonable to expect that emissions performance had reduced over time, as suggested by the lower grid factor for the UK, reflecting a substantial uptake in the proportion of renewables in electricity generation. Therefore the published data is likely to overstate the present state of affairs. This is illustrated by the cases pertinent to this study, which are current specification models with lower power consumption than even the best of those shown above. Comparing with the rounded median value of 10 gCO2e per dry (Excel dryer above), the GWP emissions figures would be:

| | |
|---|---|
| Dyson | 4 |
| Excel | 10 |
| Standard | 17 |
| Unit A | 8.2 |
| Unit B | 6.9 |

A third consideration is that of the model type and its exact specification. As can be seen from the published data, there are significant differences between best, high and standard performing models. These performance differences reflect design differences in efficiency (power consumption, run time), construction (aluminium, steel, plastics) and the weight of the unit, its components and packaging. Differences are sufficiently large that it is not reasonable to attach a single GWP figure to a generic dryer type. Nor is it meaningful to average emissions figures across models.

We can also observe the importance of a range of key variables each affecting the GWP performance of electric dryers:

- dryer run time
- lifetime run cycles
- grid mix for manufacture and use phases
- location of manufacture and use.

It is an advantage of these dryers over paper towels that they effectively amortise their emissions in the manufacturing phase across a lifetime measured in years. Although five years has been taken in the literature, seven or more years is not unreasonable, which would reduce the per dry GWP figure even further. The run time is the most significant influence overall, and the main reason for superior GWP performance.

With regard to paper towels, the 'use intensity' is also a significant variable, depending whether a user takes one, two or three towels to dry their hands to a satisfactory degree. The studies examined have all taken two as their base comparison but it seems there is no actual measured evidence to support this. This is significant: if a single towel were to achieve the same drying effect as an 18s hands-in hot air dry, then the published GWP figures for paper towels could potentially halve.

The literature offers mixed views on the GWP benefit of using recycled pulp in manufacturing. In the European context, paper making is typified by harvesting trees and producing pulp in Sweden, with manufacture in either Germany or the UK. The paper industry in general seems not to be increasing its use of recycled fibre in spite of government encouragement to do so (BEIS, 2017). As noted earlier, end of life recycling is rare with the bulk of waste paper going to landfill or incineration. The UK incinerates or composts proportionately more than is common in the USA and the published figures for paper towels might therefore be higher than would apply in the UK due to the GWP effect of methane emissions from landfill.

End of life recycling for dryers would show minimal positive impact due to the need for transport and processing, although there is some benefit in recycling aluminium components into the supply chain.

## Conclusions

Lifetime emissions based on 200000 dry cycles over five years:

| | |
|---|---|
| - best performing dryer | 4.5 x 200000 / 1000 = 900 kgCO2e |
| - high performing dryer: | 10 x 200000 / 1000 = 2000 kgCO2e |
| - standard dryer: | 17.5 x 200000 / 1000 = 3500 kgCO2e |
| - case unit A: | 8.2 x 200000 / 1000 = 1640 kgCO2e |
| - case unit B: | 6.9 x 200000 / 1000 = 1380 kgCO2e |
| - paper towel: | 15 x 200000 / 1000 = 3000 kgCO2e + 800kg to waste |
| - 100% recycled: | 9 x 200000 / 1000 = 1800 kgCO2e + 800kg to waste |

Note that one paper towel = 2g while used paper towels are not commonly recycled (Montalbo et al, 2011).

The data consistently show that efficient modern models of electric hand dryer have lower lifetime GWP than using paper towels: "We can say with a high degree of confidence that the high speed dryers have a lower impact than paper towels and cotton roll towels" (Gregory et al, 2013).

For certain environmental (GWP) advantage over paper towels, dryer cycle run time must be 20s or less and the grid mix favour renewables. The newer, more efficient dryers achieve this consistently, whereas 'standard' dryers offer a less clear difference.

For dryers, electric power consumed during the use phase represents by far the greatest contribution to GWP which means that greater efficiency in use offers more scope for improvement than the location of manufacture. The current lower power models offer significant improvements in both actual energy consumption and in GWP emissions.

For paper towels, the manufacturing phase is the most GWP intensive, coupled with waste production.

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# Appendix

PUBLISHED CHARTS

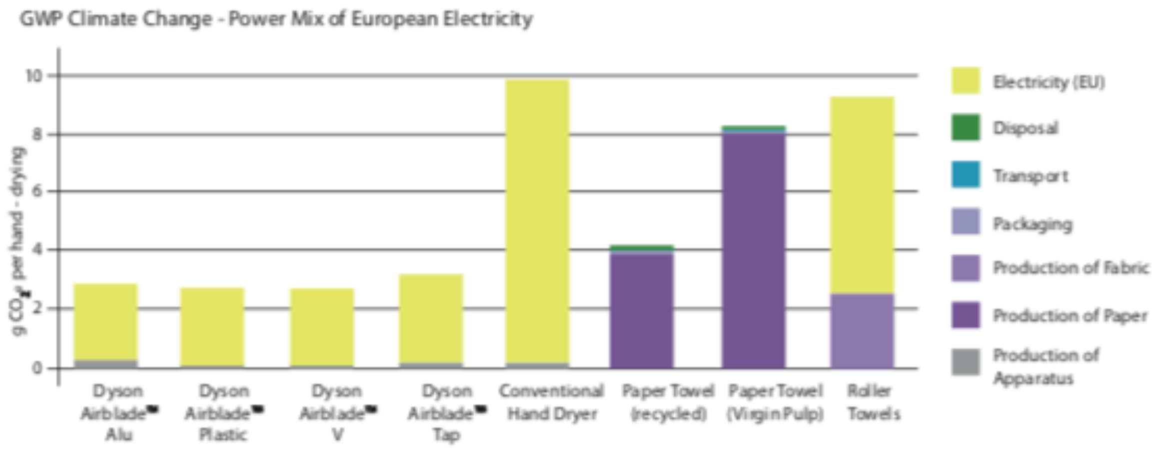
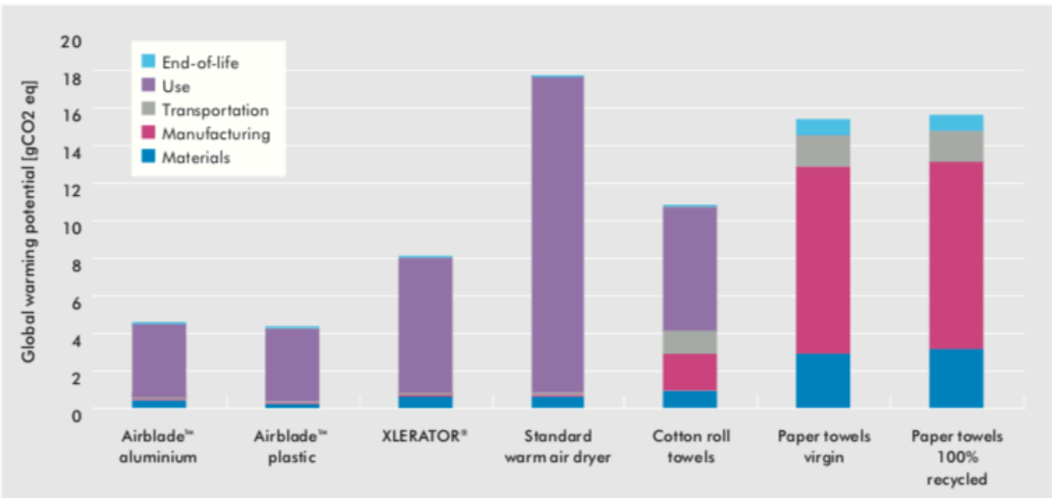



Fig. 2: Climate change based on calculations with the European power mix.

Climatop, 2013

Montalbo et al, 2011



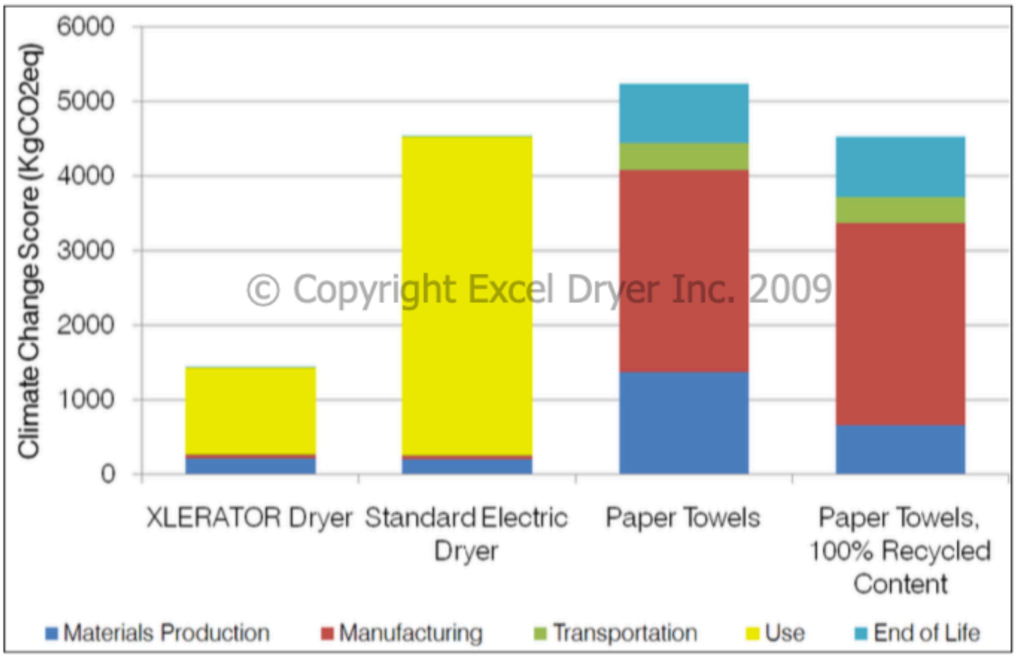



Figure 5: Total life cycle climate change score for each of the systems

Dettling & Margni, 2009