Dryers

HIGHLIGHTS

■ **PROCESS AND TECHNOLOGY STATUS –** Dryers are an increasingly important appliance, particularly in developed countries with climates that are not amenable for outdoor drying. For example, it has been estimated that drying accounts for approximately 7% of US electricity consumption and that in 2009, 79% of US households owned a laundry dryer. The US domestic tumble dryers market has grown by more than 50% over the last 15 years, mostly driven by sales of electric dryers. The EU domestic market also appears to be dominated by the electric dryer, although market penetration is lower compared to the US. In Europe, annual sales were in the range of 4.1 - 4.4 million units (2005). In comparison, the global commercial market is much smaller; the volume of tumble dryers sold is approximately 85,000 units per year. In the EU approximately 30,000 units are sold per year. The EU commercial market is growing on average by 2% a year. In the US, commercial market growth is slightly higher at 3% a year. More energy efficient technologies are available on the global market. The most notable are heat pump condenser dryers and gas tumble dryers. Heat pump condenser dryers are currently only a few percent of the global market. Heat pump condensers are the only dryer where heat is recovered and returned to the air stream flowing into the drum. Only in Switzerland and Austria have sales reached significance at over 25% of the market (2009), but there are signs that the technology is breaking through as sales have risen to 10-15% in Germany and Italy. In many countries, gas tumble dryers also represent a very small percentage of the domestic market; 0.3% in the UK, the Netherlands and Portugal. In the US, sales figures for electric and gas dryers are similar.

■ **PERFORMANCE AND COSTS –** In 2010/11, the national average energy efficiency of domestic laundry dryers in Europe, USA, Canada and Australia was approximately 0.7 kWh per kilogram of dry fabric. Switzerland has improved its average efficiency to 0.69 kWh per kilogram in 2010, but along with Austria it has seen annual growth in energy consumption due to increased ownership and usage. The gap between countries' average efficiencies has narrowed. Within each country, however, technology profiles are still quite different. In Canada and the US, most technologies have energy efficiencies that are in the range +/- 7% from the national average. In comparison, the Australian and EU markets have a greater range (+/- 25%) and include products which are much more efficient (and less efficient) compared to the Canadian and US markets. This highlights the potential for energy savings if the most efficient technologies were available in every country. Switzerland plans to ban the sale of tumble dryers that do not achieve EU energy labelling class A standards from 2012. More generally, it seems that the EU energy labels have been most successful at reducing sales in the lowest label classes. The EU energy labelling system is currently undergoing small changes to include gas dryers and review the energy categories. Gas dryers are not yet included in energy efficiency labelling in the EU, but they are typically equivalent to class B [expert opinion]. Heat pump (condensing) dryers are most efficient and are typically in class A. On average they consume less than half the energy of conventional vented and condensing dryers. They have energy efficiencies of 0.3 - 0.4 kWh per kilogram compared to 0.6 - 0.9 kWh per kilogram for a typical conventional dryer. There is a price premium for heat pump products of 30% from major brands. For example, in Germany, the average price of heat pump dryers was €1618 (2012). Recent entrants into this area are significantly cheaper, so the market could be developing. For example, the Creda heat pump dryer was released onto the UK market (2011) at approximately €475.

■ **POTENTIAL AND BARRIERS –** There is potential for reductions in energy consumption from dryers. In the best performing parts of the market, the technology is already there but due to the 13 year lifetime of dryers, there is a delay between annual sales and the new technology occupying a significant proportion of the existing stock. Higher costs are one of the biggest barriers limiting sales of the most efficient dryers. Price and longer drying cycles are significant barriers to the uptake of heat pump technology in the US market. There may be a lack of customer interest/awareness when it comes to energy labelling in Europe. Lower market demand may prevent manufacturers from selling the most efficient technologies if they do not believe customers will pay for it. Another minor barrier is the constant market demand for low capacity dryers, either due to the lower price or because customers lack space to accommodate larger models. Compact dryers are amongst the least energy efficient types. For gas dryers, there are barriers such as customer concerns over safety and additional installation considerations that might put consumers off purchasing them. Once a purchase has been made, there are a number of customer behaviours which can impact the real world efficiency of the dryer. These include the use of delay timers, leaving the appliance on stand-by mode, lack of cleaning of dryer components, using the appliance at half load and others. These should also be targeted to ensure appliances are used in the most efficient manner and some technology solutions, like sensor controls, can help to mitigate these.

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Process and Technology Status

Laundry dryers are used in the residential, commercial and industrial sectors to remove moisture from clothing or other textiles. In 2009, 79% of US households used a laundry dryer at home [7]. In the US, the domestic market has grown over the last 15 years by more than 50%. The sale of electric dryers accounts for two thirds of this growth, whereas sales of gas dryers have remained fairly stable [5]. It has been estimated that drying accounts for approximately 7% of US electricity consumption, as the market penetration is much higher than in Europe [11]. In Europe, the stock is estimated to be more than 54 million units and is increasing. Annual sales are somewhere in the range of 4.1 - 4.4 million units [3], [11]. Similar to the US, the EU domestic market appears to be dominated by electric dryers [3].

The commercial dryer market is smaller and more difficult to estimate. The global market volume of tumble dryers sold is approximately 85,000 units per year. The EU market volume sold is approximately 30,000 units per year with 70% of these units made in Europe. The EU market is growing on average by 2% a year [3]. In the US, market growth is slightly higher at 3% a year [4]. Total commercial and industrial equipment sales in the US were worth $186 million in 2007 [4].

The main dryer product components are [6]:

- **Drum –** the drum rotates around 40 revolutions per minute (RPM) and heated air evaporates water from the clothes in the drum. Evaporating water cools the air and increases its humidity as it leaves the drum.
- **Motor –** the motor rotates the drum and drives the fan to move the air. It draws approximately 200 to 300 watts (W) of electricity. Motor options include the brushless direct current (DC) motor, brushless direct drive, and three phase motors and their associated controls. Some clothes dryers use separate motors to rotate the drum and to drive the fan.
- **Fan –** the fan draws air through the components at 100 to 150 cubic feet per minute (CFM).
- **Electric Heater –** an electric resistance heater typically draws about 5,000 – 5,500 W at 230 volts and 22 amps. The air in the cabinet is drawn into the heat duct and heated to 93– 149 °C. The main technologies are open coil heating elements and sheathed element heaters.
- **Gas burner –** gas burners are typically rated at 6 to 7 kilowatts[1] per hour (kWh). Most use inshot style burners to deliver heat to the drum.

For the commercial and industrial sector, additional features might include automatic dry controls, heavy duty materials and construction, self-cleaning lint screens, self diagnostic microcontrollers, machine tilting capabilities, multiple door configurations, full-body insulation, full burner modulation for temperature monitoring, coaxial ducting to transfer heat energy from the exhaust to the incoming air, automatic fuel metering control, integration with data management systems and Ethernet ports for remote management [4] and many others.

Technologies across the sectors vary according to: capacity; the mode of drying (heated cabinets, tumbler dryers and centrifugal spin dryers); the heat source (electricity or gas); the air usage (vented or condensing types); functionality (top or front loading) and end of cycle controls (time control or automatic sensors). Commercial technologies have increased functionality and increased energy efficiency as the cost of energy is more significant [4].

■ **Laundry Dryer (domestic) –** residential laundry dryers typically have a capacity of 4 to 10 kg. There are no products over 6 kg available in the US or Canada, but in Europe and Australia domestic products are available up to 10 kg [2]. Dryers exceeding this capacity are not considered as domestic models.

Mode of drying: heated cabinets, tumble dryer or centrifugal spin - Heated cabinets are heated drying cabinets or cupboards where laundry remains hanging or static, air is passed through the cabinet and dehumidified to remove the moisture. In Europe sales of heated cabinets for drying are very low, but are more common in the US. No data has been identified on sales in other parts of the world [2]. Tumble dryers extract the moisture by tumbling the laundry load in a rotating drum through which heated air is passed [1], [3]. Centrifugal dryers involve spinning the fabric at high speeds and using centrifugal forces to reduce the water content. Data on centrifugal dryers are sparse. These are considered as a separate product in the EU.

Heat source: electricity or gas - Laundry dryers can use supplied electricity or gas (natural gas or propane) as an energy source. Electric dryers tend to require a 240 or 130 volt (V) outlet [6] and typically a coiled wire is heated with an electric current. The current is varied to adjust the temperature [3]. Electric dryers can be vented or condensing – see below. Gas appliances require a gas supply and due to safety risks are always vented [6]. The air temperature is altered by changing the size of the flame or by switching off and relighting the flame [3]. In many countries, gas tumble dryers represent a very small percentage of the domestic market; 0.3% in the UK, the Netherlands and Portugal. In the US, sales are more similar to electric dryers [1].

Air usage: vented or condensing - In a vented tumble dryer, air enters from the surrounding environment, it is heated and passed through the appliance, and the exhausted air containing moisture from the laundry must be expelled to the outside using a vent pipe through an open window or a hole in the wall. In Canada, the US and Australia, vented types are the most common. Australia had sales at close to 100% vented types until 2007, when this fell to approximately 90%. Sales in Canada and the US were 100% vented in 2010 [2]. Condensing appliances do not require a vent; air used for the drying process is reused after it has been dehumidified by cooling. The condensed water is removed either through a drainpipe or stored in a

[1] Conversion from BTU, where 1000 BTU= 0.2930 kWh

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collection tank for disposal by the consumer. In Europe, there has been a trend away from vented products towards condensing types. Condensing types accounted for 63% of the EU market in 2008, up from 47% in 2000 [2]. Condenser technologies have dominated the Eastern European market. There has been rapid annual growth and condensing types represented over 75% of annual sales in Eastern Europe (2005) [3]. Condenser dryers remain only a few percent of the market in the US and Canada [2].

There are typically three types of condensers on the global market:

- *air condensers* are the most common and use air from the room as a coolant;
- *water condensers* are only used in combined washer-dryers and water is the coolant;
- *heat pump condensers* are a very small proportion of the global market and use a heat pump to transfer the heat back into the circulating air.

According to industry experts, heat pump dryers are the new technology that should increase in market share over the next few years. Heat pump condensers are the only dryer where heat is recovered and returned to the air stream flowing into the drum. The additional energy required to run the heat pump is far exceeded by the energy recovered [1]. Heat pump appliances account for only a few per cent of most markets [2] and are not available in the US [4]. However, as of 2009, a policy drive in Switzerland and Austria had boosted sales to over 25% in these markets [2]. There are also signs that the technology is breaking through in other EU countries as sales have risen to 10-15% in Germany and Italy [11].

Functionality: top or front loading - Conventional top loader dryers have a vertical axis drum [9]. Modern top and front loading dryers both have a horizontal axis drum. Top loaders have a door on the top and the drum has a hatch in its side. Front loaders have a door opening on one of the faces of the drum [1]. Front loaders represent the majority of sales in Europe (78%), 2.9 million of over 3.7 million total sales [3]. In the US top loader dryers are more common [9]. Top loading dryers provide easier access, as users do not have to bend down to fill the dryer. Front loading dryers benefit from ability to stack appliances where floor space is limiting.

End of cycle controls - The end of the cycle can be determined by a time control where the dryer stops after a given duration set by the user. Alternatively, automatic tumble dryers are switched off when a certain moisture level is reached. The moisture level can be detected in a number of ways:

- *temperature sensors* detect the temperature of the exhaust air;
- *moisture sensors* can be included in the drum outlet and stop the drying process when a pre-set value is reached. Note that moisture sensors are not reliable if the drum is under-loaded;
- *resistance sensing rods* measure the resistance of the laundry, which increases as the moisture level decreases. This involves measuring the weak electric current across two plates each time the linen hits them [3], [6].

Survey results indicate that over 60% of tumble dryers in the UK, France and Poland had time controls in 2008 [3]. The authors note that most modern dryers feature a moisture control runtime option, especially condenser types. Premium brands tend to have more sensors compared to basic brands that have more timers [expert opinion].

■ **Commercial and Industrial Devices –** Commercial clothes dryers are segmented into single-load dryers, larger capacity tumble dryers and industrial-sized dryers. The different types include standard and high capacity tumble dryers, stacked dryers and industrial sized dryers. The major differences are capacity and physical configurations [4].

Single-load dryers - Single-load dryers are residential style dryers, which tend to be designed for simplicity of use. They are often found in multi-house facilities or in small coin operated facilities. They usually have capacities of around 9.1 kg[2] of laundry per load [4]. This is slightly larger than US domestic dryers which do not exceed 6 kg [2]. They may be stand alone or stacked to enable a greater drying capacity per meter of floor area. Features may include automatic drying controls; multiple cycles for cottons and delicates; and multiple heat selections [4].

Large-capacity tumble dryers - These dryers have larger capacities in the range 9– 34 kg2, but some have capacities as large as 80 kg2 [4]. Stand alone or stacked configurations are available and these appliances are typically found in large coin operated laundries or on-premise facilities such as prisons, hotels or hospitals. They can also be found in off-premise facilities, such as commercial laundry services, that serve a number of customers and often replace on-premise facilities. Nearly all large-capacity tumbler dryers are gas-fired. The additional technology features for large-capacity tumble dryers include reverse tumbling mechanisms to prevent the 'balling' and 'roping' of clothes; automatic drying controls; heavy duty material and construction; self cleaning lint screens to improve efficiency and reduce manual cleaning; and self diagnostic micro-controls [4].

Industrial dryers - These dryers have a capacity in the range of 54– 318 kg2 [4]. They are mainly used in large on-premise or off-premise laundry facilities. They may be stand alone or 'pass through' dryers for use with continuous tunnel washer systems. Industrial dryers are more complex and sophisticated than tumbler dryers. They include more advanced energy-saving features. Features include full body insulation to reduce heat loss; full burner modulation for precise temperature control; inlet and outlet temperature monitoring; automatic fuel metering control; automatic drying control; coaxial ducting to transfer heat energy from exhaust to incoming air. In addition there are a number of features to improve ease of use and safety such as: machine tilting capability for easier loading; multiple

[2] Conversion US pounds to 0.4536 kilograms

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door configurations; self-diagnostic microprocessors; sensor activated fire extinguishing system; integration with data management systems and ethernet ports for remote monitoring and control [4].

PERFORMANCE

Dryer performance is assessed by the following parameters:

- **Consumption metric (kWh per cycle)** – Measured as kilowatt hours per standard cycle, this is the most common metric. It is widely used around the world in countries such as Japan and China, as well as European countries. It measures energy use for a cycle but the standard cycle can vary significantly between countries [1].
- **Energy efficiency (kWh/kg load)**[3] – Measured as kilowatt hours per kg of dry load, this is the most useful metric. It describes the energy use per kg load of dry textiles. The lower the value the more efficient the dryer. It removes the uncertainty associated with differing cycles (metric above) [2];
- **Energy factor (lb/kWh)** – Measured as internal volume of the drum (cubic feet) per kWh, this is often used as the energy efficiency metric in the US and Canada. The higher the value the more efficient the dryer [2]. Dryer performance depends on applications as domestic, commercial or industrial dryer efficiencies will differ. The primary environmental impact of this product is related to the energy consumption [3] and depends on the energy required to heat up the appliance, to turn the drum and to control the temperature. Energy use also depends on the amount of water to be removed, the level of dryness to be achieved and the ambient room temperature. Tumble dryer energy efficiency is inherently linked to the size (capacity) of the dryer and larger dryers with the same design will be more efficient than smaller dryers because they have more insulation and more space for tumbling [2]. It is also important to compare country usage patterns because a shift to air drying could have a far greater impact than improving energy efficiency of appliances.
- **Cycles per year** – this is a common metric to compare the average usage between countries [2].

Aggregated energy consumption has been estimated at 10 TWh per year for Canada; 4TWh/y for UK and <1TWh/y for Australia; Austria, Denmark and Switzerland. In Canada there is a high usage, approximately 420 cycles per year, which is similar to the US. In Europe, the average is <200 cycles per year. Australia, which benefits from weather suitable for drying clothes, has an average of 50 cycles per year [2]. Appliance performance within each country should be considered in this context.

■ **Laundry Dryer (domestic) –** In 2010/11, the average energy efficiency of domestic laundry dryers in Europe, USA, Canada and Australia was approximately 0.7 kWh per kilogram. Between 2003 and 2010, Switzerland has improved its average efficiency to 0.69 kWh per kilogram but along with Austria it has seen annual growth in energy consumption due to increased ownership and usage. In recent years, the gap between national average efficiencies has narrowed. Within each country, however, the technology profiles are quite different. In Canada and the US most technologies have energy efficiencies around the average (+/- 7%). In comparison, the Australian and EU markets have a greater range (+/- 25%); these markets include products that are much better and much worse than the Canadian and US markets [2], thus highlighting the potential for improvements across the global market. The best technologies are not available in every country.

Energy efficiency classes - In Europe, a labelling scheme has been in operation since 1996. It was introduced through Directive 95/13/EC and is currently undergoing small changes to include gas dryers and review the energy categories. Energy classes A+ and A++ do not yet exist for tumble dryers (as they do for other products) - the highest class is A. Between 2002 and 2005, the market for class C dryers grew while sales of class D dryers dropped by 6%. During the same time period, A and B classes represent less than one percent of sales, however, trends show a significant increase of sales in these classes by 27% and 375%, respectively. During the same time period, there were no sales of class F and G classes in Eastern Europe [3].

There is not an even split of technologies and capacities across the energy efficiency classes. Compact dryers do not achieve as high energy efficiency ratings as full size models [1]. There has been some criticism that energy labelling encourages manufacturers to produce larger capacity appliances to benefit from better energy efficiency labels for the same technology. The larger capacity machines will only translate into real world efficiency savings if they are used at full capacity [2]. In Canada and US, capacity has remained fairly static so energy efficiency gains are likely to be from inherent technology improvements [2].

Under the EU energy efficiency classes, the heating benefit of condensing dryers allows them to consume around 8-10% more energy in a label class. For example, in class C a condensing dryer must consume <0.73 kWh per kilogram whereas a vented dryer must consume less than 0.67 kWh per kilogram [1]. There is inconclusive evidence on whether condenser or vented technology groups are more efficient [2].

Air usage: vented or condensing - Both gas dryers and electric heat pump dryers are considered to be Best Available Technology [3]. Gas (vented) dryers are more energy efficient; a higher penetration could reduce cycle time and energy consumption. Gas dryers are not yet included in energy efficiency labelling in the EU, but they are typically equivalent to class B [expert opinion].

[3] National appliance testing may be done with a fixed load, such as in the US or Canada or it may be done at full capacity as in Europe. This significantly affects the comparisons of the energy efficiency metric and normalised data was used by the authors.

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They produce less CO_2 than most conventional electric dryers.
Heat pump (condensing) dryers are the most efficient; they typically consume less than half the energy of conventional vented and condensing appliances [2]. They have energy efficiency in the range of 0.3-0.4 kWh per kilogram compared to 0.6-0.9 kWh per kilogram for a typical conventional dryer [1].

End of cycle controls: - Moisture sensors (described above) can achieve some energy savings [1].

■ **Commercial and Industrial Devices –** During a typical commercial clothes dryer cycle, heating air consumes 90% of the energy with the remaining 10% associated with the electric motors. The greatest opportunities for improving dryer energy efficiency involve decreasing the amount of heat input per kg per laundry [5].

There are a number of developments which can improve the performance of single-load standard commercial dryers [4]:

- **Exhaust heat recovery –** This requires a heat exchanger that is suited to recover exhaust heat energy and use it to preheat the inlet air. It also requires a heat recovery wheel. The wheel is constructed of alternative layers of flat and corrugated aluminium. Half of the heat recovery wheel is exposed to the dryer air inlet and the other half is exposed to the dryer exhaust inlet. As the wheel spins the heat is extracted from the exhaust outlet and transferred to the cold dryer inlet air. At the moment this has limited availability commercially, but manufacturers claim fuel reductions of 44 to 51% using the heat recovery wheel.
- **Improved cycle termination –** Temperature and humidity sensors inside the dryer can be used to control the length of the cycle and prevent unnecessary drying. This technology is already available in the residential clothes dryers.
- **Improved air circulation –** The drum can be re-designed to improve the airflow to direct and maintain heat efficiently. This is under continuous improvement in the commercial sector.
- **Inlet pre-heat condensing mode** – A highly effective heat exchanger is used to transfer heat from the exhaust air to the inlet air. The condensing water vapour in the exhaust air will transport more heat than the non condensing case. Condensing dryers are in-use.
- **Modulating gas burners –** Most gas dryers on the market today have a fixed input rate and fixed airflow rate. Modulating gas burners match the heat input rate to the moisture level of the laundry load. This saves energy because less heat is required towards the end of the cycle. Modulating gas dryers can detect when cloths are becoming dry and reduce the heat input rate accordingly. Dry cycle times can reduce from 20% to 40% and the energy savings can reduce by 13% to 23%. The fabric temperatures can also reduce by 2.2 to 13.3 °C. Prototypes have been tested.
- **Heat pump –** (electric only) Exhaust air is re-circulated back to the dryer while moisture is removed by a refrigeration/ de-humidifier system. These are available in Europe. Heat pump clothes dryers achieve roughly 40% to 60% reduction in energy consumption compared to traditional clothes dryer designs. The expense and longer drying times are considered significant market barriers for the US.
- **Microwave –** (electric only) Microwaves are used to evaporate the water in the clothing. There are some limitations as clothes with metal accessories cannot be used. Prototypes have been developed. Microwave dryers use 17 to 25% less energy than typical electric dryers and they achieve 25% faster drying times, but they could be more expensive than conventional models.

A subset of these energy saving features could apply to industrial large-capacity tumble dryers. In the US, large capacity tumble dryers are mainly gas fired. The industrial-sized commercial dryers have enormous capacities and process thousands of kg of laundry each day. Energy consumption is a major expense at these facilities and so there is already a large incentive to design energy saving features. Many of the energy savings features are already available in the highest-capacity industrial sized dryers.

COSTS

■ **Laundry Dryer (domestic) -** Most respondents in a 2008 European survey spent about €200-€399 when they purchased their current dryers. Most respondents bought dryers before 2006 and this price range corresponds to the price of an air vented dryer [3]. It is widely accepted that compact (almost exclusively air vented) models are cheapest, followed by full size air vented ones, followed by condenser types, with the most expensive ones being heat pump condensing dryers [expert opinion].

Energy efficiency classes - It seems that the EU energy labels have been most successful at reducing sales in the lowest label classes [3]. Between 2002 and 2005, there was an 8% fall in the price of class C dryers in Western Europe to €375, whereas the class A and B dryers had seen price increases of 50% between 2002 and 2005. In 2005, the average price of class A and class B dryers exceeded €600 [3]. There is evidence that for certain brands there is still a price premium for class A and B dryers, shown in Table 3. In 2012, UK market prices were in the range €260 - 2,530[4] for class A and €230 - 1,600 for class B dryers[5]. The fact that some dryers are available at the cheaper end of these ranges suggests the market might be opening up in these energy efficiency classes [14].

Air usage: vented or condensing - There is a price premium for the most efficient heat pump products of 30% from major brands. Only in Switzerland and Austria do prices match the non-heat pump prices [2]. Switzerland will introduce a mandatory requirement for EU energy label class A (~0.35 kWh/kg) in 2012, which will be difficult for anything but heat pump products to

[4] Using the conversion factors from the Coinmill website on the 28th Mar 2012 (1 USD = 0.75 Euro and 1 GBP = 1.19 Euro). Price ranges taken from http://www.pricerunner.co.uk
[5] not including compact products

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achieve. In Switzerland, the average price for a class A heat pump dryer is €1875 (2012) [13]. In Germany, where heat pump dryer are approximately 10-15% of annual sales [11], the average price of a heat pump dryer was €1618 (2012) [13]. There is some evidence that cheaper heat pump dryers are entering the market. For example, the Creda heat pump dryer was released onto the UK market (2011) at approximately €475[11] [12].

■ **Commercial and Industrial Devices -** In the US, the average price of a single-load commercial dryer was €600[11] (2009) [4]. These dryers are very similar to the European domestic dryers in price and capacity. As the capacity increases and technical controls are enhanced, the price increases. The majority of large capacity tumble dryers are gas powered and prices are around €2100[11] [4]. This is similar to the European prices for a standard capacity heat pump condenser dryer at ~€2195[11]. It has been suggested that the higher prices and longer drying times have prevented heat pump technologies breaking the US market [4]. A recent testing programme has been developed to adapt the technology to consumer expectations, voltage and frequency with the aim of accelerating the introduction of heat pump dryers in the USA [11]. The industrial dryers are more expensive on average €60,000[11] [4].

POTENTIAL AND BARRIERS

There are energy efficient dryers currently on the global market but a number of barriers exist that limit the sales of these technologies such as:

- **High costs:** Higher costs associated with energy efficient products are likely to be the most limiting factor combined with the availability of cheaper lower efficiency products. Purchasing price is the most influential factor according to 83% of manufacturers and this is supported by the 2008 European Ecodesign EuP (lot 16) consumer survey where it was the most influential factor for 60% of respondents [3]. The fact that heat pump dryers are yet to penetrate the US commercial market has been blamed on the high cost of the technology and the longer drying cycles [4].
- **Lack of customer information/awareness:** a large number of respondents in a 2008 European survey did not know the energy efficiency class of their dryer (47%) [3]. This suggests a lack of interest about the energy performance of dryers and a lack of understanding about the potential cost and energy savings from buying a more efficient appliance. Lower market demand may prevent manufacturers from selling the most efficient technologies if they do not believe customers will pay for it.
- **Lack of space:** In some countries space is a limiting factor [3]. As discussed earlier, smaller capacity dryers take up less space but are also less efficient. There has been a constant demand for the compact dryer because it responds to a niche consumer market where there is a lack of space [3]. In Europe, the compact dryer was only 6% of the market sales in 2005 [3]. In the UK, compact dryers are a larger proportion of the market at 16% in 2005, dropping slightly to 14% in 2010 [10]. Further innovation could be required in this end-user market.
- **Old stock:** the average lifetime of dryers is 13 years but it can be up to 19 years [3]. For 42% of respondents in a 2008 European survey, 'a longer lifetime' was an important factor in the buying decision. Due to the long lifetimes, there is a time lag between energy efficient dryers becoming available to constituting a significant proportion of the stock; and
- **Perceived safety issues:** There are concerns over safety and installation issues associated with the installation of gas dryers. Dryers with exhaust air need special tubing for exhausting [3].

There are also barriers to achieving high performance even if an energy efficient product has been purchased. The energy consumption of a dryer depends on the behavior of the operator and a number of actions might increase energy consumption such as:

- **Loading the dryer below the manufacturer's recommendations:** A 2008 European survey found that 40% of respondents 'always', 'often' or 'sometimes' run the machine with a relatively small amount of laundry inside. Other respondents vary the kg load depending on the kind of laundry [3]. For these respondents there is the potential to reduce energy consumption by increasing the size of the loads.
- **Unnecessary use:** Between 23-40% of respondents 'always' or 'often' used their tumbler dryer in summer. In winter these percentages were in the range of 38-66%. 50% of respondents 'always' or at least 'often' resorted to using tumble dryers. In the summer, most respondents use their dryer for one cycle per week, which (accounting for the number of persons per household) averages at 0.7 cycles per week per person. In winter, the frequency of use greatly increases, 26% of all respondents use their dryers for 6 and more cycles per week, averaging at 1.1 cycles per week per person [3].
- **Use of the delay timer:** Typically there is extra energy consumption, on average 2.9W (~7.25 Wh), associated with the use of a delay timer [3]. 20% of respondents in a 2008 European survey claim to have used this function and delayed the start by ~2.5 hours [3]. During this time the dryer is in a waiting mode. However, delay timers have benefits such as timing the end of a cycle to match a family member returning home or to benefit from off peak energy rates.
- **Leaving the appliance in stand-by mode:** after the cycle has finished there is a period where the appliance is waiting for user attention. When the appliance is left in this 'stand-by' mode there is extra energy consumption of on average 2.6 W (1.6 Wh) [8].
- **Lack of machine maintenance:** manufacturers recommend cleaning the fluff-filter following each drying cycle to ensure better efficiency. A 2008 European survey found that 64% of respondents do not clean the fluff filter after each drying cycle. Manufacturers also recommend cleaning the heat exchanger regularly - 80%of respondents claim to clean it at least once a year but 20% never do. These behaviours increase the energy demand of the appliances [3].

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Table 1 – Summary Tables – Typical Key Data and Figures for Dryer Technologies

Domestic Dryer - Typical current international values (most recent year)						
Technical Performance	EU		US	Canada	Australia	Austria
	Eastern	Western				
Capacity (in kilograms) [2]	6.6 (2008)		4.7 (2010)[6]	5.2 (2010)[6]	4.9 (2009)	6.5 (2009)
National average energy efficiency (kWh/kg) [2]8	0.74 (2008)		0.69 (2009)	0.69 (2010)	0.70 (2009)	0.73 (2009)
Energy consumption (kWh/cycle) [2][8]	2.36 (2008)		2.21 (2010)	2.19 (2010)	2.22 (2009)	-
Estimated stock in millions [2]	-		-	11.1 (2008)	4.69 (2009)	1.09 (2007)
Energy consumption of stock electric dryers (GWh/year) [2]	-		-	10.39 (2007)	0.73 (2009)	0.44 (2007)
Usage (cycles per year) [2]	160		-	416	52	110[7]
Sales	% annual sales, [2][8]					
Vented	27 (2009)		100 (2010)	100 (2010)	89 (2010)	5 (2010)
Condenser	73 (2009)					
Heat-pump condenser	-		-	0 (2009)	2 (2009)	23 (2009)
Stock Projections – EU 15 [3]			2005	2010	2015	2020
Future stock estimation (million units)			53.7	60.5	65.2	70.2

US commercial Dryer - Typical values				
Technical Performance	Single-load dryers	Large capacity tumble dryers	Industrial dryers	Heat Pump technologies
Capacity (in kilograms) [4]	9 kg[9]	9 – 34 kg9	55– 318kg9	6 – 7 kg
Energy consumption (kWh/hr) [4] - Total (billion)[10]	6-7	23	27	-
Electricity	3	21	23	-
Gas	3	2	4	-
Estimated stock in millions [4] (2008)	1.45	2.00	0.025	
Average purchase cost [4]	€600[11]	€2,100[11]	€60,000[11]	€2195[11]
Energy efficiency (kWh/kg) [4]				0.27 – 0.34
Sales	Global	Europe		
Sales in thousand units [3]	85	30		

[6] US and Canadian capacities have been converted from capacities in cubic feet
[7] Implied figure calculated by the author compared to Government estimates for the rest of the row.
[8] The market share data for the EU, US, Australia, Austria and Canada are considered indicative by the referenced authors. These data have been normalised so they are more comparable despite different national testing procedures. They should be considered illustrative, for more details see page 18 ref [2]
[9] US pounds to 0.4536 kilograms
[10] Conversion from BTU, where 1000 BTU= 0.2930 kWh
[11] Using the conversion factors from the Coinmill website on the 28th Mar 2012 (1 USD = 0.75 Euro and 1 GBP = 1.19 Euro).

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Table 2 – Energy Savings for technology options for standard capacity commercial dryers [4]

Technology Option	Fuel Type	Estimated Energy Savings (%)
Recycle exhaust heat	Gas and Electric	45
Heat pump	Electric	50
Improved cycle termination	Gas and Electric	15
Modulating gas burner	Gas	15
Microwave	Electric	25
Inlet air preheat, condensing mode	Gas and Electric	14
Improved air circulation	Gas and Electric	Unknown
Improved drum design	Gas and Electric	Unknown

Table 3 – Summary Table – Price and % sales for EU energy efficiency labels [3]

	Price in Euros					% sales distribution		
Energy efficiency class	Switzerland (2012) [13]	Germany (2012) [13]	UK (2012) [14]11	W Europe (2005) [3]	E Europe (2005) [3]	W Europe (2005) [3]	E Europe (2005) [3]	UK (2010) [12]
A	1875	1618	260 - 2530	617	732	0.5	0.5	0.04
B	-	-	230 - 1,900	670	269	0.5	0.2	8.2
C	-	-	140 - 860	375	468	89.6	96.8	77.6
D	-	-	113 - 430	225	435	2.9	1.8	12.3
E	-	-	-	347	204	0.1	0	
F	-	-	160 - 300	180	NA	0	0	1.0
G	-	-	-	310	NA	0	0	
Unknown	-	-	-	300	253	2.8	0.7	0.2

Grey shading - Note prices for classes A and B might not be meaningful because market volume was low

Table 4 – Average Price in Euros for technology types in UK (2012) [10][11]

	Technology types		
Energy Class (current 95 reg)	Condenser dryers	Vented dryers	Compact dryers
A++	859.56		
A	712.71		
B	496.24		
C	283.42	£232.31	
D	393.10 (full size £279.64)	£151.89 (full size £186.24)	£152.32
E			
F			£205.52
G			
Unknown		£254.64	

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