Cold Appliances

HIGHLIGHTS

■ **PROCESS AND TECHNOLOGY STATUS –** Refrigeration and cold appliances are mature technologies which market has reached the saturation level in most developed countries, with penetration rates of nearly 100%. In 2009, the European Union (EU-27) residential refrigerator and freezer stock were estimated at around 191 million units and 84 million units, respectively. In the EU, about 15% of electricity consumed in households is used to satisfy the energy demand for domestic cold appliances, i.e. **fridges** for fresh foodstuff preservation, **freezers** for preservation at temperature of -18°C, and combined **fridge-freezers**. Today's market is characterised by a significant decrease in the freezer size, with an increase of combined refrigerator-freezers. Commercial refrigeration devices (**service and blast cabinets, walk-in cold rooms, packaged condensing units, process chillers**) are used in restaurants, hotels, pubs, cafes, supermarkets and in industrial processes. In some types of commercial buildings (e.g. supermarkets) refrigeration accounts for up to 50% of the building's energy consumption. All these devices include compressors, expansion valves, condensers and evaporators, evaporator fans, and appropriate process fluids. As far as the process fluid is concerned, in the last decades of the 20th century, freon-based gases, CFC and HCFC have been widely used because they are efficient, stable and safe. However, regulations to protect the atmospheric ozone layer have led to phase out most of these gases, and alternative hydrofluorocarbon (HFC) gases have been developed and are currently used. Fluids with a smaller global warming potential are currently under development. The energy demand for cold appliances can be reduced by efficiency improvements such as thermal insulation by vacuum and polyurethane foams, adaptive defrosters, more efficient heat-exchangers, compressors and fans, and electronic control. The domestic cold appliance market is growing fast in the emerging countries such as China, Brazil and India.

■ **PERFORMANCE AND COSTS –** Over the last twenty years, the energy efficiency of new fridge-freezers has been improving in almost all regions. In 2006, the best available refrigerator-freezer used 19% of the energy used by the equivalent product on the European market in 1992, although the average new domestic cold appliance used about 60% of the energy of the equivalent 1992 model. Between 2005 and 2008, the energy use of fridge-freezers has reduced from 0.86 kWh per litre per year (kWh/l-y) to 0.69 kWh/l-y in the United States, from 0.97 to 0.73 kWh/l-y in China, and from 0.92 to 0.84 kWh/l-y in Europe. The annual energy consumption of domestic fridge-freezers is moving toward the common level of 350-400 kWh/y (about 270 to 370 kWh/y for domestic freezers), with exception of China where the energy consumption is smaller (193 kWh/y) due to the smaller average volume of Chinese domestic cold appliances. Room for energy efficiency improvements exists in particular in regions with less efficient devices. As far as cost is concerned, based on the United Kingdom market, prices of domestic cold appliances vary depending on function and performance: Fridge-freezers prices range from €528 for A++ efficiency-rated products to €283 for B rated products; Fridges price ranges from €404 for A++ to €132 for B; Chest freezers cost approximately from €344 for A++ to €141 for C, while upright freezers cost from €509 for A++ to €188 for B rated products. The typical energy consumption (per unit) of European commercial cold appliances are 2,000 kWh/y for service cabinets, 3,500 kWh/y for blast cabinets, 12,200 kWh/y for walk-in cold rooms, 364,500 kWh/y for process chillers, and 22,000 kWh/y for packaged condensing units. Typical, average prices of commercial cold appliances vary significantly as a function of capacity and other features. Service cabinet refrigerators can cost from €850 to €3,000, service cabinet freezers from €1,000 to €3,000, blast cabinets from €2,000 to €30,000. The typical price of an average walk-in cold room is around €8,800. An average process chiller can cost €60,000 and a remote condensing unit is priced at approximately €5,000.

■ **POTENTIAL AND BARRIERS –** Today's cold appliances are technologically mature and further dramatic improvements are not expected in the short to medium term. Incremental efficiency increases can be obtained in the short term from vacuum-based thermal insulation, improved gaskets, and other technical improvements of major components (compressors, exchangers, fans, control electronics). More important advances in terms of sustainability could stem from novel process fluids with low-global warming potential. Expected improvements of commercial appliances are likely to enable a 13% reduction in energy consumption by 2020 and a 19% by 2030 (relative to 2011 level). In both the domestic and commercial sectors, a barrier to the adoption of highly-efficient cold appliances is the initial high cost. In the domestic sector, the lack of consumer awareness about efficiency savings is an additional barrier to the uptake of more efficient products. More radical innovations that might bring efficiency benefits in the long term are acoustic refrigeration, ammonia (sealed hermetics), electro-caloric refrigeration, optical cooling and magnetic refrigeration. The incremental cost of these new systems are not yet clear, but evidence suggests they could be very significant. Policy measures aimed to replace old, inefficient appliances (mandatory energy labelling, minimum energy standards) have now been enforced in many countries, particularly in the European countries (Directive 2010/30/EU).

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PROCESS AND TECHNOLOGY STATUS

Cold appliances are mostly based on the four phases of the refrigerating machine (*reverse Carnot cycle*[1]): heat is absorbed from a low-temperature source by the isothermal expansion of a fluid; an adiabatic compression is then used to increase the fluid temperature; the heat is then released to a high-temperature heat sink by the isothermal compression of the fluid. Finally, an adiabatic expansion is used to reduce the fluid temperature and restart the cycle. The cycle can be used to extract heat from a refrigerator and to transfer it to air at room temperature The basic configuration of a refrigerating machine consists of a compressor, an expansion valve, two heat exchangers (evaporator and condenser), and an appropriated process fluid. The fluid first evaporates in the evaporator absorbing heat from the cold appliance. It is then compressed by the compressor to reach a temperature higher than the room temperature. The absorbed heat is then released by condensing the fluid in the condenser at room temperature. Finally, the fluid pressure is reduced in the expansion valve, and the temperature of the fluid decreases to below the level of the cold appliance to restart the cycle. The energy to run the process is provided by the electric energy to run the compressor and circulate the fluid.

■ **Domestic Cold Appliances -** In the OECD countries, the residential sector uses approximately 30% of all electricity generated and produces 12% of all energy-related carbon dioxide (CO_2) emissions [1, 2]. In Europe, domestic cold appliances are the second largest consumers of electricity in the residential sector, with a share of 15.3% [3]. Improving the efficiency of these products can bring significant electricity and emission savings.

A refrigerator is intended for the preservation of foodstuffs with at least one compartment suitable for the storage of fresh food and/or beverages. **A fridge-freezer** has at least one fresh-food storage compartment and at least one other compartment suitable for the freezing of fresh food and the storage of frozen foodstuffs under three-star storage conditions. **A freezer** includes one or more compartments suitable for freezing foodstuffs with temperatures down to -18°C, and is also suitable for the storage of frozen foodstuffs under three-star storage conditions. A freezer, either a chest freezer accessible from the top or an upright freezer accessible from the front side, may also include two-star sections and/or compartments within a compartment or cabinet [4].

In Europe, 95% of refrigerators use natural convective cooling to transfer heat from the evaporator to the condenser. The refrigerator compartment is often equipped with an automatic defrosting system which periodically allows the evaporator temperature to rise, while defrosting of the freezer compartment requires the user intervention [5]. In North America and Asian Pacific countries, the most common cooling approach is forced convective-cooling combined with active defrosting by heating the evaporator, known as “no frost” [6]. Worldwide, natural convective cooling is the most common and least energy-intensive refrigeration technology, but in some markets no-frost technology is gaining market share [5].

Domestic cold appliances have sizes ranging from 30 to 800 litres. They also have a variety of product configurations including vertical, chest, single door, two door, and multi door, with a freezer located on the top, bottom, or side of the appliance [7]. There is also a range of product efficiencies. The performance of domestic cold appliances varies across world regions. The energy efficiency depends on thermal insulation technology and materials (e.g., vacuum insulation panels, polyurethane foams) and performance od major components. Other developments include adaptive defrosters that operate only when it is needed, replacement of AC motors with DC motors, and the use of electronic controls. Increasing compressor efficiency and the heat-exchange area in the evaporator and condenser, and using low-energy fans for the heat exchangers do also provide efficiency improvements.

Recently, the refrigerator stock reached penetration rates of around 100% in almost all EU-27 countries [8]. At the same time, the freezer market registered a significant decrease, due to the increased use of combined refrigerator/freezer appliances. In 2009 the EU-27 refrigerator stock in the residential sector was estimated to be around 191,000 million units and the freezer stock at around 84,000 million units [3].

In China, the number of refrigerator/freezer units is likely to have surpassed the total number of combined Canada, Denmark, France, Korea and the United Kingdom in 2010 [9]. In India, refrigerator uptake rates are rising [9]. In the OECD regions, the market is expected to grow slowly unless households choose to purchase a second refrigerator. Large differences exist in the market distribution of cold appliances by efficiency class, as countries hold different national and regional energy efficiency policies and programmes.

■ **Commercial Cold Appliances -** Commercial refrigeration products are used in diverse environments such as restaurants, hotels, pubs, cafes, supermarkets and industrial processes. Refrigeration in some types of commercial buildings, such as supermarkets, represents up to 50% of the building’s energy consumption [5]. In the UK, retail food outlets are responsible for around 3% of total electrical energy consumption and 1% of total greenhouse gas emissions. A large proportion of these emissions can be attributed to refrigeration [11].

[1] The *Carnot cycle* (Sadi Carnot, 1824) is a theoretical thermodynamic process to convert thermal energy into mechanical energy using the thermodynamic transformations of an ideal fluid (perfect gas): a) the heat provided by a high-temperature source (e.g. combustion) is first absorbed by the isothermal expansion of the fluid; b) the fluid then expands adiabatically (e.g. in a piston or a turbine) and generates mechanical energy, while reducing its temperature; c) the residual heat of the fluid is then released during an isothermal compression; d) finally, an adiabatic compression increases the fluid temperature to the initial level to restart the cycle. In the common practice, the theoretical *Carnot* cycle translates into the *Rankine cycle* using a phase-change fluid.

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Most important commercial cold appliances in terms of energy consumption include service cabinets, blast cabinets, walk-in cold rooms, packaged condensing units and chillers for industrial process [13]. **Service cabinets** are all cabinets used for the storage (as opposed to sale) of food products. **Blast cabinets** use a blast of cold air to bring down the temperature of hot food rapidly so it can be stored safely avoiding bacteria growth. **Walk-in cold rooms** are insulated enclosures with similar operational principles to any refrigerator, but capable of storing significantly more goods. A **packaged condensing unit** is defined as an assembly of a condenser and one or more compressors with interconnecting pipe work. A **process chiller** is a refrigeration system using halocarbon or ammonia refrigerants that provide cooling for industrial processes and application [12].

All these devices include compressors, expansion valves, condenser and evaporator heat exchangers, evaporator fans, case display lighting to illuminate the merchandise, defrost heaters in frozen food cases and control systems. Improving the performance of some of these components offers a significant opportunity for energy efficiency improvements.

PERFORMANCE AND COSTS

■ **Domestic Cold Appliances -** There has been considerable improvement over the last twenty years in domestic refrigeration performance. In 2006, the best available refrigerator-freezer used 19% of the energy used by the equivalent product available in the European market in 1992; however, the average new domestic cold appliance used about 60% of the energy of the equivalent 1992 model[2] [5]. In other words, by using best available technologies we could obtain a significant additional efficiency gain (about 40% in 2006 relative to 1992). Room for improvement in domestic refrigeration appliances is substantial particularly in those regions with less efficient devices.

The most common approach to efficiency metrics for household refrigeration is the energy consumption at defined conditions per unit (volume) of cooled space [7]. The energy efficiency of new fridge-freezers has improved in almost all regions; in the US, it has moved from 0.86 kWh/litre/year in 2005 to 0.69 in 2008. In China, the efficiency has improved from 0.97 kWh/l/year in 2005 to 0.73 in 2008. In the EU, energy efficiency was 0.92 kWh/l/year in 2005 and improved to 0.84 in 2008. Although the rate of improvement varies significantly across countries, higher improvement rates are often found in countries with lowest initial efficiency level [9].

A benchmarking study by IEA-4E[3] [9] states that differences in fridge-freezer energy consumption between individual products in various countries are relatively small, with all countries appearing to move toward a plateau of normalised new product energy consumption of 350 to 400kWh/year. China is the exception, where unit consumptions are significantly lower at 193 kWh/year. The average fridge volume in China is 118 l and the average freezer volume is 68 l, while in Europe the average fridge volume is 213 l and the average freezer volume is 78 l. Given the difference in volumes between countries, this difference is considered to be smaller than expected. The consumption of freezer-only units also continues to reduce within a band of 270–370 kWh/year [9].

As far as cost is concerned, substantial differences may exists among world regions. For example, in 2002-2004, fridge prices in Western Europe were 41% higher than in Eastern Europe [4].

The UK Market Transformation Programme [14] uses the following cost assumptions[4]:

- Fridge freezers: from €528 for A++ to €283 for B
- Fridges: from €404 for A++ to €132 for B
- Chest freezers: from €344 for A++ to €141 for C
- Upright freezers: from €508 for A++ to €188 for B

■ **Commercial Cold Appliances –** There is a variety of commercial cold appliances, with a range of performance levels. Major increases in efficiency are not expected in the medium term because commercial cold systems are a mature technology [15] and efficiency improvements have already been introduced in the past years. However, room for incremental improvements still exists, and all commercial cold appliances could benefit from standard approaches to improving energy efficiency of major components and technologies. These include compressors, motors inverters, control, larger heat exchanger surfaces, and more efficient control systems, [16].

In the EU-27 region, estimated average total energy consumption for various commercial cold appliances are as follows: Service cabinets consume around 2,200 kWh/year; Blast cabinets 3,500 kWh/year; Walk-in cold rooms 12,200 kWh/year; Packaged condensing units approximately 22,000 kWh/year; and Industrial process chillers the most energy at 364,500 kWh/year [12]. A common efficiency metric for commercial cold appliances is the coefficient of performance (COP). It is defined as the cooling delivered by the core[5] components of the system divided by the energy input [15]. The COP of commercial cold appliances is expected to improve from today's (2011) 2.5 to 2.89 in 2020 and 3.1 in 2030 [15]. In other words, in 2020 cold appliances could be 16% more efficient than 2011 equivalent devices and in 2030 the increase could reach 24%.

As far as cost is concerned, selling prices of commercial cold appliances vary significantly as a

[2] Other estimates suggest that new appliances use around 2/3 less energy than the typical 1980 models [15].

[3] IEA Implementing Agreement for a Co-operating Programme on Efficient Electrical End-Use Equipment (4E)

[4] Conversion factor to uplift 2009 GBP to 2011 GBP estimated from http://www.hm-treasury.gov.uk/data_gdp_fig.htm; Average 2011 exchange rate to convert GBP to Euro from http://www.ecb.int/stats/exchange/eurofxref/html/eurofxref-graph-gbp.en.html

[5] core components are the compressor, the expansion valve and the refrigerant circuit that connects them.

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function of volumes. In Europe, average, typical selling price of service cabinet refrigerators ranges from €850 to €3,000 and service cabinet freezers are from €1,000 to €3,000. Estimated average prices for blast cabinets with foodstuff capacity between 3 and 240 kg range from €2,000 to €30,000. The selling price of an average walk-in cold room is around €8,800. The estimated price for an average 270 kW cooling capacity chiller is €60,000. A typical remote condensing unit sized 5 to 7 kW has an average price of €5,000 [12].

POTENTIAL AND BARRIERS

■ **Domestic Cold Appliances -** There is a variety of options to increase the energy efficiency and sustainability of refrigerators and freezers. These include advanced thermal insulation systems, improved gaskets and refrigeration systems, the use of low global warming process fluids, more efficient fan motors, compressors, heat exchangers and defrost mechanisms [17]. Magneto-caloric and thermo-electric refrigeration systems are being researched and have a potential to provide significant energy savings. Other technologies that may become relevant in the future include Stirling/pulse tube, thermo-acoustic, absorption and adsorption refrigeration systems [17].

In spite of the fact that lifecycle energy costs can largely exceed the purchase price of the cold appliances, consumers and buyers do not always consider the energy consumption as a primary decision driver when buying new cold appliances. The lack of consumers' awareness of the benefits obtained from using more efficient refrigeration appliances seems to be a major barrier to energy-saving [5].

The European Union has policy measures in place aimed to removing the worst performing domestic cold appliances from the market and informing consumers. Policies include mandatory energy labelling (Directive 2010/30/EU) and Minimum Energy Performance Standards introduced in 2009 (EC Commission Regulation No 643/2009). Appliances must comply with a minimum energy performance which improves over time and is determined by the Energy Efficiency Index (EEI[6]), i.e.:

Compression-type refrigerating appliances:
From 1 July 2010: EEI < 55
From 1 July 2012: EEI < 44
From 1 July 2014:EEI < 42

Absorption-type and other-type refrigerating appliances:
From 1 July 2010: EEI < 150
From 1 July 2012: EEI < 125
From 1 July 2015: EEI < 110

■ **Commercial Cold Appliances -** Incremental improvements are also expected for commercial cold appliances, though no radical change is expected in the next decade. Energy consumption of a refrigerator-freezer is directly related to the cabinet internal load and cabinet thermal performance. Thus improvements to insulation and gaskets can increase the efficiency of commercial cold appliances. Efficiency and environmental improvements can also be achieved by using low global warming fluids. The capital cost of new equipment is a common barrier [17]. Potential radical innovations such as acoustic refrigeration, ammonia (sealed hermetics), electro-caloric refrigeration, optical cooling and magnetic refrigeration could also bring benefit in the future [11], though they are not expected to have an impact in the short to medium term, given the early stage of development.

[6] EEI (Energy efficiency index) compares annual energy consumption to standard product energy consumption. Calculation guidance provided in Commission Delegated Regulation (EU) No 1060/2010 of 28 Sept 2010, Annex VIII, 3.

References and Further Information

1. IEA, Key World Energy Statistics, 2011
2. IEA, Cool Appliances: Policy Strategies for Energy Efficient Homes, 2003
3. P. Bertoldi and B. Atanasiu, Electricity Consumption and Efficiency Trends in European Union. 2009.
4. ISIS, Dec. 2007, Preparatory Studies for Eco-design Requirements of EuPs; Lot 13: Domestic Refrigerators & Freezers.
5. IEA, Energy Technology Perspectives. 2006.
6. Energy Technology Collaboration and Climate Change Mitigation, Case Study 3: Appliance Energy Efficiency. 2005.
7. Paul Waide, Navigant Consulting (in partnership with CLASP). Opportunities for Success and CO2 Savings from Appliance Energy Efficiency Harmonisation. March 2011.
8. Cold appliances data, ODYSSEE, www.odyssee-indicators.org. Accessed on 17/11/11.
9. Benchmarking of Domestic Cold Appliances. IEA-4E (IEA Implementing Agreement for a Co-operating Programme on Efficient Electrical End-Use Equipment (4E), August 2010
10. M.A.McNeil et al.: Potential Carbon Emissions Mitigation Impacts from an International Standards and Labelling Program. 2008.
11. Refrigeration Road Map. Carbon Trust, March 2010.
12. Preparatory Study for Eco-design Requirements of EuPs, Lot1: Refrigerating and freezing equipment. May 2011.
13. D. Gibson and A. Couch. Review of EU preparatory study on DG ENTR Lot 1 Refrigerating and Freezing Equipment. June 2011.
14. Market Transformation Programme (MTP), BNCO03: Domestic Chest Freezers, Upright Freezers, Fridges and Fridge-freezers: Government Standards Evidence Base 2009: Policy Scenario, 2009
15. Long Term Energy Performances for energy-using domestic and commercial appliances and products. AECOM, June 2011.
16. Saving Energy Through Better Products and Appliances. DEFRA, December 2009
17. P.Bansal, E.Vineyard and O.Abdelaziz, Advances in household appliances – A review, 2011
18. Market Transformation Programme (MTP), BMCO01: Domestic Chest Freezers, Upright Freezers, Fridges and Fridge-freezers: Government Standards Evidence Base 2009: Key Inputs, 2009
19. Cold appliances market data. Mintel, gmn.mintel.com. Accessed on 07/11/11
20. A. McNeil et al, Global Potential of Energy Efficiency Standards and Labeling Programs, CLASP, November 2008
21. Virginie Letschert and Michael McNeil. The Boom of Electricity Demand in the Residential Sector in the Developing World and the Potential for Energy Efficiency. Lawrence Berkeley National Laboratory, 2008.
22. Anibal de Almeida, Paula Fonseca, Barbara Schlomann, Nicolai Feilberg. Characterization of the household electricity consumption in the EU, potential energy savings and specific policy recommendations. March 2011.
23. Michael A. McNeil, Virginie E. Letschert and Stephane de la Rue du Can, Global Potential of Energy Efficiency Standards and Labelling Programs, Lawrence Berkeley National Laboratory, November 2008

Table 1 – Summary Table: Key Data and Figures on Commercial Cold Appliances

Commercial Cold Appliances [12]					
Technical Performance	**Typical current international values and ranges**				
Technology Variants	**Service Cabinets**	**Blast Cabinets**	**Walk-in Cold Rooms**	**Process Chillers**	**Packaged condensing units**
Average energy input (kWh/yr) (c)	2,200 (a)	3,500 (a)	12,200 (a)	364,500 (a)	22,000 (a)
Energy efficiency (COP)	1.11 (b)	N/A	1.5 (e)	2.80 (f)	1.9 (g)
Typical size	100-2000 l	N/A	25 m^3 (e)	N/A	N/A
Technical lifetime, years	8.5 (b)	8.5 (d)	10 (e)	15 (f)	8 (g)
EU Market share (2008), %	19%	8%	4%	2%	28%
EU Market share (2020 est.), %	20%	10%	5%	2%	23%
Environmental Impact					
CO_2 emissions, g/kWh	This figure depends on the electricity emissions rate				
Costs (€ 2011)					
Average product cost, Euro/unit	1,000 (b)	3,400 (d)	8,800 (e)	55,000 (f)	3,100 (g)
Typical cost breakdown, % (material, process, labour)	N/A	N/A	N/A	N/A	N/A
Data Projections					
Efficiency (COP), 2011-2030	N/A	N/A	N/A	N/A	N/A
Product cost (€), 2010-2020 (2030-)	N/A	N/A	N/A	N/A	N/A
Lifetime, (hours) 2011-2020 (2030-)	N/A	N/A	N/A	N/A	N/A
Data Projections					
EU Market share (2008), %	19%	8%	4%	2%	28%
EU Market share (2020 est.), %	20%	10%	5%	2%	23%

(a) Rounded to the nearest significant figure; (b)Typical high temperature service cabinet; (c)This is the average total energy consumption per product type; it may not correspond to the typical base case values listed for energy efficiency, lifetime or cost; (d)Typical vertical blast cabinet, 20 kg capacity, chilling from 70 C to 3 C in 90 minutes; (e) Most common product configuration on the market; (f) Typical medium temperature process chiller; (g) Typical medium temperature remote condensing unit.

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Table 2 – Summary Table – Key Data and Figures on Domestic Cold Appliances

Domestic Cold Appliances			
Technical Performance	**Typical current international values and ranges**		
Technology Variants	**Fridge-Freezers**	**Freezers**	**Refrigerators**
Energy input (kWh/yr) – EU [9]	360 [(a)]	276 [(a)]	163.7 [4]
Energy input (kWh/yr) – US [9]	476.7 [(a)]	513.2 [(a)]	N/A
Energy input (kWh/yr) – China [9]	193 [(a)]	362 [(a)]	N/A
Energy efficiency (kWh/l/year, 2009) – EU [9]	0.84 [(a)]	1.47 [(a)]	N/A
Energy efficiency (kWh/l/year, 2009) – US [9]	0.68 [(a)]	0.69 [(a)]	N/A
Energy efficiency (kWh/l/year, 2009) – China [9]	0.73 [(a)]	0.79 [(a)]	N/A
Typical size (l, 2008) – EU [9]	213 (fridge)/78 (freezer) [(c)]	169 [(c)]	N/A
Typical size (l, 2009) – US [9]	415 (fridge)/200 (freezer) [(c)]	441 [(c)]	N/A
Typical size (l, 2008) – China [9]	118 (fridge)/68 (freezer) [(c)]	214 [(c)]	N/A
Technical lifetime, years (2009) [18]	15	15-16	12.5
UK Market share (2009), % [19]	47%	25%	28%
Mexico Market share (2009), % [19]	50%	8%	42%
Hong Kong Market share (2008), % [19]	85%	2%	14%
Environmental Impact			
CO_2 emissions, g/kWh	This figure depends on the electricity emissions rate.		
Costs (€ 2011)			
Product cost, Euro/unit	333	186-302	223
Data Projections (by technology variant)			
Efficiency (kWh/year) - PAO [20] [(c)]	N/A	N/A	537 (2006); 476 (2010); 318 (2020)
Efficiency (kWh/year) – NAM [20]	N/A	N/A	562 (2006); 506 (2010); 391 (2020)
Efficiency (kWh/year) – WEU [20]	N/A	N/A	364 (2006); 268 (2010); 271 (2020)
Efficiency (kWh/year) – EEU [20]	N/A	N/A	483 (2006); 268 (2010); 271 (2020)
Efficiency (kWh/year) – FSU [20]	N/A	N/A	644 (2006); 483 (2010); 271 (2020)
Efficiency (kWh/year) – LAM [20]	N/A	N/A	440 (2006); 261 (2010); 216 (2020)
Efficiency (kWh/year) – MEA+SSA [20]	N/A	N/A	445 (2006); 364 (2010); 271 (2020)
Efficiency (kWh/year) – CPA [20]	N/A	N/A	489 (2006); 353 (2010); 302 (2020)
Efficiency (kWh/year) – SAS-PAS [20]	N/A	N/A	548 (2006); 301 (2010); 223 (2020)
Product cost (€), 2010-2020	154-222 (2010) 145-209 (2015) 138-199 (2020)	328 (2010) 308 (2015) 293 (2020)	191 (2010); 180 (2015); 171 (2020)
Data Projections (by application)			
UK Market share (2009), % [19]	47%	25%	28%
Mexico Market share (2009), % [19]	50%	8%	42%
Hong Kong Market share (2008), % [19]	85%	2%	14%

(a) Product weighted average of new appliances; the best product consumes 208 kWh/year while the worst product demands 572 kWh/year
(b) Average compartment volume of new appliances
(c) PAO: Pacific OECD countries; NAM: North America; WEU: Western Europe; EEU: Central and Eastern Europe; FSU: Former Soviet Union; LAM: Latin America; AFR: Sub-Saharan Africa; MEA: North Africa and Middle East; CPA: Centrally Planned Asia; SAS: South Asia; PAS: Other Pacific Asia.

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