# ECODESIGN & LABELLING REVIEW
# Household Refrigeration Appliances

Stakeholder Meeting 1 July 2015

# Agenda

| | | | |
|---|---|---|---|
| • 9.30h | Registration | | |
| • 10.00 | Start meeting | | (interim report) |
| | Introduction | | (Ch. 1 & 2) |
| | Task 1 | Scope | (Ch. 3) |
| | | Standards | (Ch. 4) |
| | | Legislation | (Ch. 5) |
| • LUNCH | ca. 12.30-13.30h | | |
| | | | |
| | Task 2 | Market | (Ch. 6) |
| | Task 3 | Users | (Ch. 7) |
| | Task 4 | Technical | (Ch. 8) |
| | AOB | | |
| • 17.30 (latest) | Meeting closed | | |

# Study team

Research:

- Van Holsteijn en Kemna B.V. (**VHK**), The Netherlands, project leader;
- Association pour la Recherche et le Développement des Méthodes et Processus Industriels (**ARMINES**), France, technical specialist (Task 4) & technology roadmap;

In collaboration with:

- Viegand Maagøe A/S (**VM**), Denmark, reviewer;
- **Wuppertal Institute** for Climate, Environment and Energy GmbH, Germany, reviewer.

Contract manager:

Vlaamse Instelling voor Technologisch Onderzoek NV (**VITO**), Belgium

# Assignment

Article 7 of Commission Regulation (EC) No. 643/2009 [Ecodesign]

Article 7 of Commission Delegated Regulation (EU) No. 1060/2010 [Energy Labelling]

1. *"The Commission shall review this Regulation in the light of **technological progress** no later than five years after its entry into force and present the result of this review to the Ecodesign Consultation Forum. The review shall in particular assess the **verification tolerances** of Annex V [VII] and the possibilities for removing or reducing the values of the **correction factors** of Annex IV [VIII]."*
2. Need for **ecodesign** requirements for **wine storage appliances**
3. **Technology Roadmap [ → Horizon 2020]**

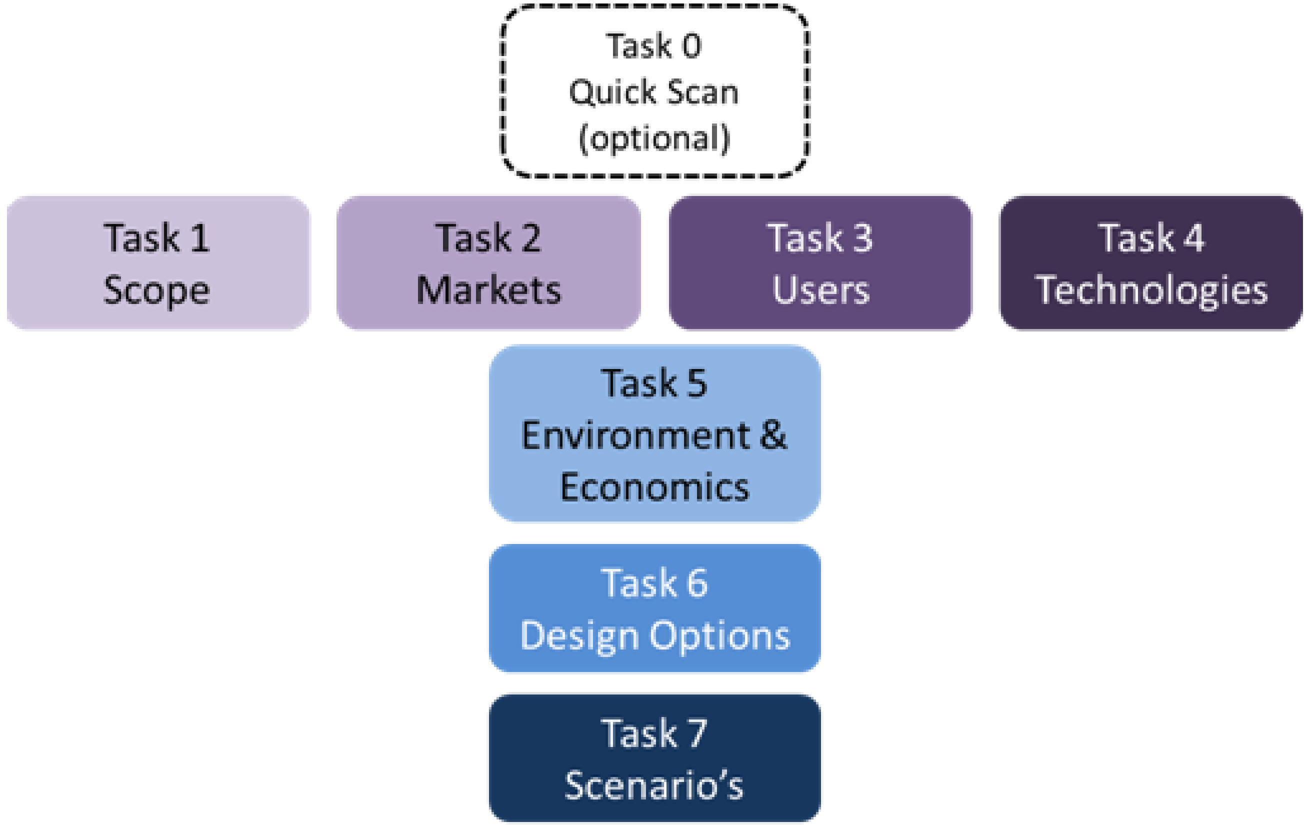
1 & 2: Adapted **MEErP** methodology

1 & 2: Build on 2014 **Omnibus** review (decision Consultation Forum 5 May 2014)

1 & 2: As outcome **Labelling Review** is pending, assume 7 classes + empty top class

3: **TRL** (Technical Readiness Level) assessment, US DoE format

# MEErP structure



# TRL (Technology Readiness Levels, Horizon 2020)

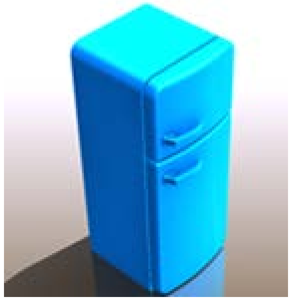
- TRL 1 – basic principles observed
- TRL 2 – technology concept formulated
- TRL 3 – experimental proof of concept
- TRL 4 – technology validated in lab
- TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
- TRL 7 – system prototype demonstration in operational environment
- TRL 8 – system complete and qualified
- TRL 9 – actual system proven in operational environment (competitive manufacturing in the case of key enabling technologies; or in space)

# Timeplan

| Date | Event/plan |
| --- | --- |
| **December 2014** | Start contract 23.12.2014 |
| **January 2015** | Launch website |
| **31 May 2015** | Publication Draft Task Reports 1-4 (interim) |
| **July 2015** | Stakeholder meeting 1 July |
| **October 2015** | Draft Final Report |
| **December 2015** | Final Report |

# Consultation & data retrieval

- **Website:** www.ecodesign-fridges.eu



- **Industry & expert meetings** (CECED and TopTen documents on website)
- **Desk research**, key sources (apart from Omnibus 2014 study):
  - IEC 625522 & related standards, Re/genT reports on new standards, Ecofys Standards Monitoring for EC
  - Legislation, IEA-4$^{E}$ Benchmarking study (update 2014), CLASP database & CLASP 2013 study,
  - EC Integrated Roadmap, US DoE TRA-Guide, Ecodesign Smart Appliances study, EC study on refrigerator durability
  - Topten.eu (incl. GfK data 2007-2013), Intertek report on correction factors

# Inventory of (earlier) positions

- Revisit correction factors for climate (remove), built-in (re-assess), no-frost (adapt)
- Align to new IEC 62552 standard
- Not linear curve but exponential (curved) reference  (SAE formula in par. 5.3)
- Not only efficiency, but total energy consumption important
- Cooling capacity may be relevant (according to latest StiWA test)
- Address non-energy resources efficiency

# Task 1
# Scope, standards & legislation

## Task 1.1 SCOPE

NOW

# Scope: Article 1

**1.1** This Regulation establishes ecodesign requirements for the placing on the market of **electric mains-operated household refrigerating appliances** with a storage volume **up to 1 500 litres**.

**1.2** This Regulation shall apply to electric mains-operated household refrigerating appliances, including those sold for **non-household use** or for the refrigeration of **items other than foodstuffs.**

It shall also apply to electric mains-operated household refrigerating appliances that can be **battery-operated**.

**1.3** This Regulation **shall not apply to** :

a) Refrigerating appliances that are **primarily powered** by **energy sources other than electricity**, such as liquefied petroleum gas (LPG), kerosene and bio-diesel fuels;

**b)** **battery-operated** refrigerating appliances that **can be connected to the mains through an AC/DC converter, purchased separately**;

c) custom-made refrigerating appliances, **made on a one-off basis** and not equivalent to other refrigerating appliance models;

d) refrigerating appliances **for tertiary sector** application where the removal of refrigerated foodstuffs is electronically sensed and that information can be automatically transmitted through a network connection to a remote control system for accounting;

e) appliances where the primary function is **not the storage of foodstuffs through refrigeration**, such as stand-alone ice-makers or chilled drinks dispensers.

# Scope: Article 1

NEW

Separate Ecodesign measures for **professional** and **commercial** refrigeration appliances are underway, so (mostly) 'non-household' scope no longer necessary

Exception: non-household minibars and wine storage coolers (mentioned CF July 2014 on commercial refrigeration)

Opinion?

Art. 1.1 Start at ≥10 litres for both EL and ED? Restrict to <1000-1200 litres?

Art. 1.2 Only for non-household minibars (fridge<80 ltr.?) and wine storage? (generic 'non-household' not needed, move 'battery operated' to 1.3)

Art. 1.3 **a)** What is 'primarily powered' ? How to assess? Why needed after Art. 1.1?

**b)** 'Battery operated' is included in 1.2, but also excluded in 1.3.b (every battery- operated device can be made to work on mains with a converter)??

**c)** Eliminate (also not included for other large appliances)?

**d)** and **e)** Eliminate? (applies to non-household)

NOW

# Scope definitions: Article 2

In addition to the definitions set out in Directive ~~2005/32~~/ 2009/125/EC, the following definitions shall apply:

**1. ‘foodstuffs’** means food, ingredients, beverages, including wine, and other items primarily intended for consumption which require refrigeration at specified temperatures;

**2. ‘household refrigerating appliance’** means an insulated cabinet, with one or more compartments, intended for refrigerating or freezing foodstuffs, or for the storage of refrigerated or frozen foodstuffs for non-professional purposes, cooled by one or more energy-consuming processes including appliances sold as building kits to be assembled by the end-user;

**3. ‘refrigerator’, 4. ‘compression-type’…, 5. ‘absorption-type’, 6. ‘refrigerator-freezer’, 7. ‘frozen food storage cabinet’, 8. ‘food freezer’, 9. ‘wine storage appliance’, 10. ‘multi-use appliance’.**

**11. ‘equivalent refrigerating appliance’** means a model placed on the market with the same gross and storage volumes, same technical, efficiency and performance characteristics, and same compartment types as another refrigerating appliance model placed on the market under a different commercial code number by the same manufacturer.

# Scope definitions: Article 2

NEW

**New IEC 62552-1:2014 definition of 'household refrigeration appliance'**

*'an insulated cabinet with one or more* ***compartments*** *that are controlled at specific temperatures and are of suitable size and equipped for household use, cooled by natural convection or a forced convection system whereby the cooling is obtained by one or more energy-consuming means'.*

*Compartment* is an enclosed space within a **refrigerating appliance**, which is directly accessible through one or more external doors, which may itself be divided into **sub-compartments**

*Sub-compartment* is a permanent enclosed space within a **compartment** which has a different operating temperature range from the **compartment** within which it is located.

Opinion?

Art. 2, 2) Use new IEC definition (also eliminates need for 'foodstuffs' here) ?

Art. 2 Move definitions not used in main regulatory text to Annex I (1 and 3-10)?

Add IEC definitions of (sub)compartment, possibly 'minibar'?

NOW

# More definitions: Annex I

Definitions applicable for the purposes of Annexes II to VI

Energy consuming means: '**compression-type**', '**absorption type**' (*Art. 2*), '**other**' (*Ann.I*)

Installation type: '*built-in*' (implicitly all other are 'not built-in')

Freezer features: '**frost-free system**', '**frost-free compartment**', '**fast freeze**'

Door position: '**top-opening/chest type**', '**upright type**', '**chest freezer**' (75% gross volume top-opening , rest may be different)

Compartments: '**fresh food**' (unfrozen foodstuffs='fs'), '**cellar**'(particular fs warmer than fresh food), '**chill**' (highly perishable fs), '**frozen-food storage**' (low-temperature for frozen fs classified by stars 0* -****), '**multi-use**' (end-user can set temperature), '**wine storage**'(ST or LT storage of wine, 5-20°C±0.5, RH 50-80%, low vibe), '**other**' (not wine storage, particular foodstuffs, >14°C)

Appliances (also from Art. 2): **'refrigerator**'(≥1 fresh food comp.), **'refrigerator-freezer'** '(≥1 fresh food comp.+1 frozen food *** comp.), **, 'frozen food storage cabinet'** (≥1 frozen food storage comp.)**, 'food freezer'** (≥1 frozen food freezing comp., also *** storage+ possibly ** section)**, 'wine storage appliance'** (no other than wine storage comp.), **'multi-use appliance'** (no other than multi-use), '**cellar**' (no other), **'refrigerator-chiller** (≥1 fresh food comp.+ ≥ 1 chill, no frozen).

# Scope definitions: Article 2

NEW

**New and more robust IEC 62552-1:2014 definitions available**

*More flexibility of the Commission in using equations, tables, etc. in the definition annex of the latest legislation*.

Opinion?

| | |
|---|---|
| Ann. 1 | Use new IEC definitions where possible. Add 'pantry compartment' (14-20°C, nom. 17°C)? |
| Ann.1 | Define compartment types by design/nominal/extreme temperatures (compare Annex IV, Tables 4 and 5), in a table and with no/minimal prose? |
| Ann. 1 | Define appliance types by possible combinations of compartments, also in a table and with no/minimal prose (compare Annex IV, Table 2) |
| | *Further simplification of appliance categories with CECED proposal?* |

# Compartment definition

compilation of CR 643/2009, Annex IV, Tables 4 & 5+pantry

NOW

| Compartment type | Tmin | Tmax | Tnom | ΔT-ratio |
|---|---|---|---|---|
| *Name* | *°C* | *°C* | *°C* | *(25-Tnom)/20* |
| Other | +14 | n.a. | n.a. | n.a. |
| Pantry | +14 | +20 | +17 | 0.40 |
| Wine storage | +5 | +20 | +12 | 0.65 |
| Cellar | +8 | +14 | +12 | 0.65 |
| Fresh food | +4 | +8 | **+5** | 1.00 |
| Chill | −2 | +3 | 0 | 1.25 |
| 0-star & ice-making | n.a. | 0 | 0 | 1.25 |
| 1-star | n.a. | −6 | −6 | 1.55 |
| 2-star | n.a. | −12 | −12 | 1.85 |
| Food freezer & 3-star | n.a. | −18 | −18 | 2.15 |
| Multi-use | as coldest compartment above that is possible | | | |

*n.a.=not applicable*

NEW

'Other' still needed? → Pantry new definition

Fresh food new : Tnom +4, Tmin 0.

ΔT-ratio: (**24**-Tnom)/20 → changes all values in column

# Appliance definition

## CR 643/2009, Table 2

*Table 2*

**Household refrigerating appliance classification and relevant compartment composition**

| Nominal temperature (for the EEI) (°C) | Design T | + 12 | + 12 | + 5 | 0 | 0 | − 6 | − 12 | − 18 | − 18 | Category (number) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Compartment types | Other | Wine storage | Cellar | Fresh food storage | Chill | 0-star/Ice making | 1-star | 2-star | 3-star | 4-star | |
| Appliance Category | Compartments composition | | | | | | | | | | |
| REFRIGERATOR WITH ONE OR MORE FRESH-FOOD STORAGE COMPARTMENTS | N | N | N | Y | N | N | N | N | N | N | 1 |
| REFRIGERATOR-CELLAR, CELLAR AND WINE STORAGE APPLIANCE | O | O | O | Y | N | N | N | N | N | N | 2 |
| | O | O | Y | N | N | N | N | N | N | N | |
| | N | Y | N | N | N | N | N | N | N | N | |
| REFRIGERATOR-CHILLER AND REFRIGERATOR WITH A 0-STAR COMPARTMENT | O | O | O | Y | Y | O | N | N | N | N | 3 |
| | O | O | O | Y | O | Y | N | N | N | N | |
| REFRIGERATOR WITH A 1-STAR COMPARTMENT | O | O | O | Y | O | O | Y | N | N | N | 4 |
| REFRIGERATOR WITH A 2-STAR COMPARTMENT | O | O | O | Y | O | O | O | Y | N | N | 5 |
| REFRIGERATOR WITH A 3-STAR COMPARTMENT | O | O | O | Y | O | O | O | O | Y | N | 6 |
| REFRIGERATOR-FREEZER | O | O | O | Y | O | O | O | O | O | Y | 7 |
| UPRIGHT FREEZER | N | N | N | N | N | N | N | O | Y ([a]) | Y | 8 |
| CHEST FREEZER | N | N | N | N | N | N | N | O | N | Y | 9 |
| MULTI-USE AND OTHER APPLIANCES | O | O | O | O | O | O | O | O | O | O | 10 |

*Notes:*
Y = the compartment is present;
N = the compartment is not present;
O = the presence of the compartment is optional;
([a]) also includes 3-star frozen-food cabinets.

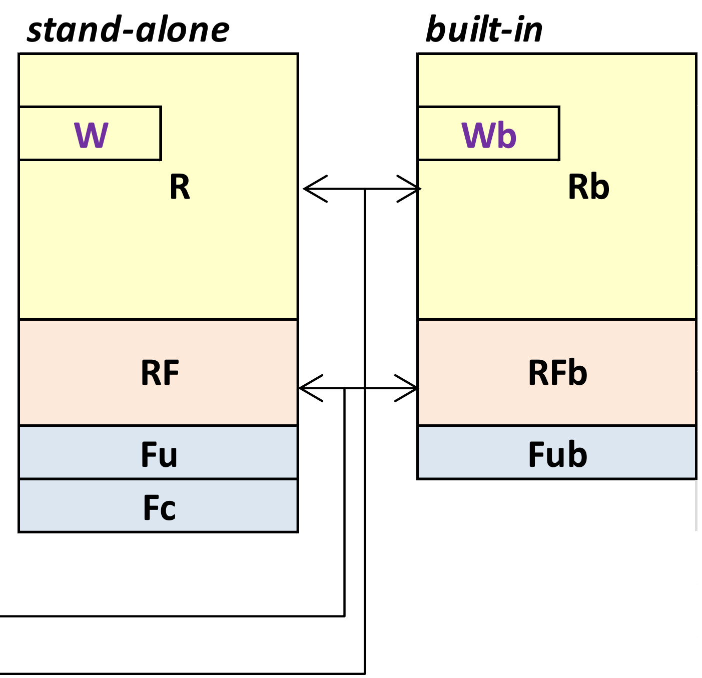
# Annex IV - Categories

NEW

| NOW | |
|---|---|
| *all climate classes* | |
| ***stand-alone & built-in*** | |
| **1** | Refrigerator |
| **2** | Refrigerator-cellar, cellar, **wine storage appliance** |
| **3** | Refrigerator-chiller and 0-star compartment |
| **4** | Refrigerator with 1-star compartment |
| **5** | Refrigerator with 2-star compartment |
| **6** | Refrigerator with 3-star compartment |
| **7** | Refrigerator-freezer |
| **8** | Upright freezer |
| **9** | Chest freezer |
| **10** | Multi-use and other refrigerating appliance |
| | *10. fridge-freezer type* |
| | *10. fridge type* |

**INDUSTRY proposal**

***all climate classes***




***BI*** Factor **1.2**
if built-in (w<58 cm)

***CC*** Factor (1.1) **1.2**
if (sub-) tropical

No MEPS for wine storage appliances
*(because of glass-door)*

***No BI and CC factors***
*See CECED documents*

# Annex IV - Categories

Opinion?

- Industry proposal: from 10 to 4 base categories of refrigerators (R ), refrigerator-freezers (RF), upright freezers (Fu) and chest freezers (Fc). Problems?
- ‘wine storage appliances’ (WI) a separate category? Glass-door correction or lower MEPS for this category more appropriate? Consider also other high temperature compartments with possibly glass-doors (‘cellar’ 12°C, ‘pantry’ 17 °C)…
- CECED proposal to mirror the categories for ‘built-in’ version (except for chest freezers) doubles number of categories again from 4 to 8? Adapted correction factor(s) not simpler?
- Frost-free correction to be discussed later (important changes in test standard)…

# Task 1
# Scope, standards & legislation

## Task 1.2 STANDARDS

# History & Status May 2015

**ISO**

ISO5155:1995
ISO7371:1995
ISO8187:1991
ISO8561:1995

ISO15502:2005

Copy

ISO15502/C1:2007
Small corrections

**IEC**

IEC62552 ed1:2007

New Global Standard

**IEC62552 ed2, Feb. 2015**

Developed by:
IEC SC59M/MT2

**Europe (CENELEC)**

EN153:.....

EN153:2006

*harmonised, OJ, Jan. 2014:*

EN62552:2013

- Wine cooler ← *RH unique*
- Small adjustments

EN62552 ed2: 2015,
2016 ?

*Draft waiting for specific mandate*

*Noise: IEC60704 1-2-3*

*Standby: CR (EC) 1275/2008*

*(networked sb 801/2013 ?)*

Based on M. Janssen (Re/genT), presentation 17/10/2013

# IEC62552:2015 Part 1 Definitions

NEW

- Two energy consumption tests, one at **16°C** and one at **32°C ambient**, whereby the reference ambient temperature will be calculated according to a regional weighting factor (no longer single ambient temperature of 25 °C)
- Fresh food target temperature is changed from 5 to **4 °C**;
- The frozen food target temperature is changed from measurement **inside the warmest package** to a measurement without packages and an **average air temperature** of 5 or more distributed sensors;
- Inclusion of **new types of compartments** such as **pantry** (14-20°C, nominal 17°C) and –now not only in EN but also in IEC standards— **wine storage** as well as **zero star** compartments;
- **NOT: Humidity control** in wine storage compartment/appliance (should stay in EN62552 draft?)

?

NEW

# IEC62552:2015 Part 2 Performance

- **Storage tests** →keep the storage temperature(s) within the required range?
- **Freezing and cooling capacity tests** (at 25 °C ambient)→ Freezing capacity, in **kg/12h** with a test load (3.5 kg per 100 l freezer volume) to be cooled from 25°C to -18°C. Cooling capacity test load (4.5 kg per 100 l refrigerator volume) to be cooled from 25°C to 10°C. (cooling capacity not in regulation/label now; new information requirement?)
- **Automated ice-maker test** (not referenced in the EU regulations)
- **Pull-down test** (Annex A) → time to cool down from 43°C --and at ambient 43°C—to the highest allowed temperature, e.g. 8°C for a fresh food compartment, -12°C for a 3 or 4 star freezer. Typical for very hot climates (no added value for the EU)
- **Wine storage appliance** test (Annex B)→ as EU, except humidity control
- **Temperature rise test** (Annex C), at 25°C ambient→ time (minutes) for 3 or 4 star frozen package to go from -18 °C to a temperature of -9 °C when appliance is off. [Relevant for smart appliance control? typical range 10-20 hours]

**Water vapour condensation** (Annex D)→ condensation at external surface (→ anti-sweat heater; less relevant in EU moderate climate?).

NEW

# IEC62552:2015 Part 3 Energy efficiency

- Daily energy consumption $E_{daily}$ in Wh/d**,** with **separate** assessment of defrost energy ($\Delta E_{df}$ x 24/ $\Delta t_{df}$ , with $\Delta E_{df}$ in Wh and $\Delta t_{df}$ in h defrost interval) and steady state power (*P* in W)

$$E_{daily} = P \cdot 24 + \Delta E_{fd} \cdot 24/ \Delta t_{fd}$$

? EU : No auxiliary energy $E_{aux}$ for ice-maker or anti-sweat heater. No processing energy $E_{processing}$ (no added value in EU, already in higher ambient)

- Steady state power *P* measured at 16° and 32 °C → $E_{16}$ and $E_{32}$ in Wh/d→ weighting factor ***f*** → single reference Annual Energy Consumption ***AEC*** in kWh/a:

$$AEC = E_{16} \cdot f \cdot 365 + E_{32} \cdot (1 - f) \cdot 365$$

? Draft EN weighting factor proposal *f* =0.432 (based on 25°C average) but *f* =0.5 (24°C) is more consistent with current outcomes → CECED argumentation

? **Tests are shorter**, building on principle of minimum 'stable operation' period**, but more** (16°C, 32 °C, defrost, etc.)

? Optimisation from multiple tests (interpolation, triangulation) is defined. Should EU allow this or stay at single test (per ambient temperature)?

? **Circumvention clause →** what penalty in EU?

# CECED's view on standard impact

- CECED Presentation (includes new categories)

# International standards TODAY

Figure

| | | EU IEC 62552 (2007) China & Korea applied IEC 62552 (2007) | IEC 62552 (revised) Proposal (2011) | AS/NZS 4474.1 (2008) | AHAMHRF-1 (2008) | CNS 2062 (1995) CNS 9577 (1989) | JIS C 9801 (2006) |
|---|---|---|---|---|---|---|---|
| Ambient temp | | 25°C 25 or 32℃ | 16 & 32℃ | 32℃ | 32.2℃ | 30℃ | 15 & 30℃ |
| requirement | Fresh food | 5°C +4℃ | +4℃ | +3℃ | +7.2℃ | +3℃ | +4℃ |
| | Freezer* | -6℃ | -6℃ | -9℃ | -9.4℃ | | -6℃ |
| | Freezer** | -12℃ | -12℃ | -15℃ | -15℃ | -12/-15℃ | -12℃ |
| | Freezer*** | -18℃ | -18℃ | | | -18℃ | -18℃ |
| Test packages | | Loaded | Water Loaded | Unloaded | Unloaded | Unloaded | Loaded |
| Door openings | | None | Yes | None | None | None | Yes |

**Overview of main parameters in global standards.** (Source: Kiyoshi SATO (JEMA): Energy Efficiency Improvement in Household Refrigerator, presentation at IEA 4E 10th ExCo & Annex Meeting, 8 Nov. 2012, Tokyo, Japan)

# International standards EXPECTED

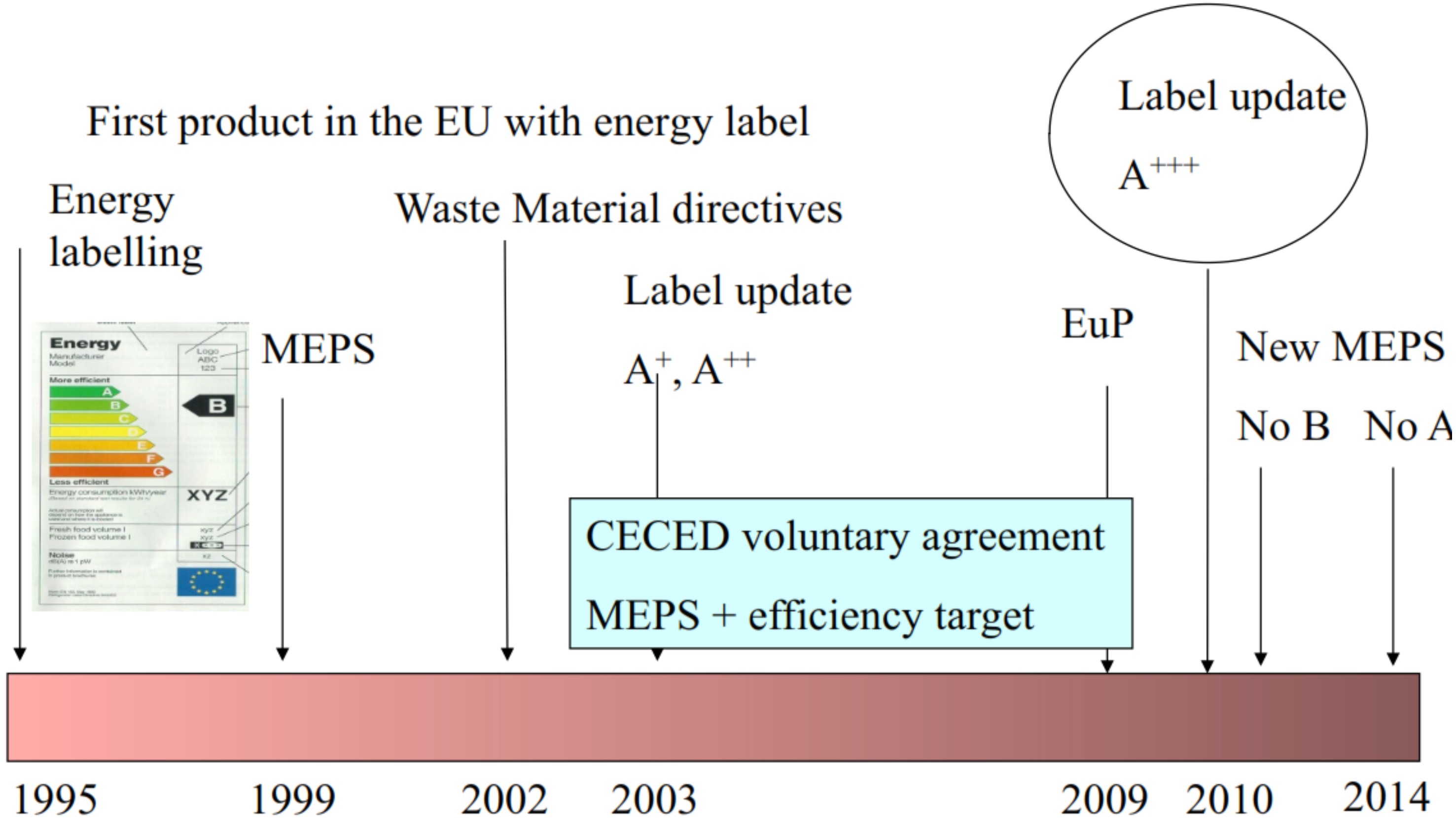
- China will introduce energy label and limit by 1.1.2016, based on a 16/32 weighting at **23.7 °C** (and load-processing test).
- Japan is expecting new measures in 2016. The Japanese weighted average between the 16/32 °C tests is **22.7** degrees C plus a correction for the load processing test.
- Australia, with load processing test at 32 °C, will introduce new limits in 2017, based on an average weighting equivalent to **22 °C**.
- The US introduced new limits in Sept. 2014; under US rulemaking the US (non IEC) test standard should then be used for at least 6 years, but the US standard is very similar to the new IEC test standard.
- *See also CECED informative papers on the Chinese measure published on the project website.*

# Task 1
# Scope, standards & legislation

## Task 1.3 LEGISLATION

# EU legislation

## Energy Label and Ecodesign('MEPS')




MEPS= Minimum Efficiency Performance Standard

CECED = European Committee of Domestic Equipment Manufacturers

Picture M. Janssen, Re/genT, 2013

# EU legislation[2]

**Montreal 1989** → ban substances with ozone depletion potential (ODP): Ban freon in refrigerant (CFC-12) and blowing agent (CFC-11).

First substitutes e.g. R134a→ no ODP but high GWP (Global Warming Potential)

Current substitutes: R600a (isobutane) for refrigerant & cyclopentane for foam → no ODP, very low GWP.

**WEEE** (cat. 1) : From 2016 minimum collection 45%, from 2019 65%.

From Aug. 2015: 85% to be recovered; 80% to be re-used or recycled.

**RoHS/REACH**: No Pb in electronics (done)

**Biocide Regulation:** addresses Ag nanoparticles (ecotoxic)

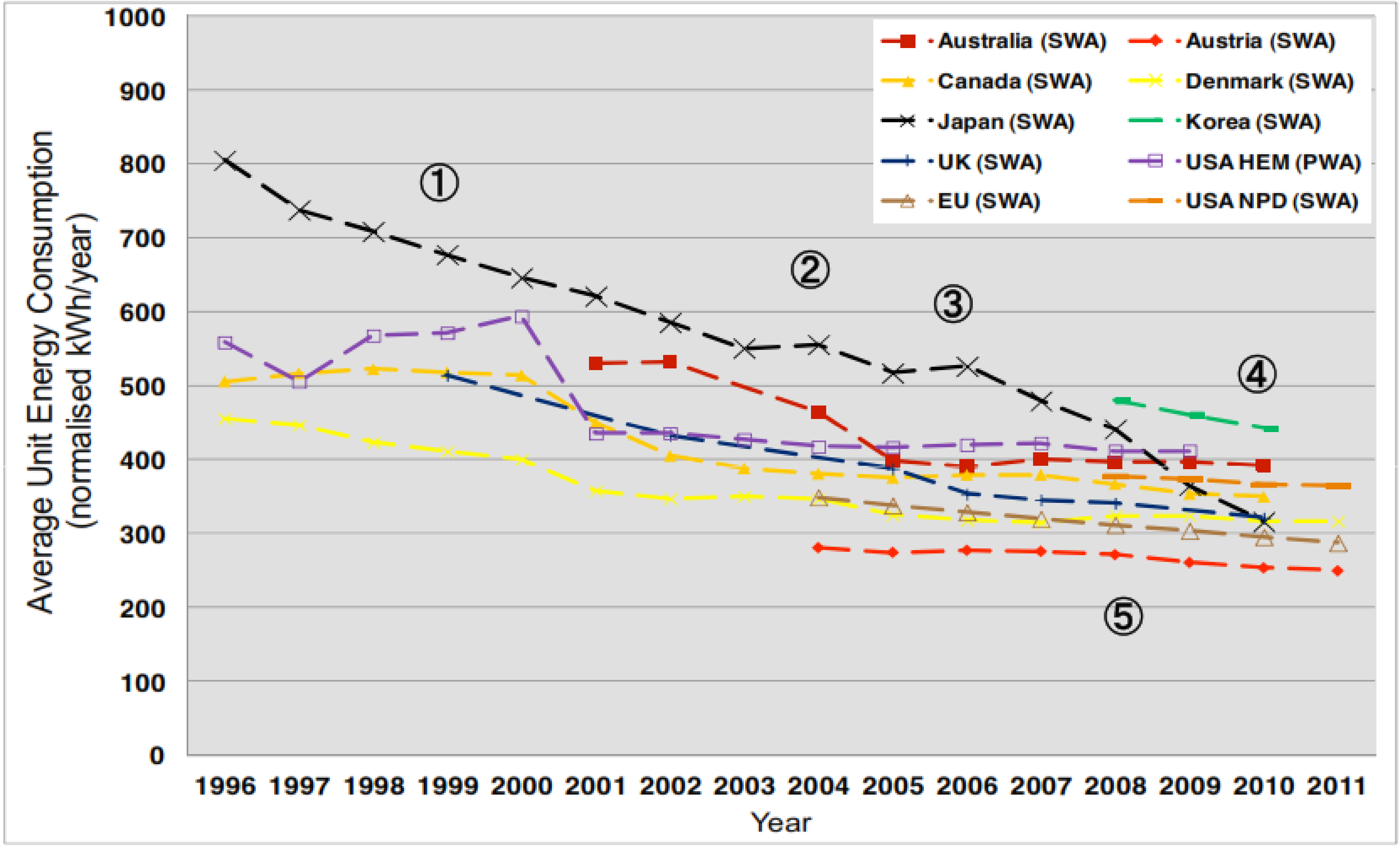
**Safety**: LVD, food-grade plastics

**Future?:**

Lamps & very large displays (>1 $dm^2$=6 inch) may be regulated under Ecodesign.

Durability demands are questionable because of adverse effect of keeping old fridges alive or export to Africa.

# Extra-EU legislation




**Average Unit Energy Consumption in selected countries and regions** (Source: IEA 4E M&B, version 2014)

NOW

# EU Metrics

The Energy Efficiency Index (EEI) is the ratio of the Annual Energy Consumption AE of a product and a calculated Standard Annual Energy Consumption SAE, both in kWh/a:

***EEI= AE/SAE***

with *AE=E24* x 365, where E24, in kWh/24h, is the 'daily'(24h) consumption according to the test of a specific model. (see 'standards')

***SAE = Veq* x *M + N +CH***

Where

- *M* (in kWh/litre/a) and *N* (in kWh/a) are category-specific indicators for the reference lines (see table below),
- *CH* is the chill-compartment compensation of 50 kWh/year, if a chill-compartment of >15 litres is present.
- *Veq* is the equivalent volume (in litres), with

NOW

# EU Metrics [2]

*Veq* is the equivalent volume (in litres), with

$$Veq = \sum[Vc \times (25 - Tc)/20 \times FFc] \times CC \times BI$$

Where

- *Vc* is the net volume of compartment c ('c' is the index of the compartment) ,
- *Tc* is the nominal temperature of compartment c,
- *FFc* is the frost free correction factor 1.2, if the compartment c has automatic defrosting (otherwise *FFc*=1),
- *CC* is the climate correction factor 1.2 ('tropical' T), 1.1 ('sub-tropical' ST) or 1 (otherwise, i.e. N or SN)
- *BI* is the built-in correction factor 1.2 if the appliance is made for, and tested accordingly, to be built-in (enclosed by kitchen cabinets), and if the width is less than 58 cm.

NOW

# EU Metrics [3]

| Category | M | N |
|---|---|---|
| **1-3** | 0.233 | 245 |
| **4** | 0.643 | 191 |
| **5** | 0.45 | 245 |
| **6-7** | 0.777 | 303 |
| **8** | 0.539 | 315 |
| **9** | 0.472 | 286 |
| **10 (no freezer)** | as Cat. 1 | |
| **10 (freezer incl.)** | as Cat. 7 | |

Opinion?

# Industry proposal

- To eliminate the climate correction factor CC completely;
- To redefine the chill-compensation CH in a fixed part Nch and a variable part (depending on Veq) Mch, which on average equals the current compensation but aims at more correct distribution
- To redefine the frost free compensation FF to make it no longer dependent on the equivalent volume Veq but to link it directly to the standard annual energy SAE. The value of such a parameter would still need to be established
- For the Built-in appliances to use different categories and thus also different reference lines (factors M and N or similar).
- To introduce a multi-door compensation for appliances with 3 or more doors. The proposal is to add a term MD to the existing M-factor, i.e. make it volume dependent with values for MD of 0.03 (3 doors), 0.05 (4 doors) and 0.06 (5 or more doors).

Task 2

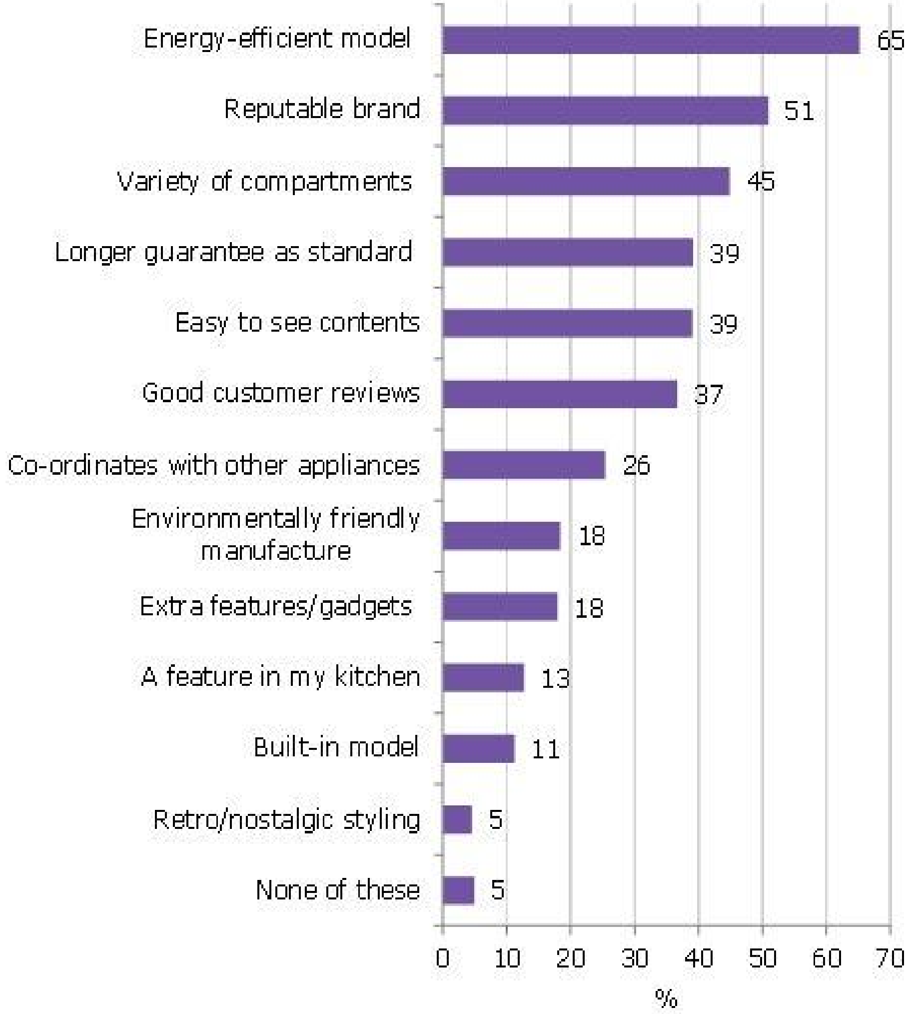
**Market**

# Key data

- SALES EU 2014: 15 million refrigerators (incl. fridge freezers) + 4 million freezers → 19 million total . Annual growth 2%. STOCK EU-2015: 303 million units (1.4 per hh)
- VALUES (Eurostat 2013) in msp: Production € 4.1 bn, Imports € 2 bn (CN 44%, TK 36%), Exports € 1 bn, Apparent consumption € 5.1 bn
- VALUES (EIA for EU-2015) : Consumer incl. VAT € 10.1 bn, of which manufacturers € 4 bn, wholesale € 0.3 bn, retail € 4 bn, VAT and levies € 1.8 bn
- AVERAGE PRICE (EU-2015): Average price € 520, Above average: Built-in (+20%), No-frost (+10%), Wine storage (x 2).
- AVERAGE VOLUME (EU 2015): Net volume 278 L., increase 1.2%/a; Equivalent volume 377 L.. Total EU stock: freezer 18.6 $Mm^3$, Total EU cool 84.4 $Mm^3$
- EU-PRODUCERS: BSH, Electrolux, Whirlpool (incl. Indesit), Liebherr, Candy, etc. . Extra-EU: Arcelik/BEKO, Samsung, LG, Haier. SMEs only in niches (Eurocave, FRIO) and OEMs.
- Industry association: CECED. Consumers: ANEC/BEUC. NGOs: Topten, ECOS, EEB, CLASP.
- EU Jobs: 147 000, of which 66k in retail, 1k wholesale, 80k industry. Industry= 1/3 split end-producers, suppliers (o.w. 50% extra-EU), business services.

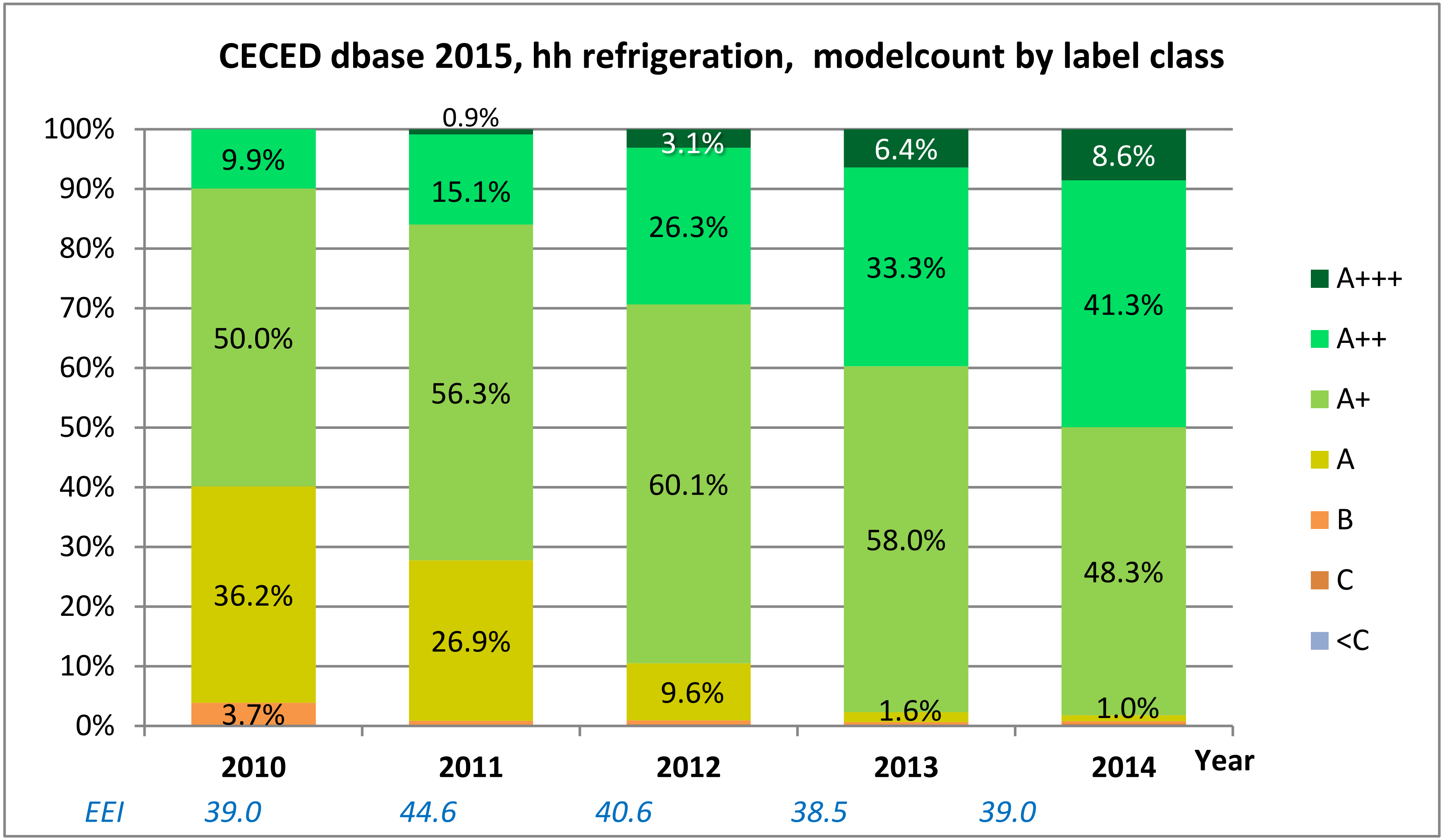
# Trends & drivers

- 1Q 2015 snapshot (GfK): Moderate growth, downward pressure on prices
- Decline in refrigerators, growth in freezers
- Built-in, no-frost and wine storage → steady growth
- ‘Energy efficiency’ remains main market driver, followed by ‘brand’ and ‘variety of compartments’ (see graph)



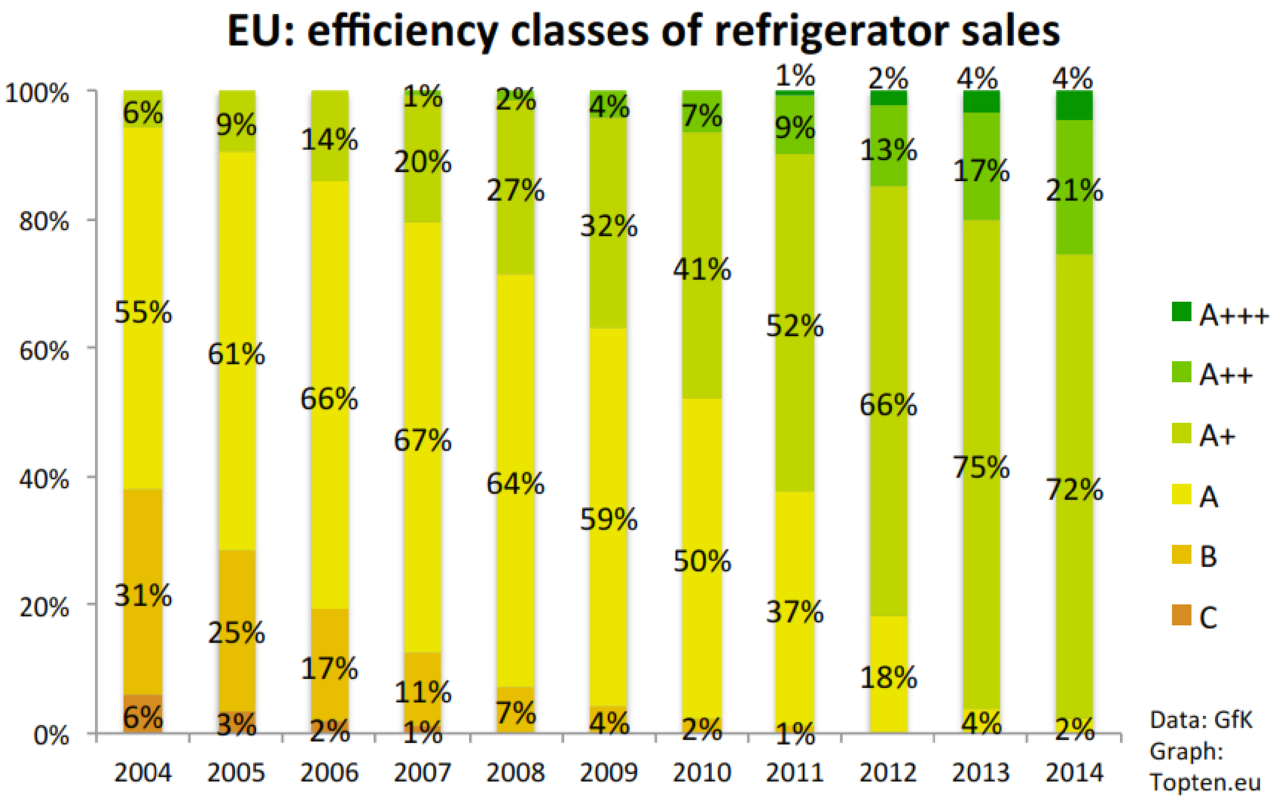

GMI/Mintel “Fridges and freezers – UK”, April 2014

# Counts by Label Class 2010-2014



# Compare GfK sales data

Sales may trail a few %-point behind, but are otherwise consistent with CECED database

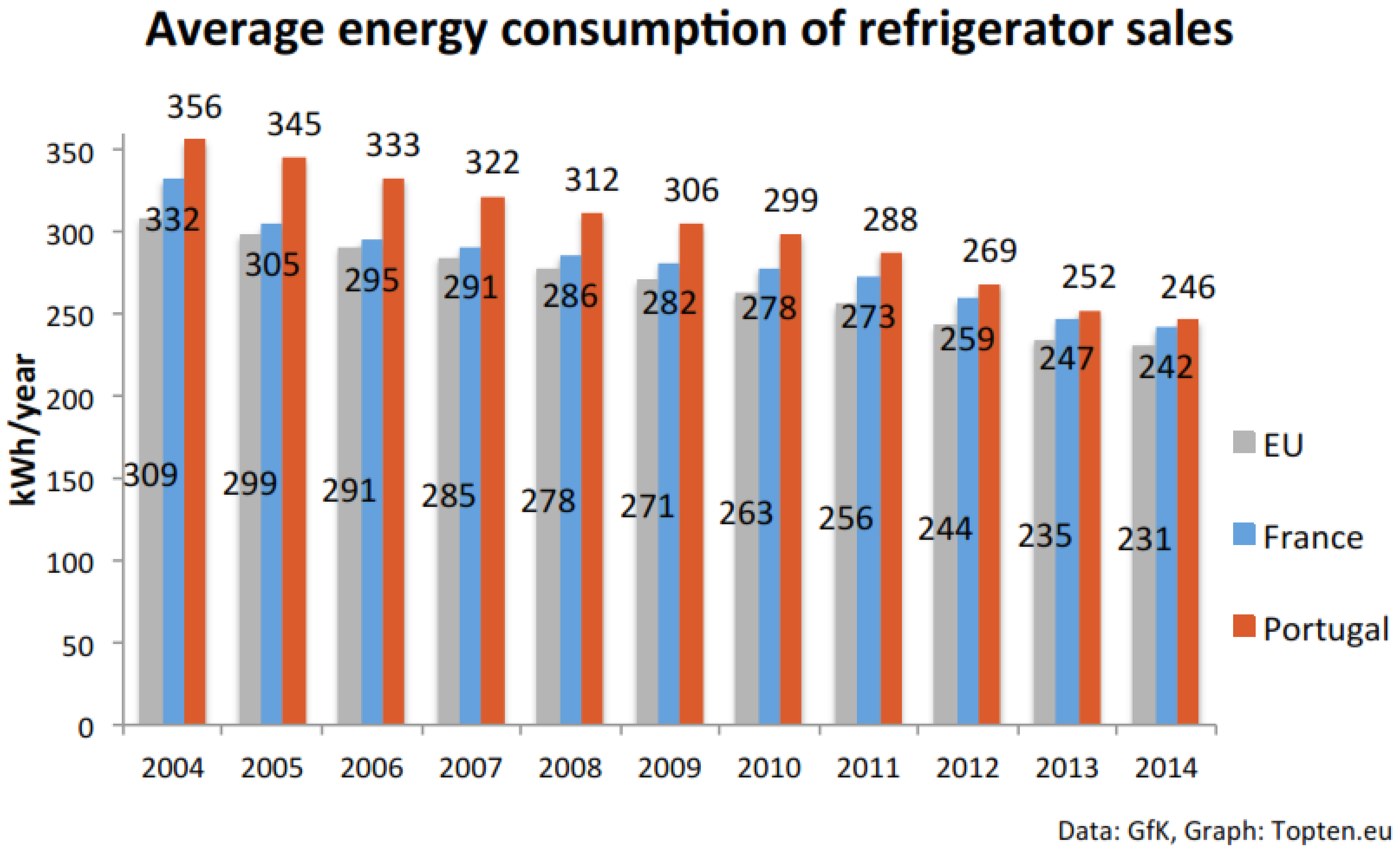



Population ***n*** of models in CECED database:

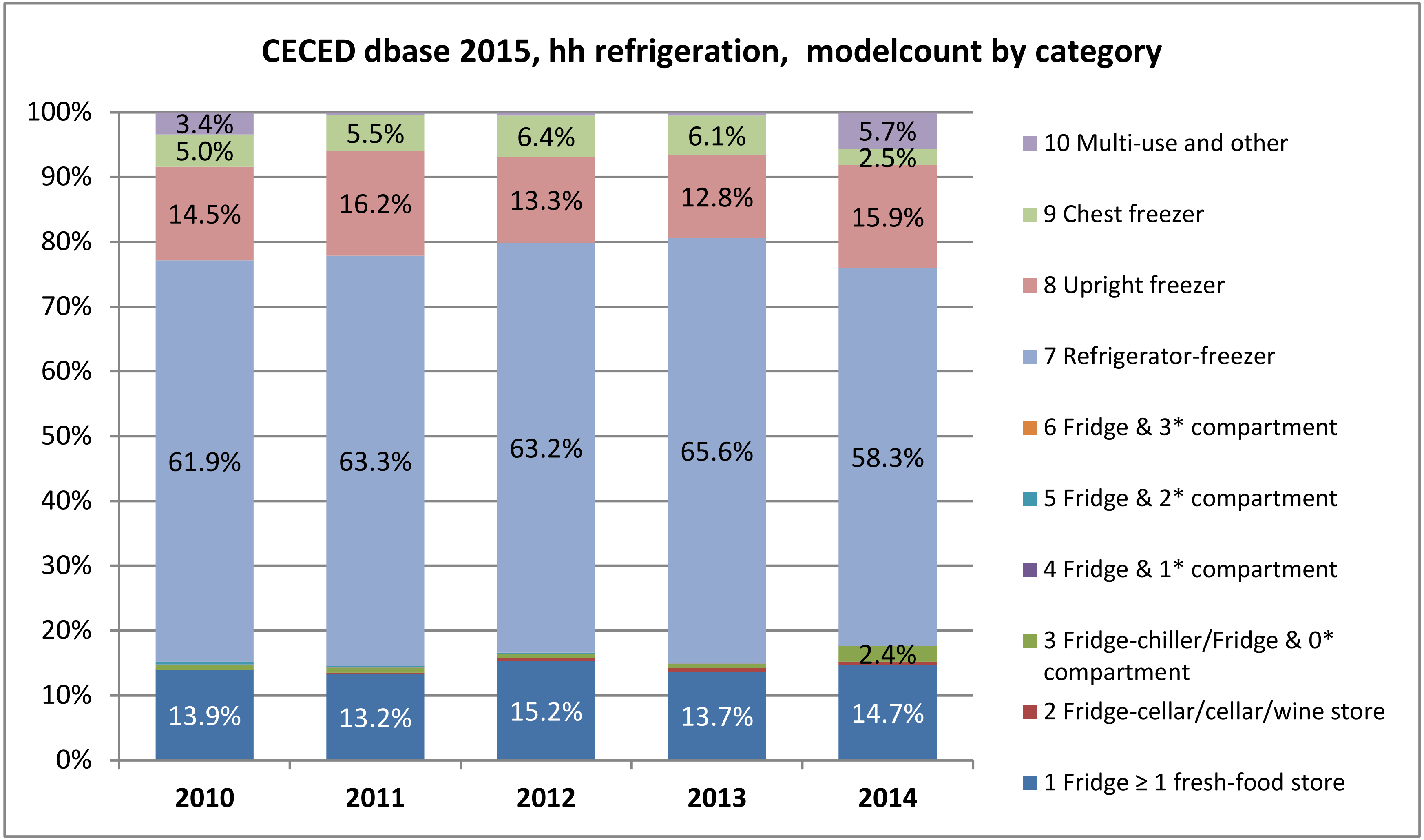
| | |
|---|---|
| **2010 (EU25)** | **11127** |
| **2011 (EU25)** | **10114** |
| **2012** | **9236** |
| **2013** | **11823** |
| **2014** | **18027** |

**Refrigerators & Fridge-freezers (excl. freezers)**
Source: GfK (EU23) in topten.ch (update 2015 see website)

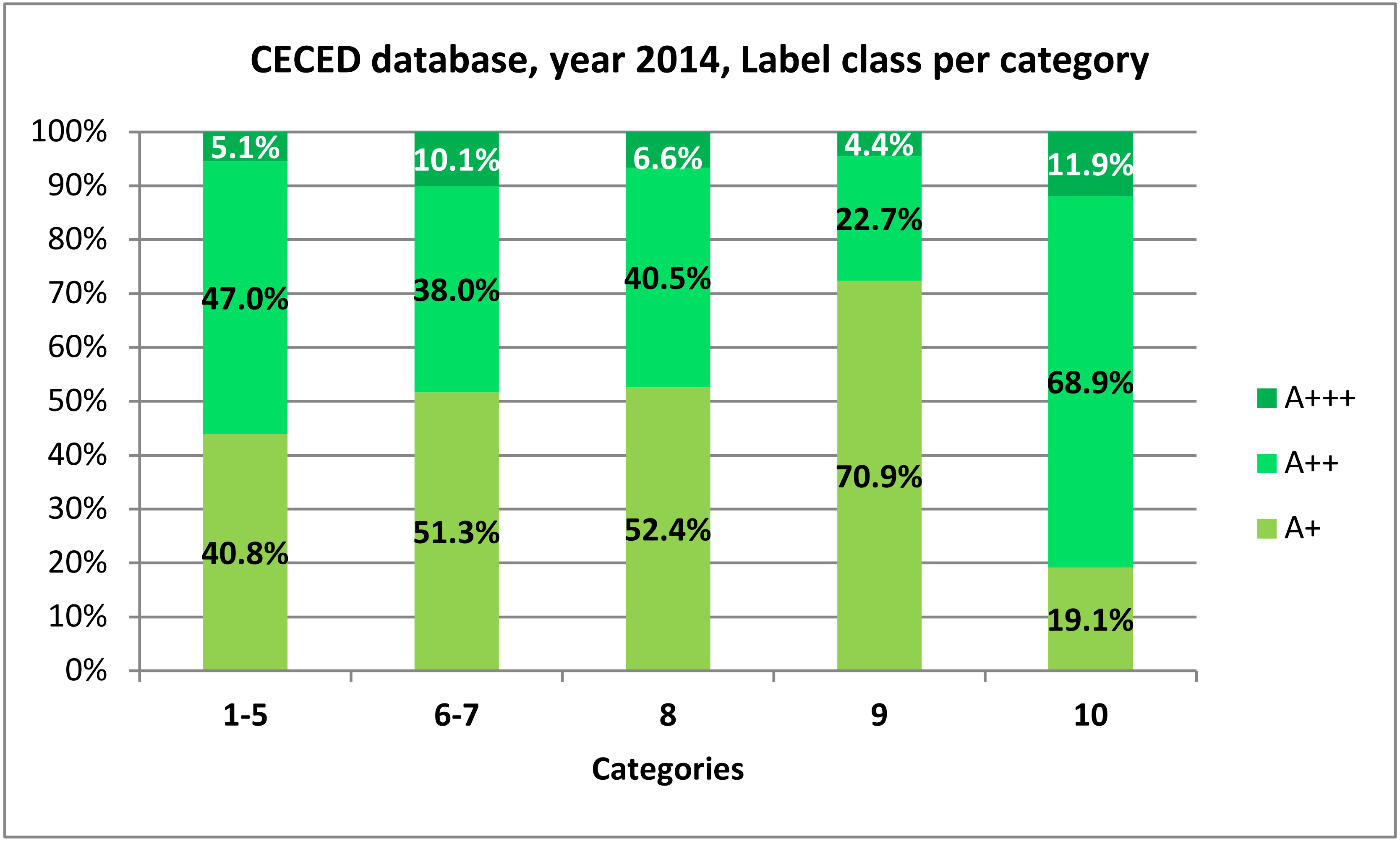
# Annual energy consumption



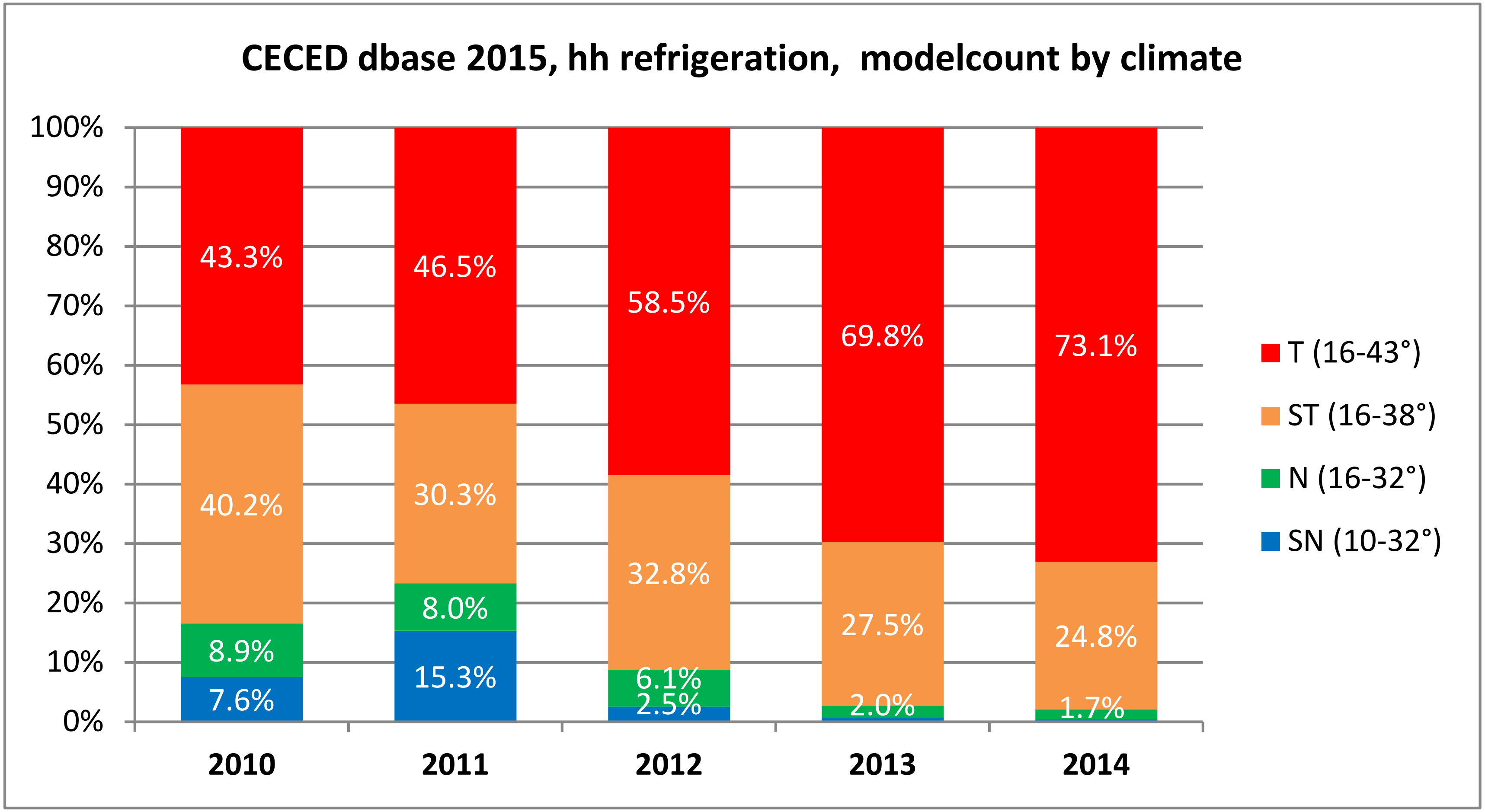
# Counts by Category 2010-2014



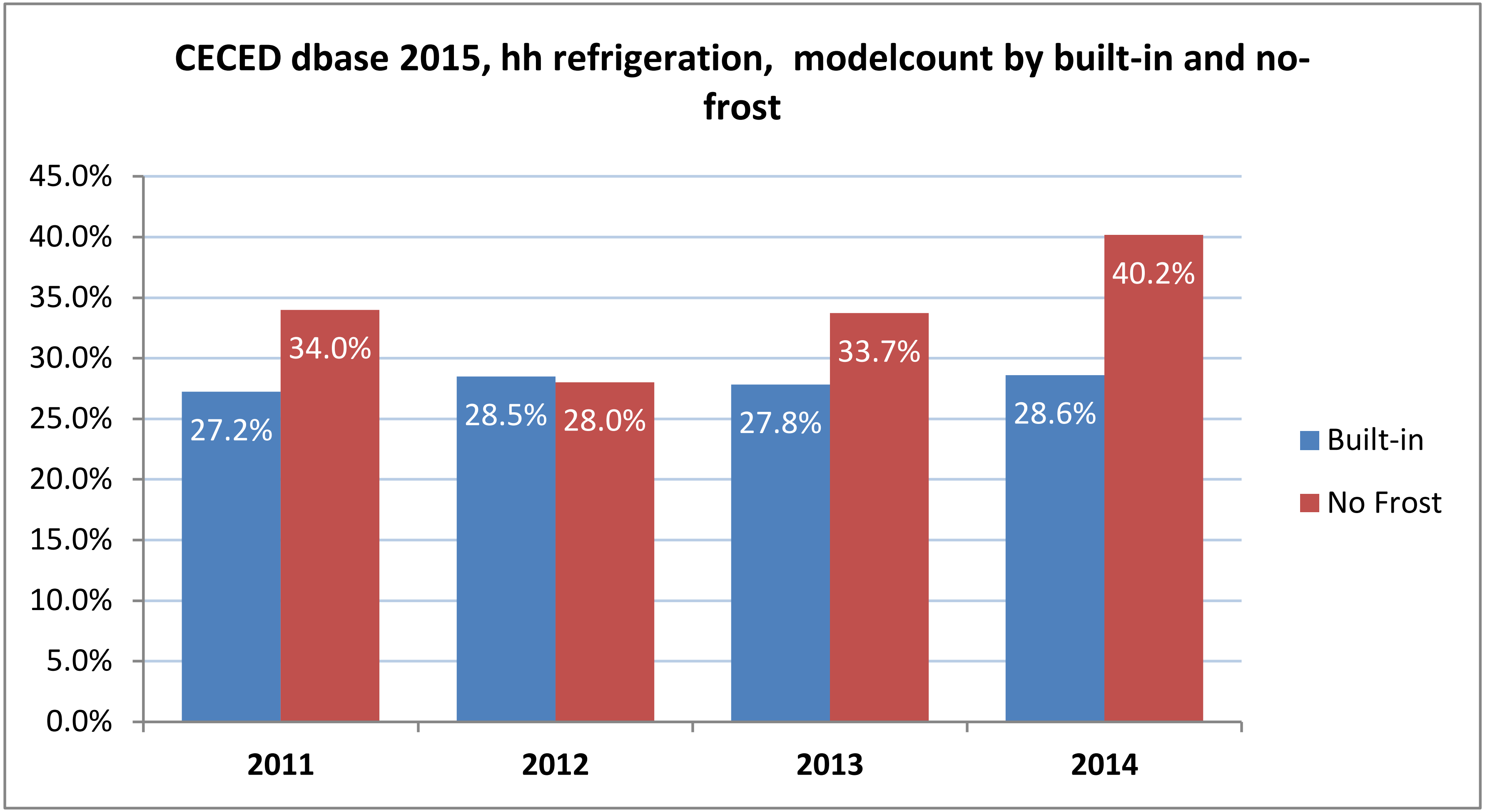
# Counts by Category & Class 2014



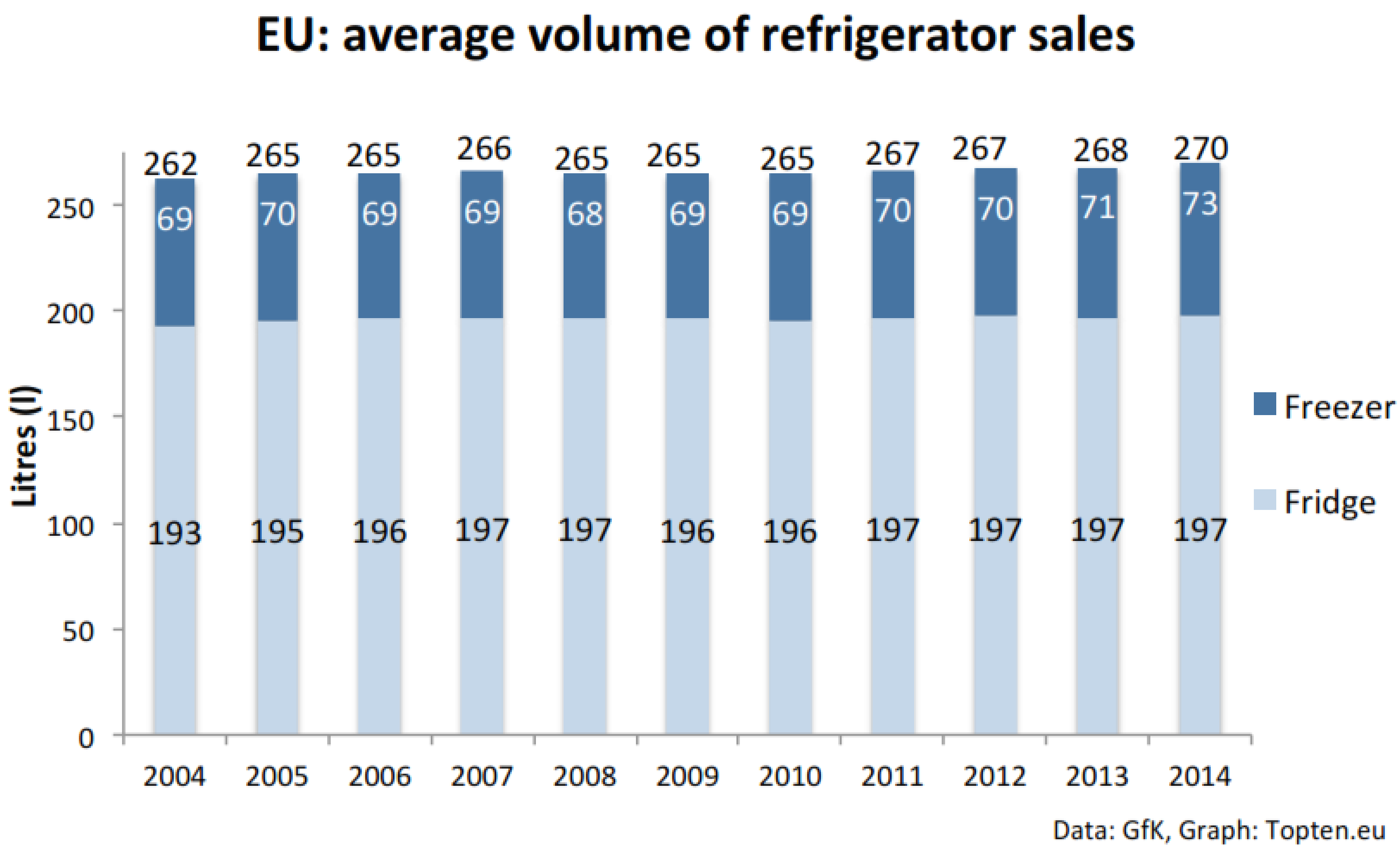
# Count Climate Correction 2010-2014



# Count Built-in & No Frost 2010-2014

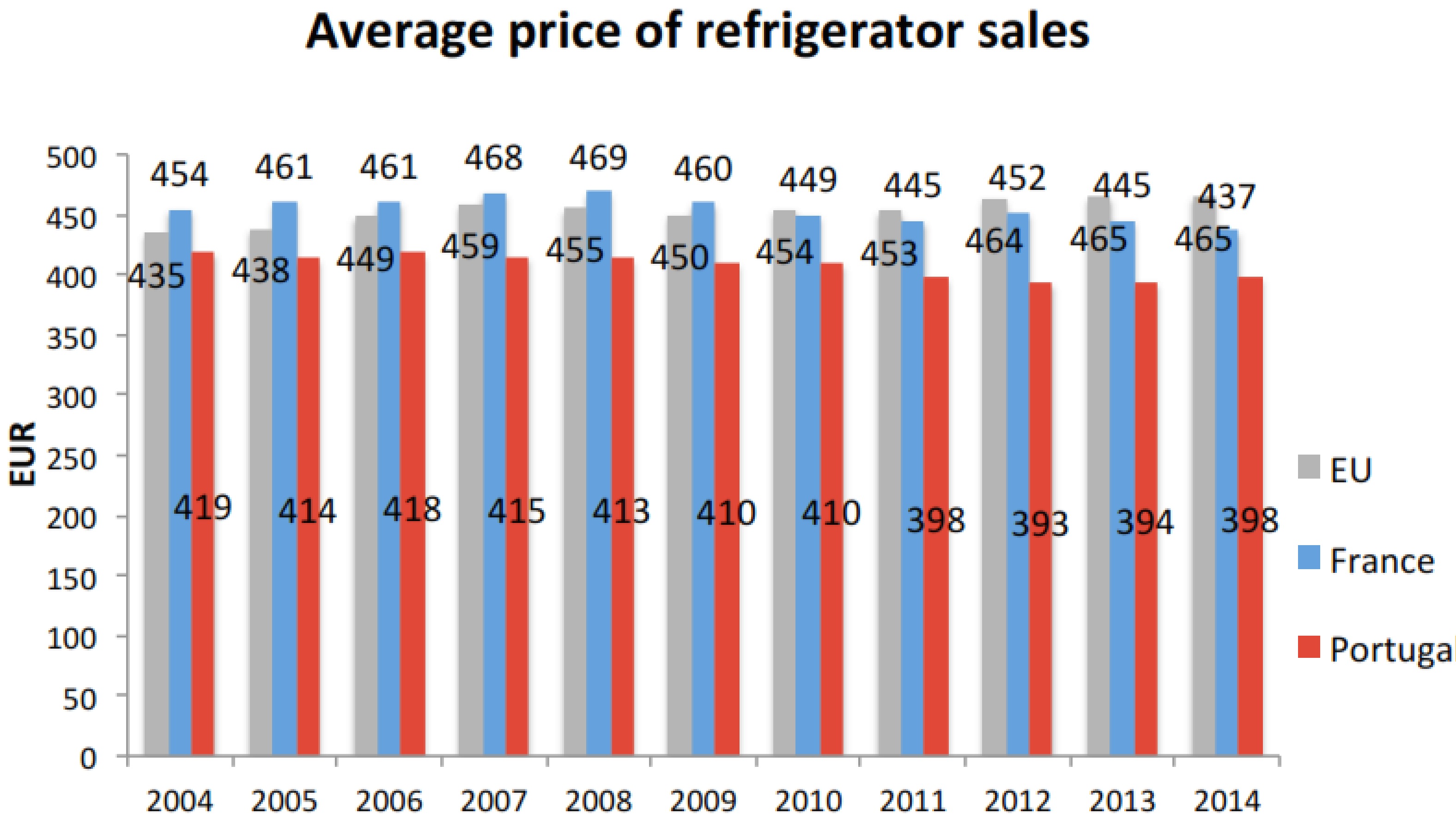


# Average volume fridge-freezers



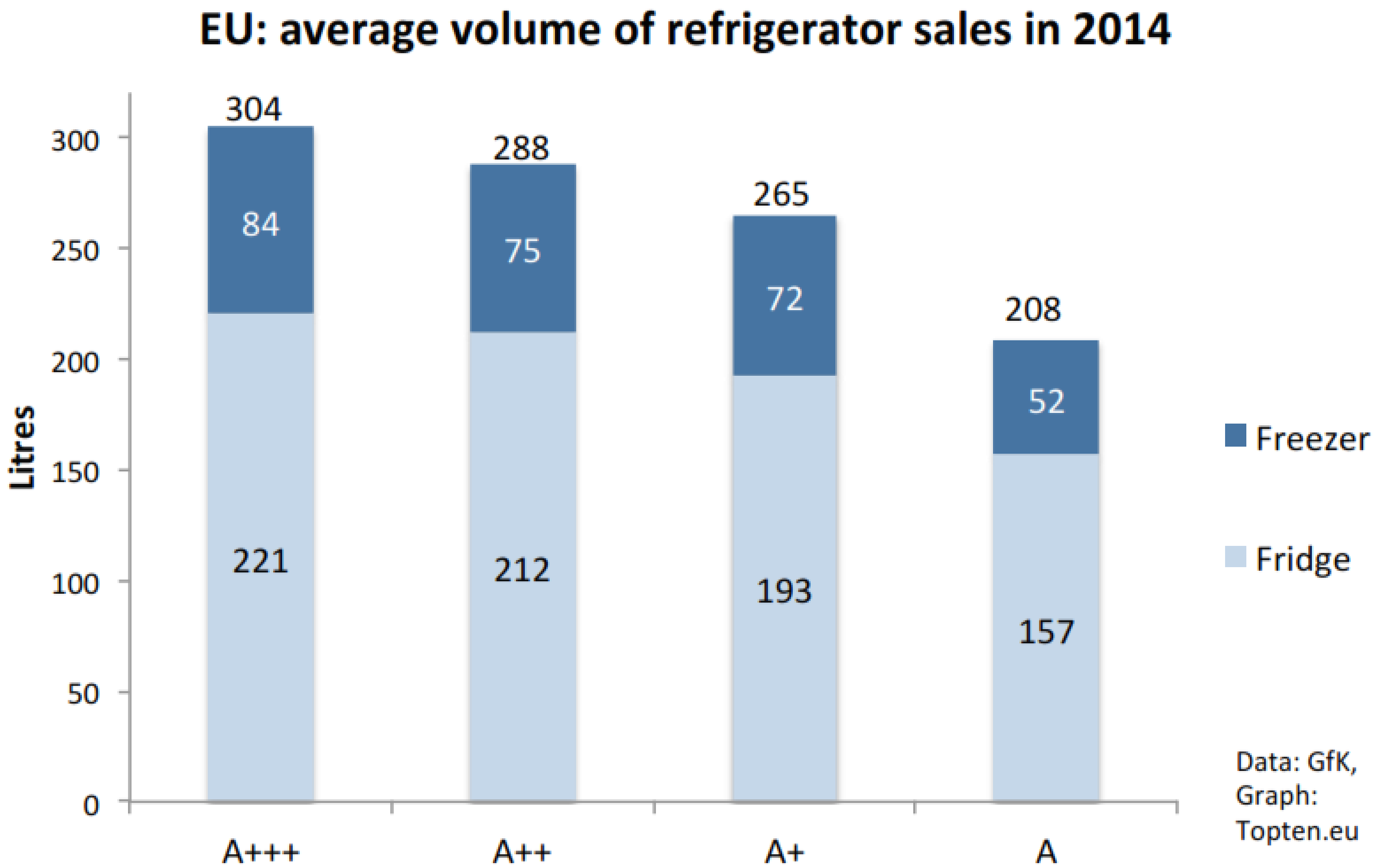

*EU GfK data are to replace graphs of DE Verbraucherzentrale in final report*

# Average prices fridge & fridge-freezer



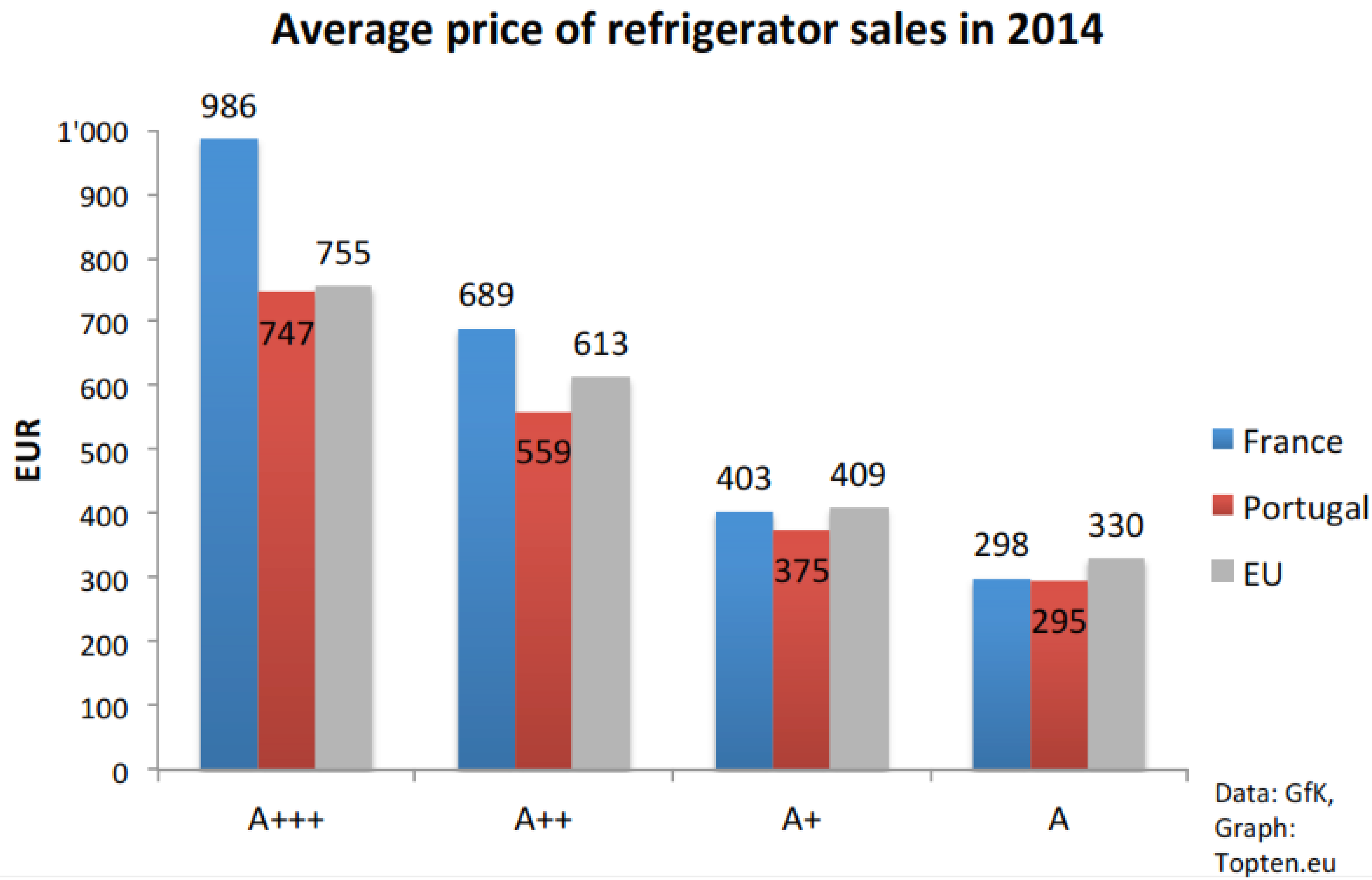

Data: GfK, Graph: Topten.eu

# Average Volume per Energy Class 2014




*EU GfK data are to replace graphs of DE Verbraucherzentrale in final report*

# Average Price per Energy Class 2014



# Prices & Rates (EIA, Eurostat)

Table 11. Price trend (VHK, EIA, 2014), including freezers (in 2010 euros)

| | Unit | 1990 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Price** | € | 421 | 487 | 491 | 510 | 514 | 518 | 522 | 533 | 537 | 534 | 551 | 524 | 498 | 474 |

Table 12. NOMINAL Electricity rate in €/kwh elec and inflation index

| | | 1990 | 1995 | 2000 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Electricity rate** | €/kwh elec | 0.12 | 0.13 | 0.13 | 0.14 | 0.15 | 0.16 | 0.16 | 0.16 | 0.17 | 0.18 | 0.19 | 0.20 |
| **Inflation** | inflation index (2010=1) | 0.67 | 0.74 | 0.82 | 0.91 | 0.92 | 0.94 | 0.96 | 0.98 | 1.00 | 1.02 | 1.04 | 1.06 |

Table 13. REAL Electricity rates, residential (in 2010 euros, inflation corrected)

| | | | 1990 | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Inc. %/a | | | | | | | | | | |
| **El. Rate** | €/kwh elec | 4% | 0.18 | 0.17 | 0.21 | 0.25 | 0.30 | 0.37 | 0.45 | 0.55 | 0.66 | 0.81 |

Task 3

**User Analysis**

NOW

# 3.1 Direct energy: Strict product approach

- EU approach: Steady-state extra high ambient (25°C versus real-life 20-21 °C) compensates for door openings and warm load.
- Reference: Average installed appliance at 25°C ambient: 270 kWh/year (1/3 freeze, 2/3 cool) → 230 kWh/year at 21°C ambient → difference 40 kWh
- CHECK: Door openings (20/day)→ < 5 kWh electricity extra (see report)
- CHECK: Warm load (2500* kg/yr, at ΔT=15K)→ < 25 kWh electricity extra (see report)
- Calculations only illustrative. For new BAT might become relevant

? (subject for review clause?)

*=worst case estimate VHK. Compare: IEC62552:2015 processing test uses 12 g load/L for fridge and 4 g load/L for freezer per day. For 200 L fridge+100 L freezer→ 2.8 kg/day→ 1022 kg/year.

NEW

# Extended product approach

IEC 62552:2015 → two different tests at different heat loads (16 and 32 °C) →

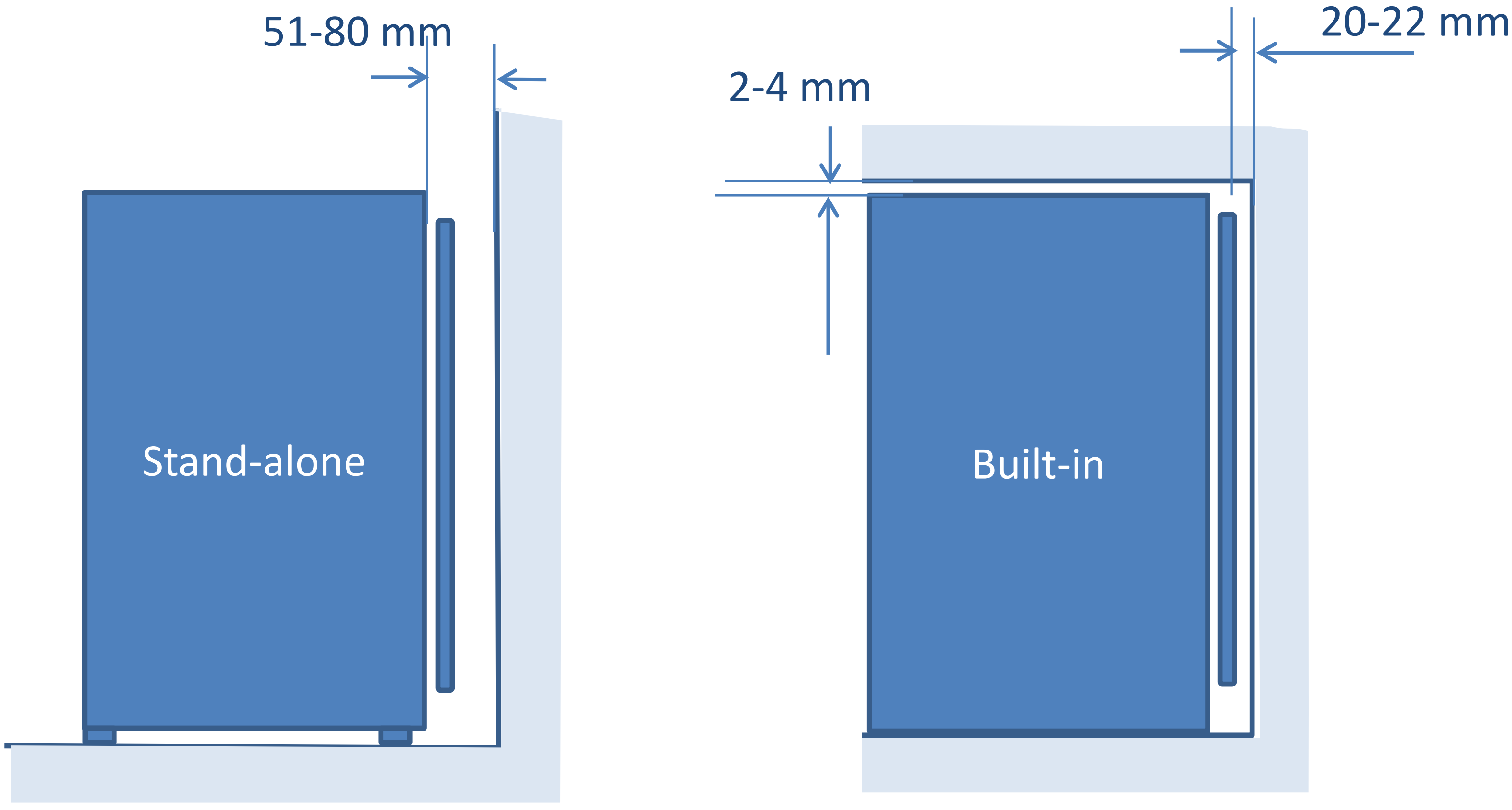
- More realistic. Indicates indirectly also the capacity to cope with cooling warm load, defrosting situations and changes in ambient temperature (e.g. garage, balcony)
- Rewards double-thermostat solutions and variable speed compressors (better part-load efficiency)
- Penalizes inefficient single-thermostat solutions

IEC 62552:2015 → specific defrosting cycle

- More robust definition (no circumvention), separate test renders more transparent
- Enables test of variable defrosting cycles (‘defrost-when-needed’)

# Technical system approach: in kitchen

- 8-10% difference in energy for the same appliance from testing stand-alone or built-in. [SIDE VIEW below]




No real obstruction to air-flow from the side

Width clearance 4-6 mm

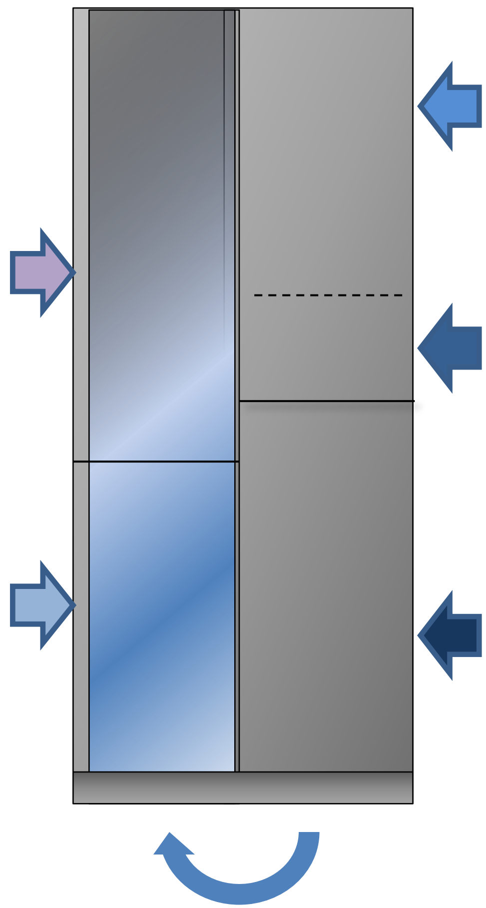
# Functional systems approach

- Storing food at correct temperature
- Auxiliary food preservation (humidity control, ventilation, $CO_2$)
- Food planning: prevent food waste (display expiry dates, QR/bar codes?)

# Functional system: optimal storage

**PANTRY/CELLAR (16 °C**, *humid or in containers, moderate ventilation)*
oranges, lemons, ripe tomatoes/ cucumbers/eggplant/melon/avocado /pineapple/mango/papaya/bananas, grapes, peaches & plumbs, apples & pears (separate ventilation --> ethylene),
potatoes (dark), red wine (dark), unopened cheese.

**DRINKS/WINE STORAGE (8-10 °C)**
white wine, beer, fruit juice, soft-drinks,
non-meat/fish leftovers, fruitcake , mayo/ketchup/salsa/honey (opened)



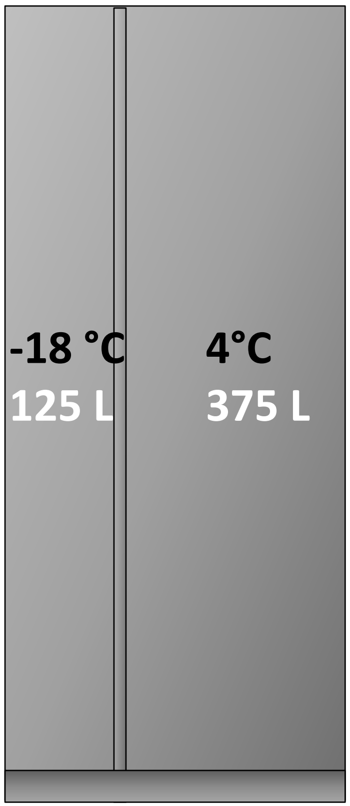
**FRIDGE**
**Fresh food (4 °C):** Diary products (milk, yoghurt, eggs, cut & fresh cheese, pudding), green vegetables (salad, broccoli) & herbs, carrots, cold cuts (ham, salami,bacon), ready-meals & leftovers
**Chill sub-compartment (0 °C):** Fresh meat, poultry, fish, shellfish, etc.

**FREEZER (-18°C):**
frozen foodstuffs all types

*defrost cool re-use*

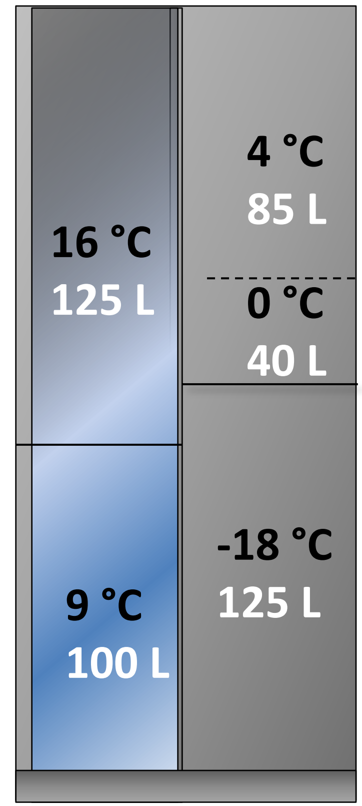
derived from e.g. http://www.zentrum-der-gesundheit.de/obst-gemuese-lagern.html

# Functional: illustration




Healthier, tastier food & drinks
Less food waste
25-30%  energy saving on cooling
10-12% energy saving total

The current metrics do not give a reward but implicitly a penalty (extra door losses)

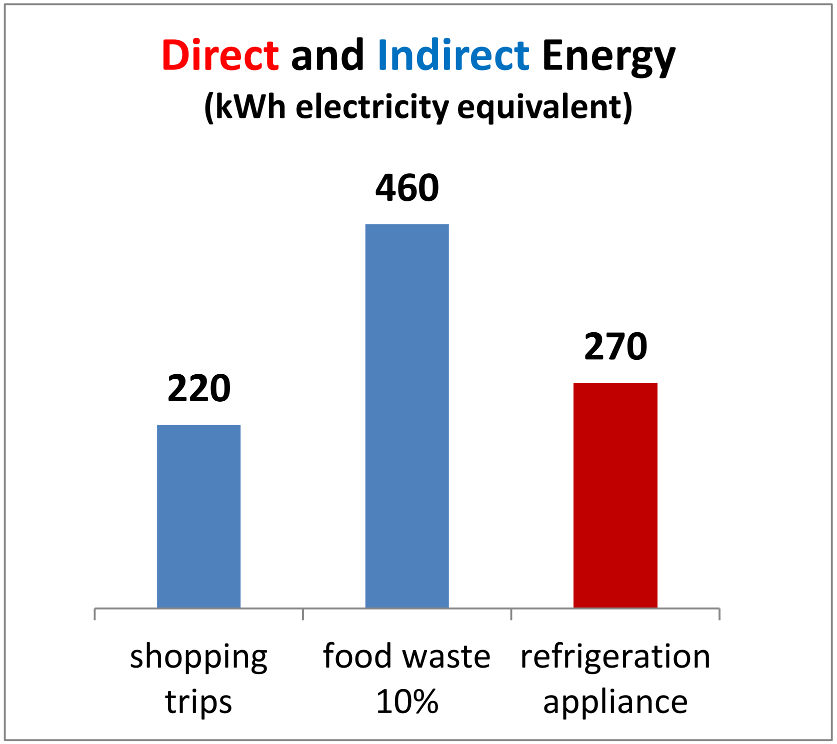





Estimated savings based on difference between compartment temperatures and 25 degree ambient

# 3.2 Indirect energy (illustrative)

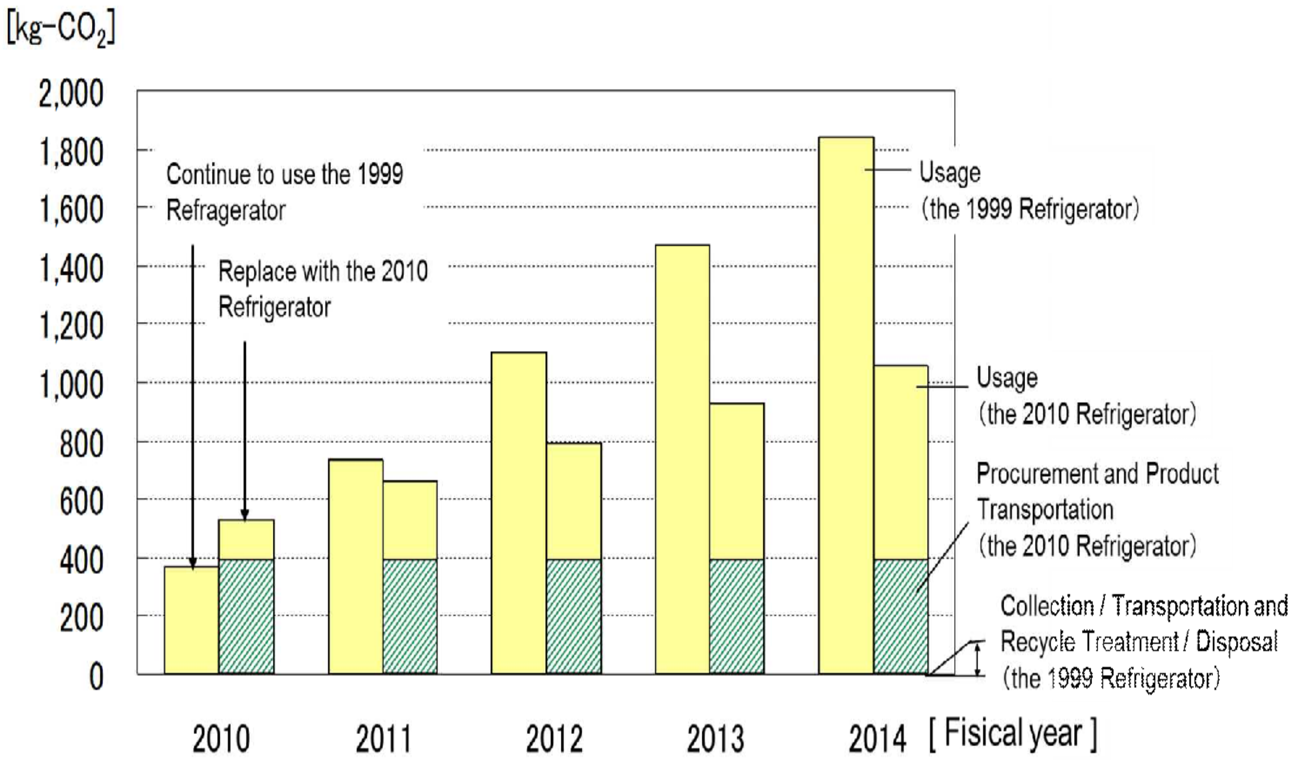
- Grocery shopping by car: Average 1-2 trips, 5-10 km per week → 500 km/year → city traffic 1 litre per 10 km→ 50 litre petrol/diesel → 2000 MJ primary/year → power generation 40%→ 220 kWh electricity/year equivalent
- Food 650 kg/yr/pp, 1500 kg/refrigeration appliance. Food life cycle energy content 25 MJ/kg* → 37500 MJ/refrigeration appliance → 4160 kWh electricity equivalent. Avoidable food waste in households (cooking failure, leftovers) 10%→ 416 kWh electricity equivalent.
- Compare: average refrigeration appliance 270 kWh electricity equivalent




*=rough estimate based on Denmark 221 PJ, 9 Mt food. Source: Markussen, M., in *Energies* 2013

# 3.3 End-of-Life

- First-time life 12-13 years
- Second life 3-4 years
- Life time extension negative (at current rate of improvement)



# 3.4 Infrastructure: Smart appliances

- Contribution to peak shaving; remote freezer switching by utilities
- EU peak load ca. 500 GW (2008), 2 hours
- 500 million freezers, 15 W average--> 7.5 GW--> **1.5% peak shaving contribution**.
- Compare: 100 million electric water heaters, 100-200 W average→ 10-20 GW (2-4% peak shaving contribution)

Task 4.1
# Technical Analysis

**Stéphanie Barrault, Philippe Rivière, Isaac Thompson**

MINES ParisTech

*ARMINES Center for Energy efficiency and Systems*

# Task 4 for Technology study

- MEErP recommendations

**MEErP 2011**

  - Technical analysis of current products on EU market
  - Inputs for the definition of Base cases
  - Identification of improvement potential
  - Full range:
    - 1 - Existing products
    - 2 - Products with standard improvements
    - 3 - BAT: Best Available Technologies
    - 4 - BNAT: Best Non Available Technologies

# 1 - Existing products on the market

Mechanical compression vapor cycle & electrical compressor with

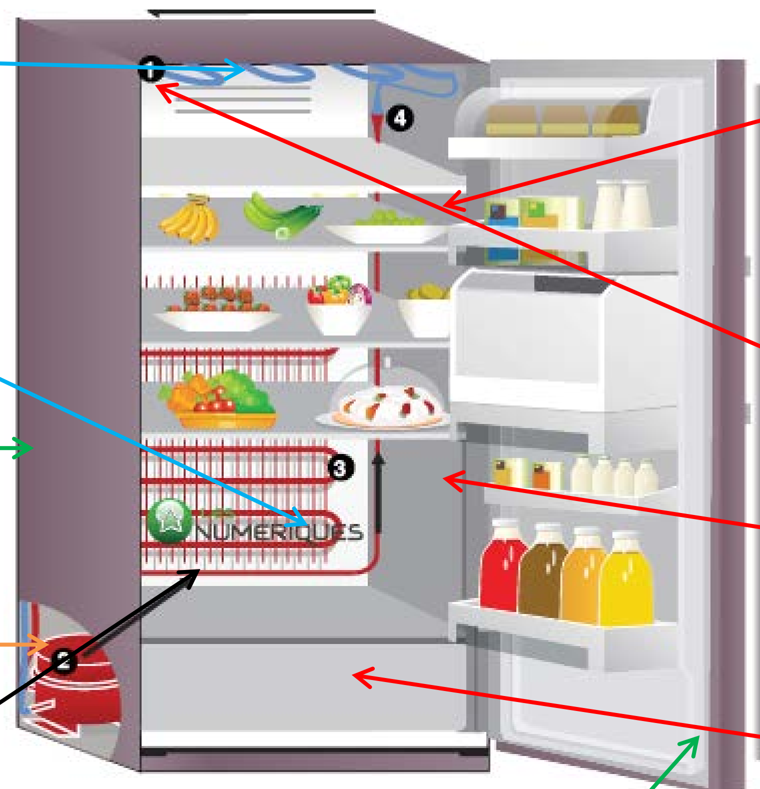
Roll bond evaporator (with fan)

Wire and tube static condenser

Increased thickness of HC or HFC PUR foams

Single speed compressor & fan

**R-600a** or R-134a as refrigerant



Mechanical or electronic thermostat

No-frost

Anti-Sweat heaters

Expansion valve

Improved door gasket

--- Insulation
--- Control and defrost managment
--- Heat exchangers
--- Compressor and fans

# 1 - Existing products on the market

- Mechanical compression vapor cycle & electrical compressor
- Refrigerants: **HC-600a** (99%) & HFC-134a (1%)
- Insulation
  - Polyurethane Foam (**Cyclo-pentane** and n-pentane (78%) or HFC(11%)) in walls and door
  - Increased insulation thickness (8cm?)
  - Improved door gaskets

*Ceced figures*

- Control and defrost management
  - Mechanical or **electronic thermostats**
  - Semi automatic or automatic **defrost system**
    - No frost models : 40 % of the EU market (Ceced)
  - **Expansion valve**: non-adiabatic capillary tube
  - **Anti-sweat heaters** with hot gas or warm liquid refrigerant loop (instead of electric resistance heater)

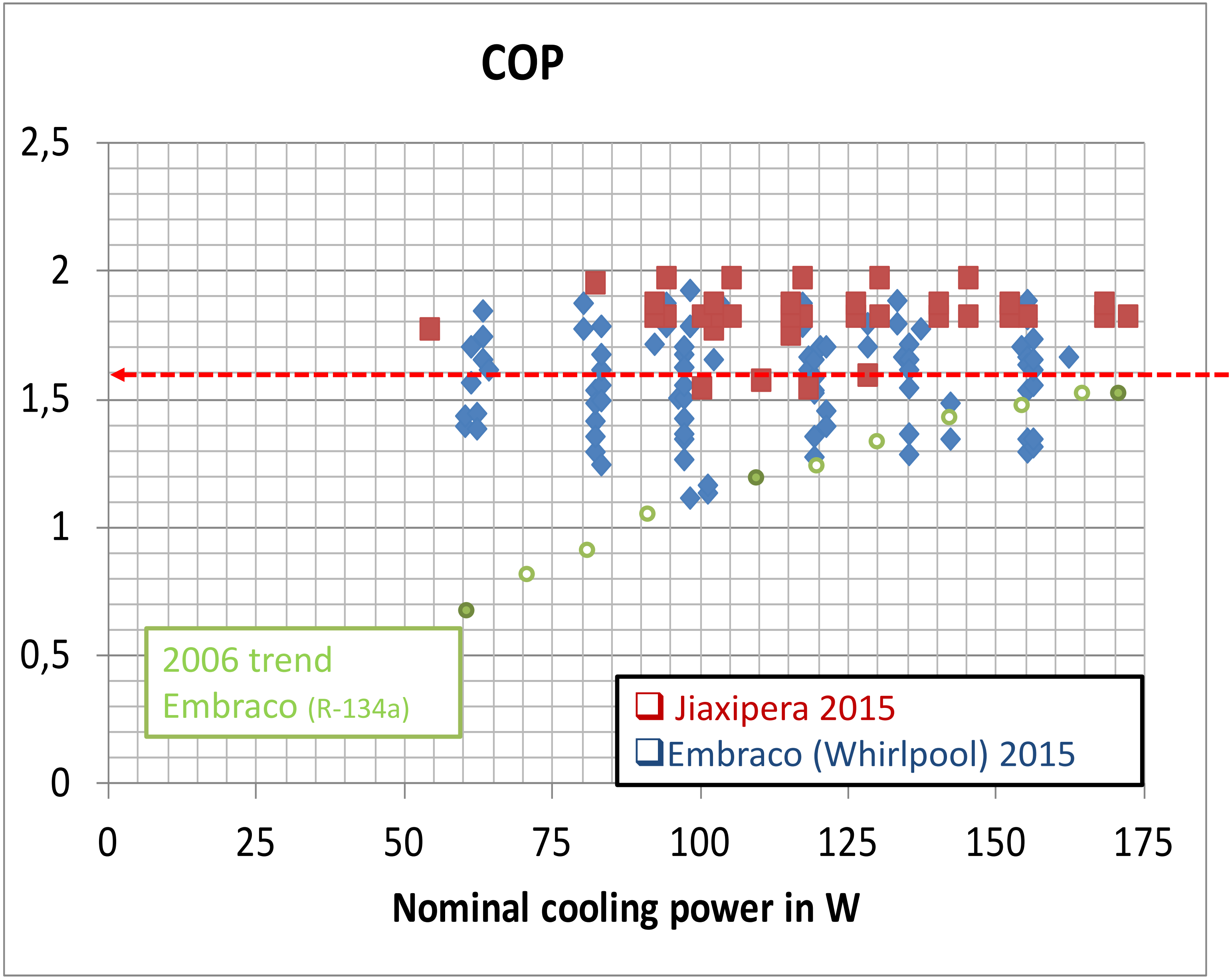
# 1 - Existing products on the market

- Heat exchangers
  - Wire and tube static condenser /different types of evaporators

    -> **static** or forced air convection (Fan)
  - For two evaporator and compartment fridges with a single compressor**: bi-stable solenoid valve**

    -> cost effective

    -> 76% of the EU fridge freezers have only one compressor *(Ceced 2014)*
- Compressor and fans
  - Fan power reductions P ≤ 5W
  - **Single speed reciprocating** hermetic compressor
  - Compressor **COP** has strongly increased since 2005
    - **1,35** (A class) **to 1,5** ($A^+$ class) in 2005
    - **1,3 to 1,9** in 2015




**R-600a hermetic reciprocating fixed speed compressor efficiency data** (Source: Embraco and Jiaxipera data 2015)

# Toward base case definitions

- EuP2007 : categories 1, 7, 8, 9

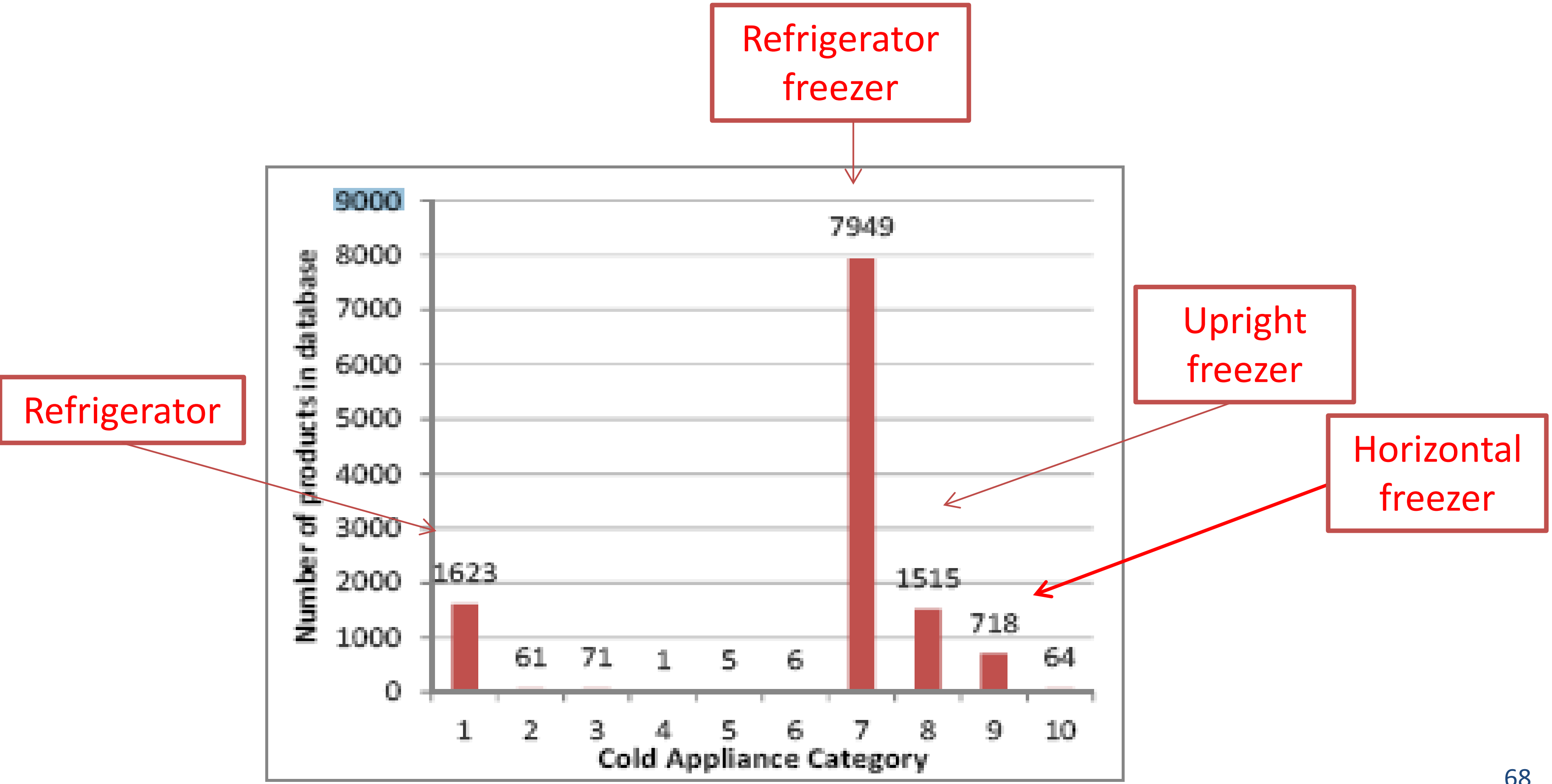



Figure 1: Appliance Distribution (CECED database 2013)

# Toward base case definitions

- Standard IEC 62552:
  - Most common categories: RF, RFb, Fu, R

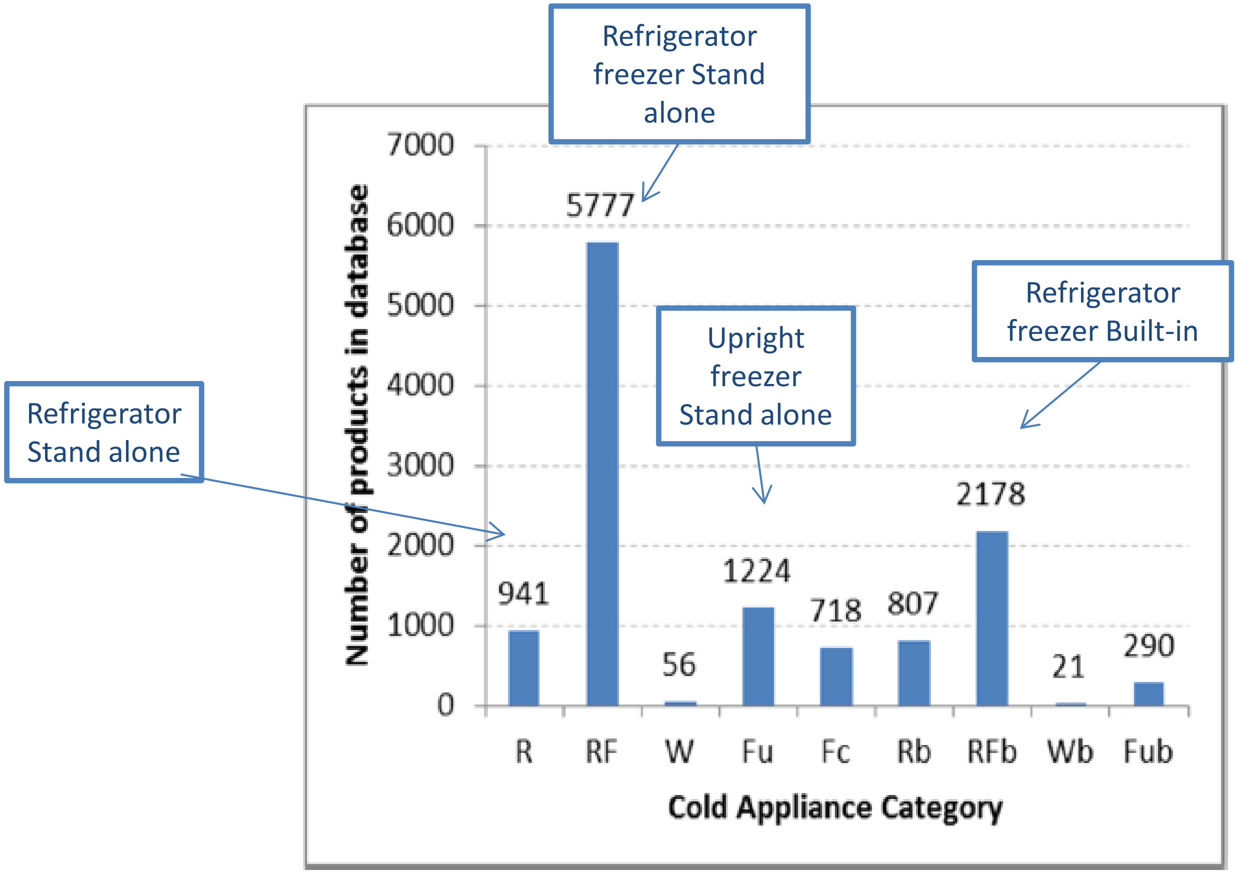


Figure 2: Appliance distribution after new categorisation (CECED Database 2013)

# Toward base case definitions

- **Prior thoughts of base cases**
  - All cases with **R-600a & n-pentane** (EU 517/2014)
  - No frost : 40% of the EU market (Ceced)

    ⇒**2 options**: static cold and no frost system
  - Electronic thermostat needed for no frost models
  - Compressor
    - **Single speed**
    - **COP=1,5**
  - **Static** Heat exchangers
  - Anti-sweat heaters
  - Expansion valve
  - In case of fridges-freezers:

    one compressor, two evaporators & a bi-stable solenoid valve

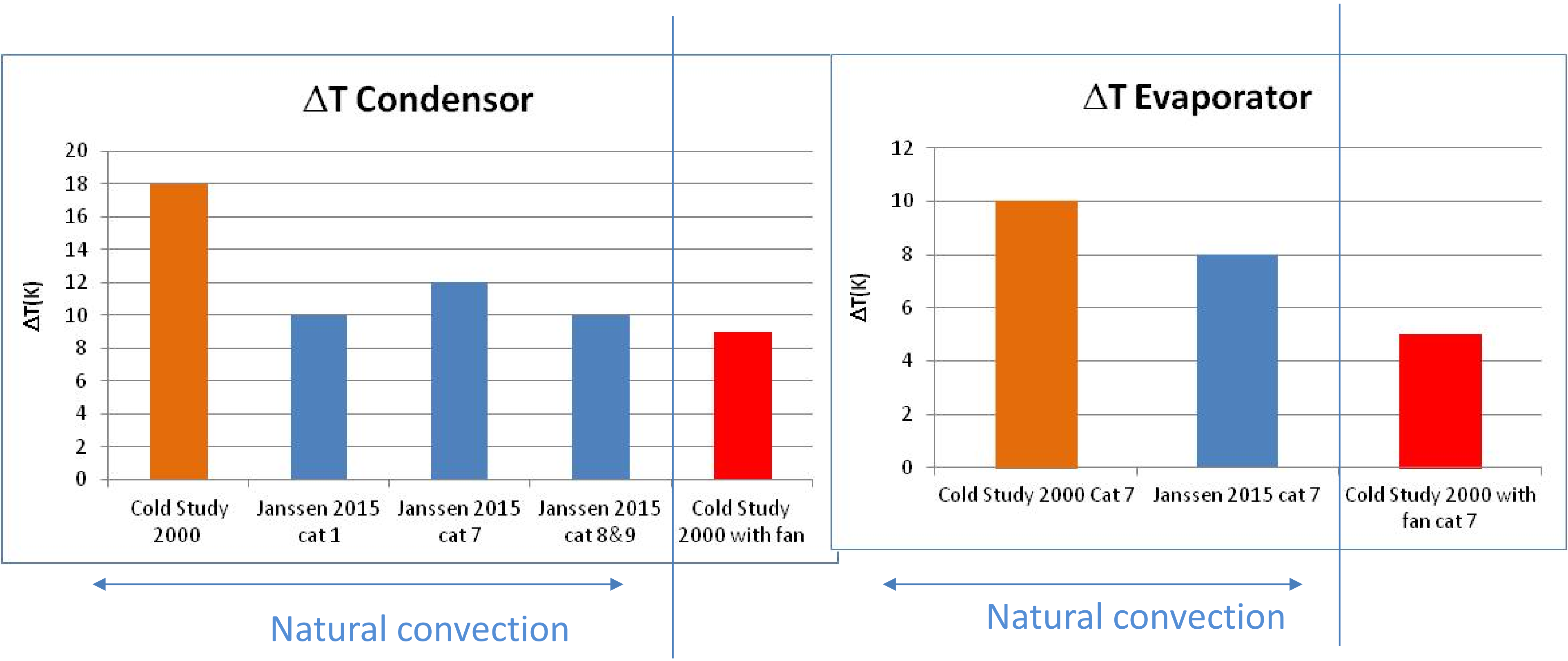
# 2 - Products with standards improvement options

- Insulation:
  - Increased insulation thickness
    - ➢ Except for buit-in models
- Control and defrost managment
  - Additional fans for air distribution control
    - Directed cooling or **brewed appliance**

    ⇒improve energy efficiency of static appliances
  - **Adaptative** defrost sytems with sophisticated electronic control
    - Could become cost effective
    - Savings about a few percents

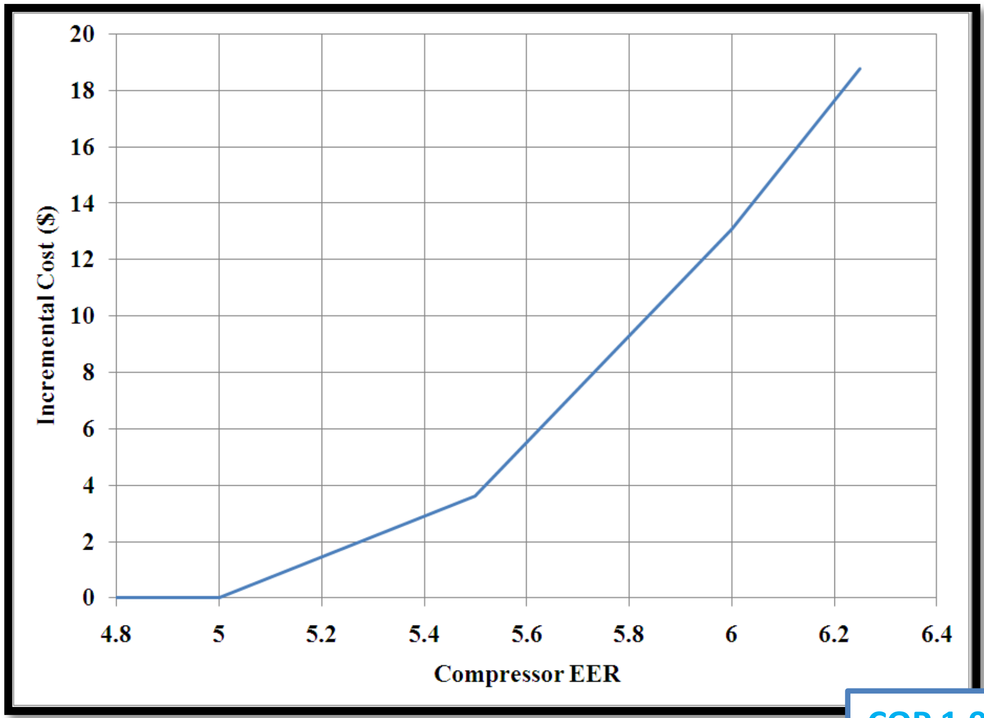
# 2 - Products with standards improvement options

- High efficiency heat exchangers
  - Condensors: **Improved heat transfer capacity 2000/2015**
  - Larger gains possible with **forced air convection** heat exchangers



# 2 - Products with standards improvement options

- Compressor and fans
  - **COP up to 1,9** in 2015




COP 1,9 ~ EER 6,5

**Cost increase** of R-134a hermetic reciprocating **fixed speed compressor** with efficiency (Embraco source)

  - Many A+++ appliances use variable speed compressors

# 3 - Best Available Technologies - BAT

- Insulation:
  - **VIP** (Vacuum Insulation Panels)
- Control and defrost managment:
  - Variable Anti Sweat Heater
- Heat exchangers
  - PCM: Phase change materials
- Compressor and fans
  - **Linear** compressor
  - **Variable Speed** Drive (VSD) compressor
  - VSD fans for no frost appliances

# Insulation VIP improvement - BAT

- Few models on the european market
  - Only 2%* of the new EU market 2014
  - 2014 VIP market (*Ceced database 2014)*
    - 49% $A^{+++}$
    - 27% $A^{++}$
- Insulation up to 8 times higher than conventional foams
- Problem of punctures
  - More durable protective films
  - Research works
- Research works **show savings in energy consumption up to 30%** *(Yusufoglu, Brunner, VIP Symposium 2013)*
- **Cost** to be checked:
  - Optimized combination of VIP with other energy efficient technologies (*Yusufoglu*)
  - VIP are used on commodity models in the USA since 2008 thanks to a tax credit

*Unspecified option in 90% of the cases in the Ceced database

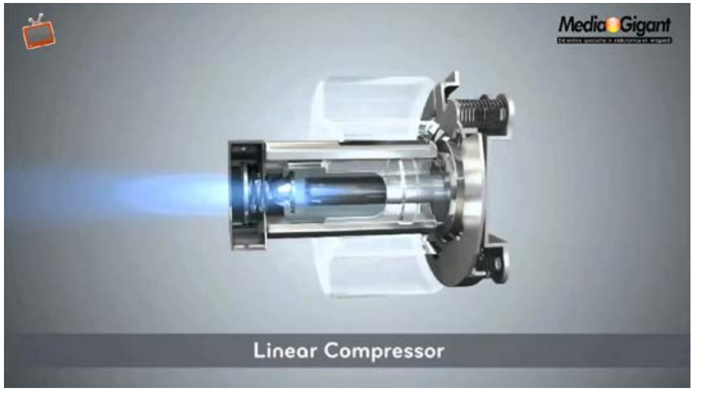
# Control and defrost managment BAT
# Variable anti sweat heater (VASH)

- VASH Principle
  - **Monitoring the environmental conditions** surrounding a refrigerated cabinet
  - R**emove** the anti sweat heaters **from operating when they are not necessary** => energy saving
- Results
  - Energy savings are low (*Yashar and Park, 2010*)
  - Technology commonly used on the **US market** (*David Yashar* )

# Heat exchangers – PCM - BAT

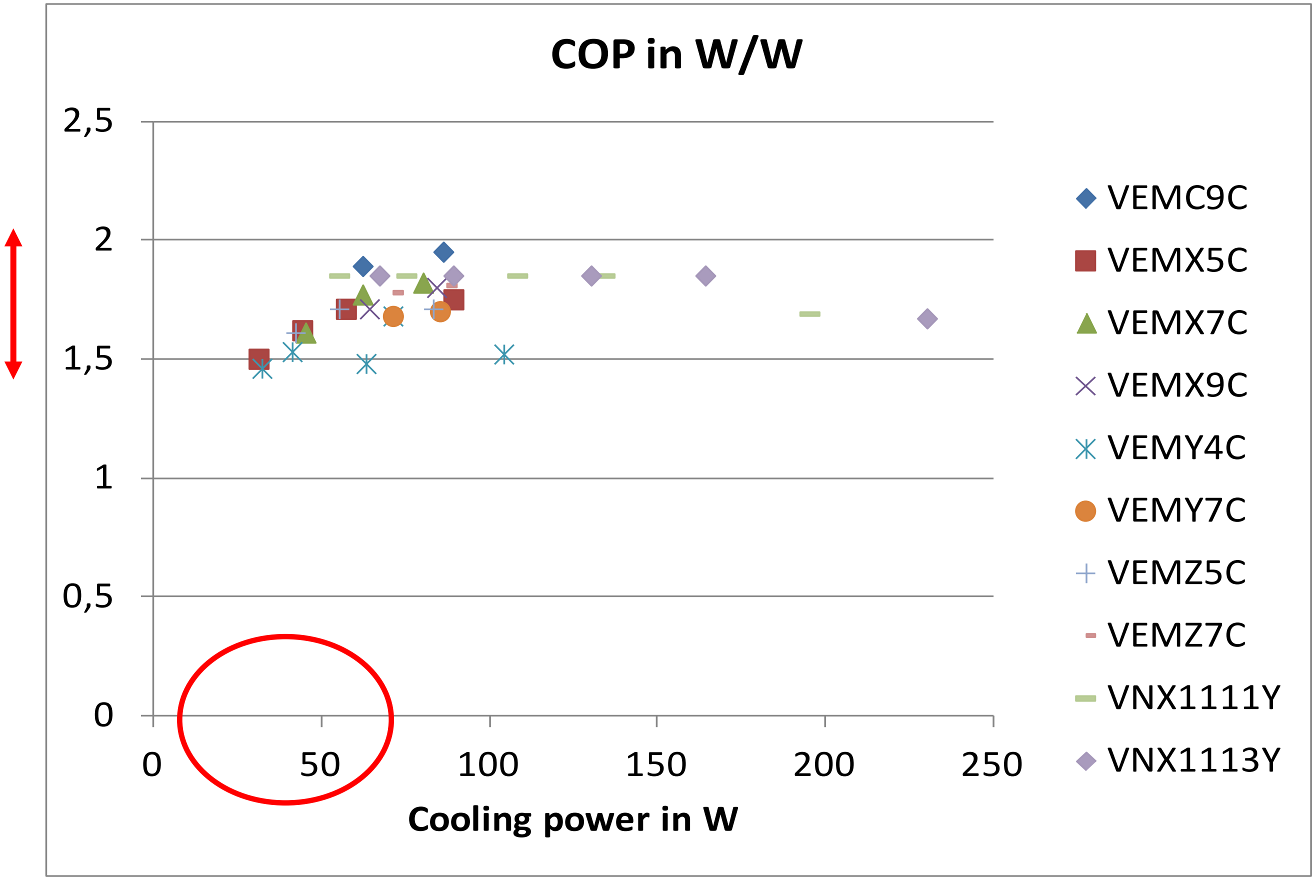
- **PCM** (Phase Change Materials)
  - Use of latent heat storage elements in heat exchangers (water, paraffine, copolymer)
  - Better energy efficiency
    - Savings of 5% (static ) and 9% (air-forced) on A+ single refrigerators
  - A few percents of the market
    - At the refrigerator´s evaporator, very small weights of eutectic solutions (<100 g) are being used *(Jadran Vrabec, UPB)*
    - Only sensible heat storages at the condenser on the market (water).
  - Research works
    - Potential savings from 10 to 30%
    - Several patents

# Compressor and fans - BAT




- Linear compressor
  - Excellent energy efficiency
  - Energy savings: 10% more than reciprocating compressor with BLDC motor
- VSD (Variable speed drive) compressor
  - Adapted for operation in the range of 10-43°C
    - ➢ T and ST climate classes = 63 % of the 2014 EU market (Ceced Database)
  - At least 20% energy savings
  - With BLDC motor => very low power levels can be reached with good efficiency
- VSD fans for no frost appliances
  - In combination with VSD compressor to reduce energy consumption

# Variable speed Compressor - BAT



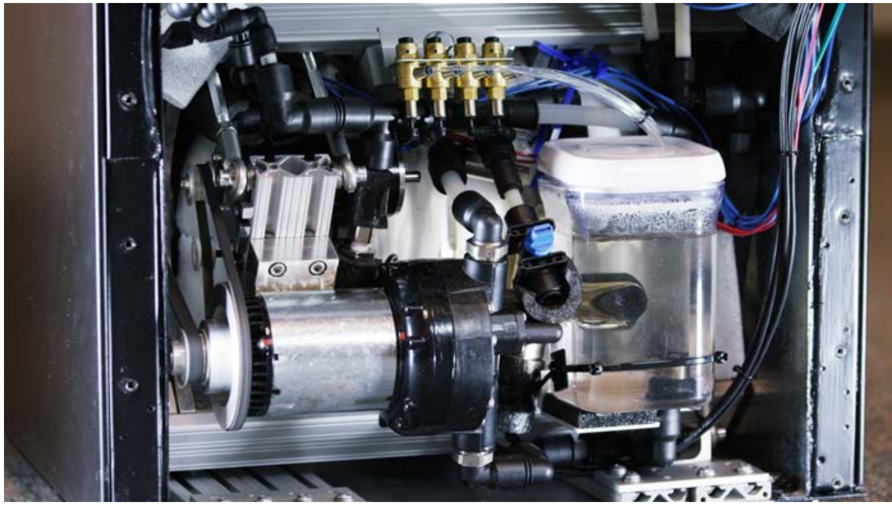

**R-600a hermetic reciprocating variable speed compressor efficiency data**
(Source: Embraco and Jiaxiperi 2015 data )

# 4 - Best Non Available Technologies – BNAT

- Insulation
  - GFP: Gas Filled Panels
  - Vacuum insulator for parts of the refrigeration system of refrigerators (**Patent**)

- Compressor and fans
  - Higher COP than about 1,93
  - Improved linear compressors

- Alternative cycle and technologies
  - Lorentz-Meutzner cycle
  - Ejector cycle
  - Stirling cycles
  - Thermoelectric cooling
  - Magnetic refrigeration
  - *Solar refrigeration*
  - *Thermo-Elastic refrigeration*
  - *Vortex Tube Gas Separation*

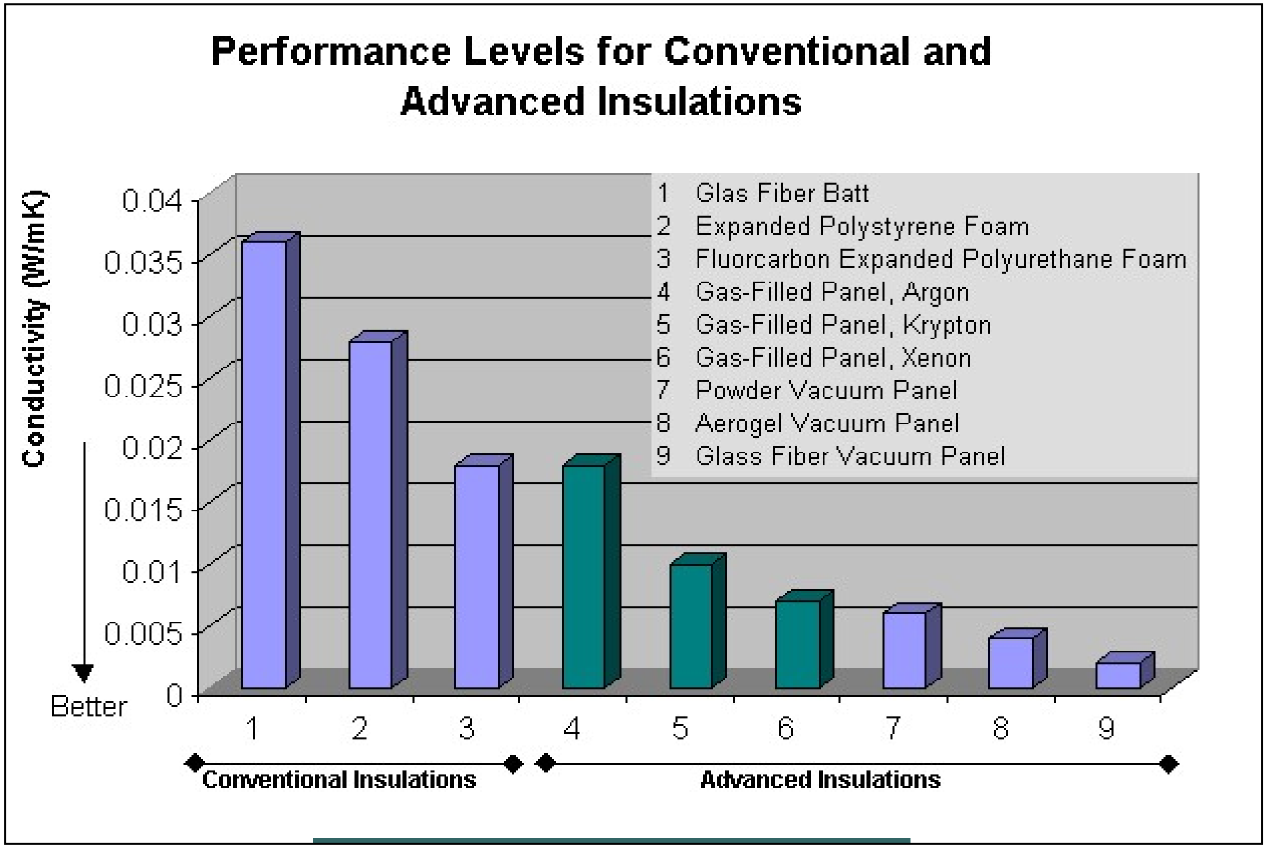


Astonautics – Premiere of Cutting-Edge Cooling Appliance at CES 2015
Wine cooler prototype (Haier, Astronautics, BASF)

# Gas Filled Panels – BNAT

- Developped at the LBNL in the 1990s
- Prototype refrigerator (2005)
- Projected savings 25%
- Pb: high cost and lack of structural integrity

-**LBNL answer: Coleman bought a license. No further developements. Expired patent.**




**Comparison of thermal conductivity depending on insulation type** (source: http://gfp.lbl.gov)

# Compressor and fans - BNAT

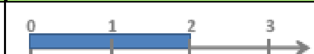
- Higher COP than 2 (80 < P < 100W)
- Improved linear compressors:
  - Still reasearches about systems with gas bearings
  - The available linear compressor on the market uses oil (LG). An oil free linear compressor should improve energy efficiency.

# Alternative cycle and technologies - BNAT

| Technology Option | TRL | Pros | Cons |
|---|---|---|---|
| Magnetic Refrigeration | 3-4 | •20% reduction in energy beyond A+++ | •Large scale collection or fabrication of Magnetocaloric material |
| Stirling Cycle Refrigeration | 4 | •Continuous process after energy input<br>•No refrigerant | •Experimental results can't reach theoretical efficiency |
| Thermo-Electric Refrigeration | 4 | •No moving parts<br>•Maximum controllability | •Small scale only such as spot cooling |
| Solar Refrigeration | 3 | •Very low grid electricity usage | •Climate variability with results |
| Thermo-Elastic Refrigeration | 3 | •No gas/liquid refrigerants | •Scale up, more development required |
| Vortex Tube Gas Separation Cooling | 4-5 | •No electrical energy input beyond air compressing<br>•No refrigerants | •Loud compressed air<br>•Hot air stream can reach high pressures and temps |
| Lorenz-Meutzner Cycle refrigeration | 3-4 | •Energy saving potential<br>•Low entropy generation | •Current standard cycle still used<br>•Only applies to RF |
| Ejector Cycle Refrigeration | 4-5 | •Easily installed in current RF system<br>•Recover lost work from expansion | •Limited gains<br>•Only applies to RF |

# Next step: Technology Roadmap

- Plan for emerging technology options given past and present standards
- This Roadmap:
  - Describes technology option
  - Potential cost, research and development
  - Pros/Cons and comparison to today's standard

| Technology Option | R&D Objective | Outcomes of Achieving Objective (TRL Advancement)[1] | R&D Tasks | Possible Performers & Roles | Duration & Resources Required | Key Risks |
|---|---|---|---|---|---|---|
| Tier 2 (Medium Priority) | | | | | | |
| **Refrigerator/ Freezer:** Improved linear compressor | Improve energy efficiency of linear compressors through optimization of design, material selection, and lubricants. |  | • Reverse engineer commercially available linear compressors<br>• Increase compressor efficiency through improved designs, materials, and lubricants to optimize performance<br>• Test optimized compressor to demonstrate improved energy efficiency | • BTP: provide funding, manage test program<br>• Third-party laboratory: perform reverse-engineering analysis<br>• National Laboratory: design and testing | **Duration: 2 years**<br>• Materials to build and test improved compressors<br>• Research staff to build, test, and analyze compressors | • May involve proprietary compressor designs |

*Research & Development Roadmap for Next-Generation Appliances US Department of Energy, 2012*

# Thank you for your attention

General comments & Tasks 1-3

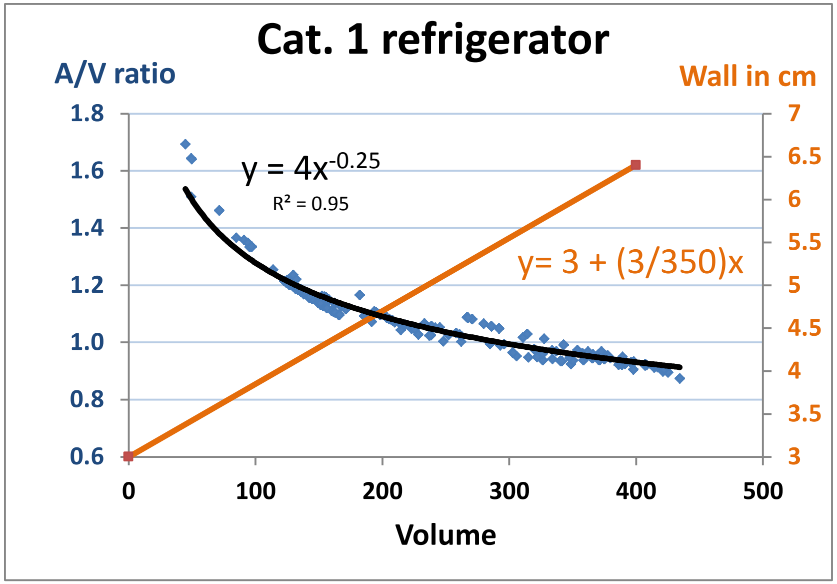
r.kemna@vhk.nl

Comments Task 4

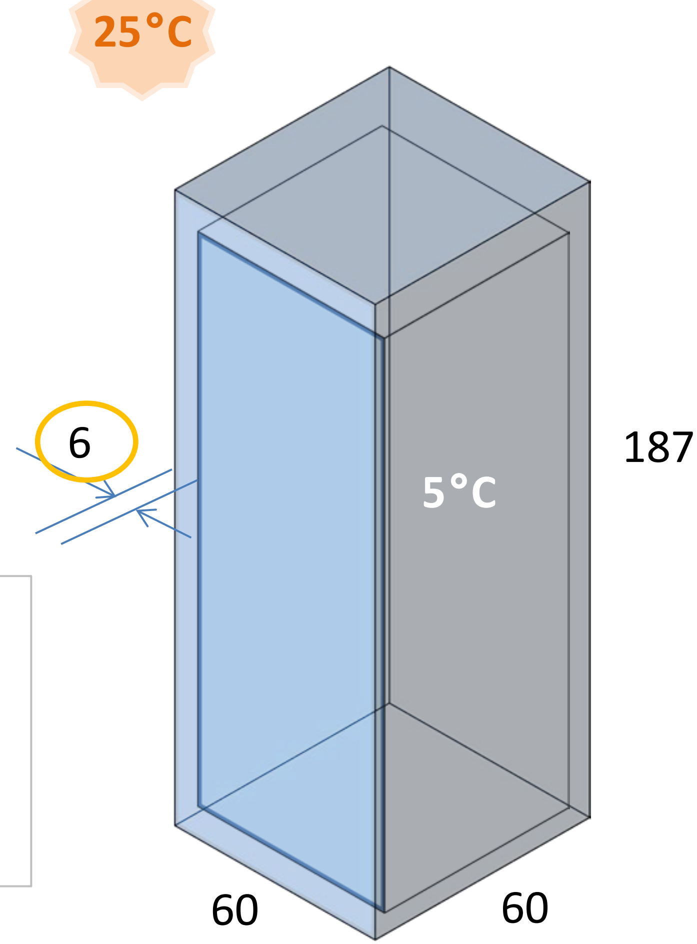
Stephanie.barrault@mines-paristech.fr

Philippe.riviere@mines-paristech.fr

# Basics I

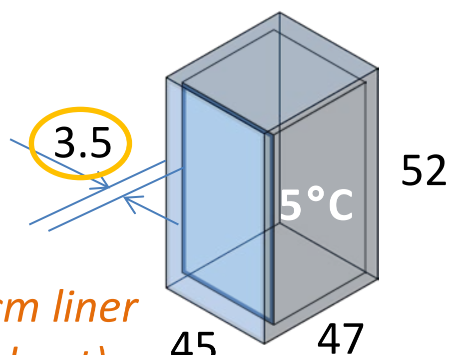



**<u>A/V ratio 0.9</u>**




**insulation thickness**

*(excl. 0.5 cm liner and steel sheet)*




**<u>A/V ratio 1.6</u>**

*For every dm³ volume **V** there is 1.6 dm² surface area **A***

# Basics II

- Work to be done (e.g. defrost) but starts to make sense