Energy efficiency in the Refrigeration and Air Conditioning (RAC) sector

Edgar Timm, HEAT GmbH, commissioned by GIZ
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Energy Efficiency in RAC sector

- Why Efficiency matters
  - Outlook R290 and reference Volkmar Hasse

- Steering Energy Efficiency – The concept
- Minimum Energy Performance Standards (MEPS)
- Labelling
- Evaluation of MEPS and Labelling
- Monitoring and Control
- Conclusion and Discussion
Global emissions from the RAC sector (abs.)
Unitary AC /Mt: 1230; 2050: BAU 4980, MIT 3360

Source: www.green-cooling-initiative.org/
Global emissions from the RAC sector (per capita)
Unitary AC kg/Capita

Source: www.green-cooling-initiative.org/
Emission reduction potential UAC

World

Emission reduction potential
1,610 Mt* in 2050

South Africa

Emission reduction potential
12.1 Mt* in 2050

Source: www.green-cooling-initiative.org/
The consequence: Environmental Legislation

- Global Conventions
- Ratification
- EU Targets
- EU Legal Instruments
- National Laws
- „Standards“
Environmental Legislation:
Example EU and Germany

Montreal, Kyoto – Prot. Amendments

Direct Emissions
- ODS
- F-Gases

Indirect Emissions
- ErP „Eco-Design“
- „Labelling“
- „Buildings“

National Laws and Regulations
- ChemG
- ChemG, KrWG
- EVPG
- ErPV

Standards
- ChemKlimaschutzV
- ChemOzonSchichtV

Consultancy services
provided by HEAT GmbH

Edgar Timm, HEat GmbH
Basic Concept of MEPS and Labelling

“RAISE THE FLOOR!”
- Eliminate inefficient products from the market
- “Push” manufacturers to produce more efficient appliances and lighting

“LIFT THE CEILING!”
- Stimulate consumer demand for energy efficient products
- Help manufacturers of appliance and lighting products to overcome investment and market barriers
Beyond MEPS and Labelling

- Target:
  - Minimum Efficiency & Quality standards for the market
  - Market transparency & Customer guidance

Start: Basic Energy Consumption

Efficiency

Buying behaviour

Goal: Significant Reduction

Consumer patterns

Labelling

Eco-Design

Communication / Education
MEPS Starting position
Example – energy efficiency of chillers in EU (2010)

How to raise the level?

\[ \eta_{low} = 0.4 \eta_{high} \]
One basic concept: Setting the MEPS at Least Life Cycle Costs (LLCC)

MEPS = point of lowest LLCC

LLCC = Upfront investment costs + Operating costs over the lifetime of the product
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• Why Efficiency matters
• Steering Energy Efficiency – The concept
• Minimum Energy Performance Standards (MEPS)
  ➔ Labelling
• Evaluation of MEPS and Labelling
• Monitoring and Control
• Conclusion and Discussion
Labelling

• Normally in connection with MEPS
• Classification needed: compare apples with apples!
• Should allow easy guidance for users / customers
• Needs regular review
### Example China: Mandatory MEPS and labels for chillers

- 5 label categories
- No 5 = MEPS, No 1 = top label
- Lower than No 5 not allowed to sell in the market

<table>
<thead>
<tr>
<th>Type</th>
<th>Rated Cooling Capacity (CC) [kW]</th>
<th>Energy Efficiency Grade (COP) [W/W]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air-cooled or evaporatively-cooled</td>
<td>CC ≤ 50</td>
<td>3.20 3.00 2.80 2.60 2.40</td>
</tr>
<tr>
<td></td>
<td>CC &gt; 50</td>
<td>3.40 3.20 3.00 2.80 2.60</td>
</tr>
<tr>
<td>Water-cooled</td>
<td>CC ≤ 528</td>
<td>5.00 4.70 4.40 4.10 3.80</td>
</tr>
<tr>
<td></td>
<td>528 &lt; CC ≤ 1163</td>
<td>5.50 5.10 4.70 4.30 4.00</td>
</tr>
<tr>
<td></td>
<td>CC &gt; 1163</td>
<td>6.10 5.60 5.10 4.60 4.20</td>
</tr>
</tbody>
</table>

**Coefficient of Performance**

\[
COP = \frac{\text{Refrigerating capacity [W]}}{\text{General Power Consumption [W]}}
\]
Energy efficiency labelling: Dynamic process for adding top label classes and banning lowest classes

- Top category for the best max 5% products
- Lowest label category (lowest 5%) → if market share falls below threshold → ban
- Lowest category = MEPS
- Regular review (i.e. every 2 years)

EU: efficiency classes of refrigerator sales

- 2010: B + C banned
- 2012 / 14: A banned
- A++, A+ added

Top category = A+++
Energy efficiency labelling: Bad example - if most of the products are just in one category

- Until 2011 all products only in one category
- Label fails to promote the most energy efficient appliances
- No potential for end user to differentiate
- Example: improvements after 2012
Labelling

Effectiveness

Refrigerators DE

Sustainability?

Washing machines DE

Source: B. Schäppi, EU-Prozess zur Entwicklung von Ecodesign-Standards und Labels – Aktueller Status, Chancen und Herausforderungen für den Zeitraum 2012-2014
Labelling Examples EU-Heating Systems:
The right amount – common sense needed!
Key indicators for energy efficiency

Group L
- COP (DIN EN 1511...)
- EER (DIN EN 14511,...)

Group C
- JAZ (VDI 4650)
- SCOP (EN 14825)
- SEER (ASHAE 116)

Gruppe F
- JAZ, SPF (Several Projects Market Surveillance)

MEASURED (Standard Rating Conditions)
CALCULATED with defined methodology
MEASURED in field under real conditions
Key indicators for energy efficiency

COP: Coefficient of performance, Energy Efficiency Ratio

\[
\text{COP, EER} = \frac{\text{USE}}{\text{EFFORT}} = \frac{\text{OUTPUT}}{\text{INPUT}}; \quad \left[\frac{\text{POWER}}{\text{POWER}}\right] = \frac{\text{WATT}}{\text{WATT}} = \frac{kW}{kW}
\]

SCOP: SEER: Seasonal Coefficient of performance, Seasonal Energy Efficiency Ratio

\[
\text{SCOP, SEER} = \frac{\text{USE}}{\text{EFFORT}} = \frac{\text{OUTPUT}}{\text{INPUT}}; \quad \left[\frac{\text{WORK}}{\text{WORK}}\right] = \frac{\text{JOULE}}{\text{JOULE}} = \frac{kWh}{kWh}
\]
Evaluation of energy efficiency

• Concepts of efficiency rating
  — Standard rating condition
  — Seasonal efficiency
  — Part load performance

▪ Standard rating condition
  — Measurement of capacity and efficiency at a single condition
Evaluation of energy efficiency

Part load efficiency: Provides more realistic representation of actual performance conditions

Efficiency (COP)

Time

- Efficiency at standard rating condition
- Average efficiency at part-load
Seasonal efficiency
Provides more realistic representation of actual performance conditions

<table>
<thead>
<tr>
<th>Outside temperature</th>
<th>Standard rating condition</th>
<th>Efficiency (COP)</th>
<th>Other rating conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit #1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unit #2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Yearly hours per temperature**

- **COLD**
- **AVERAGE**
- **WARM**

**Efficiency (COP) vs. Temperature / °C**

- Efficiency decreases as temperature decreases.
- Unit #1 and Unit #2 have different performance under varying temperatures.
- Standard rating condition is marked at 0 °C.
SCOP / SEER Evaluation Basic concept

Heat-Sink

Heat-Source

(Heat) -Load

El.- Power

Reference /Temp.- Classes

Time / Year

\( T \)

\( T_c \)

\( T_u \)

\( T_r = T_0 \)

A B C D

Full Load

Part Load classes

\( \dot{Q}_{0A} \)

\( \dot{Q}_{0D} \)

Source: Prof. M. Arnemann, izw-Seminar 2019, Dramstadt, Re-Work ETSuS UG
### Evaluation of energy efficiency
**MEPS and Labels - Some examples Chillers**

<table>
<thead>
<tr>
<th>Economy:</th>
<th>USA</th>
<th>China</th>
<th>Australia/ NZ</th>
<th>Canada</th>
<th>EU</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chiller type</strong></td>
<td>AC</td>
<td>AC</td>
<td>AC</td>
<td>AC</td>
<td>AC</td>
</tr>
<tr>
<td><strong>Full- load MEPS</strong></td>
<td>COP</td>
<td>COP</td>
<td>COP</td>
<td>COP</td>
<td>--</td>
</tr>
<tr>
<td><strong>Part- load MEPS</strong></td>
<td>IPLV</td>
<td>IPLV</td>
<td>IPLV</td>
<td>IPLV</td>
<td>ESEER</td>
</tr>
<tr>
<td><strong>Testing Standard</strong></td>
<td>AHRI 550/590</td>
<td>GB 19577-2004</td>
<td>AS/NZS 4776</td>
<td>CSA-C743-02</td>
<td>EN 14511</td>
</tr>
<tr>
<td><strong>Label</strong></td>
<td>--</td>
<td>Mandatory</td>
<td>--</td>
<td>--</td>
<td>Voluntary</td>
</tr>
</tbody>
</table>

**Label**
- USA: Mandatory
- Canada: Optional
- EU: Mandatory
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Monitoring, Verification and Enforcement (typical approach)

Encouragement

- Grants, subsidies, tax incentives for the use of high efficient

Monitoring

- Self certification obligation for all manufacturers (both for MEPS and Label); For each new chiller type;
- COP, SCOP etc. reporting according to uniform standards
- Reporting, registration in central database and internet publication

Verification / Market surveillance

- Independent random test
- Testing at independent testing institute

Enforcement

- If test fails → repeat test paid by manufacturer until test passes or product taken from the market (EU) OR penalty, fine per product and immediate removal from the market if tolerances exceeded (either for new products or for all products historically sold)
Thank you for your kind attention!

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