# Ecodesign preparatory study for lifts implementing the Ecodesign Working Plan 2016-2019

# Task 3 report (revised draft): Users

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Team:
Contact Technical Team leader: Rohde Clemens

Main contractor: VITO (Belgium), Technical leader (Fraunhofer ISI)

Technical team leader: Clemens Rohde
Fraunhofer ISI - Clemens.Rohde@isi.fraunhofer.de

Authors: Simon Hirzel
Fraunhofer ISI – simon.hirzel@isi.fraunhofer.de

Antoine Durand
Fraunhofer ISI – antoine.durand@isi.fraunhofer.de

Review: Paul Waide
Waide Strategic Efficiency

Project website: https://www.eco-lifts.eu/

SUBMITTED BY:
IN COLLABORATION WITH

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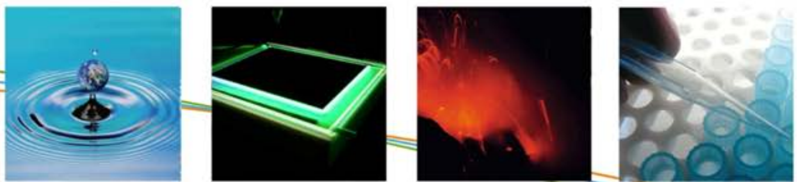
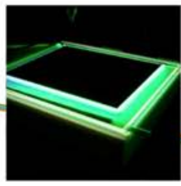


**History of the document:**

**Draft version of 31.01.2018**: made available for comments prior to first stakeholder meeting

**Revised draft of 23.05.2018** (this document): revised report after consideration of stakeholder comments received until deadline for comments of 15.03.2018

Please be aware that this is a draft consultation document that is only published for the purpose of receiving stakeholder comments. It may still undergo substantial revisions prior to being released as a final report of this preparatory study.

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# List of Abbreviations and Acronyms

| | |
|---|---|
| BfE | Bundesamt für Energie (Switzerland) |
| e4 | European project “energy-efficient elevators and escalators” |
| EC | European Commission |
| ELA | European Lift Association |
| EN | European Standard |
| EU | European Union |
| EU28 | 28 Member States of the European Union |
| ISO | International Organization for Standardization |
| MEERP | Methodology for Ecodesign of Energy-related Products |
| GSM | Global System for Mobile Communications |
| VDI | Association of German Engineers |
| ZVEI | Zentralverband Elektrotechnik- und Elektronikindustrie (Germany) |

# 3. Task 3 - Users (product demand side) – for Ecodesign and Energy labelling

User behaviour is particularly relevant for the environmental impact of lifts as it directly determines their utilisation. This task therefore deals with the influence of users on the life-cycle performance of lifts. The aim of this discussion is two-fold: on the one hand, its aim is to discuss barriers and restrictions to potential Ecodesign measures due to infrastructural, social and cultural aspects. On the other hand, it also aims at quantifying user-parameters with influence on the environmental impact differing from the standard test conditions as described in Task 1.2.

## 3.1. Preliminaries

As a starting point for reviewing user impact on the environmental performance of lifts, it is helpful to get an overview of different stakeholders involved in the life cycle of lifts, to further define "lifts users" among them and to describe the impact of the stakeholder setting for lift performance in general.

### 3.1.1. Stakeholders involved in the life cycle of lifts

Unlike typical commodity products such as white goods, lifts are customized products usually based on selecting and adjusting standard components. Lift manufacturers make a selection of suitable components, combine them and if necessary modify them according to the individual customer requirements. For special lift installations, e.g. for specific industrial applications and large office buildings, individually tailored components may also be part of the lift installation.

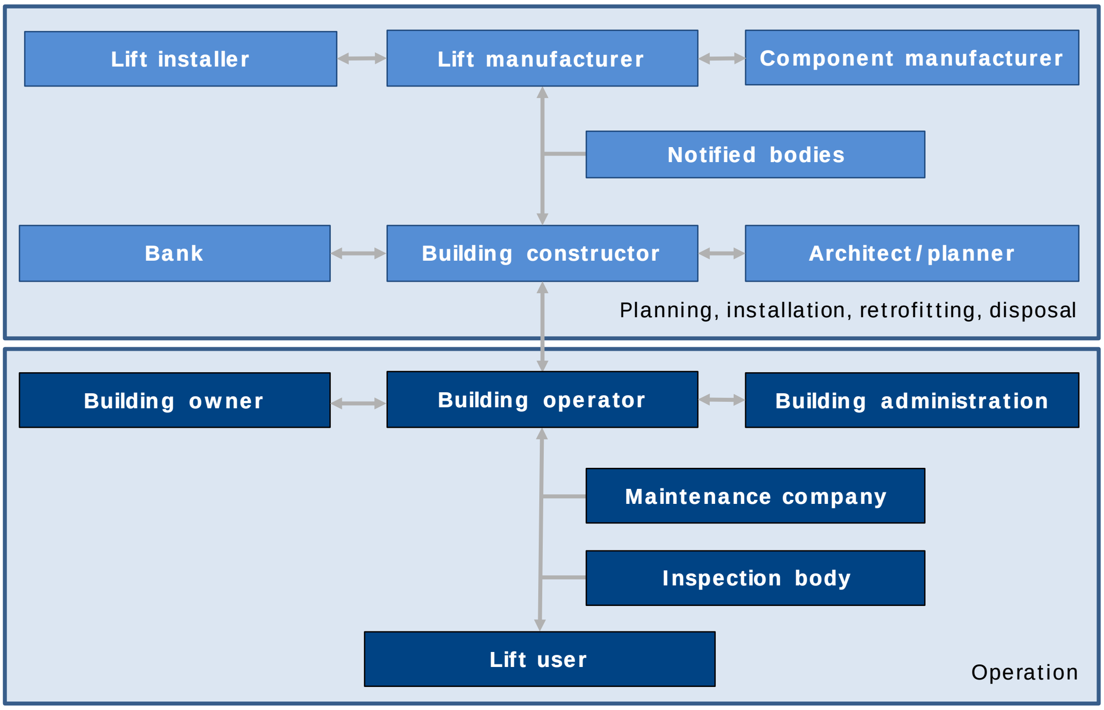


Figure 3-1: Overview of stakeholders involved in the life cycle of lifts (source: modified from Hirzel/Blepp 2017 and Dütschke/Hirzel 2010)

Figure 3-1 provides an overview of the different groups of stakeholders involved in the life-cycle of lifts. The upper part of the illustration shows major stakeholder groups mainly involved in the planning, installation, retrofitting and disposal phase of a lift project. It should be noted that the relevance of the different groups of stakeholders varies over time. The lower part illustrates stakeholders involved during the operation phase. The individual groups and their influence on the environmental performance can be summarized as follows:

- **Lift manufacturers:** Lift manufacturers basically design, manufacture and assemble lifts to suit the specific customer requirements , i.e. from the constructor of the building, a planner or an architect. Depending on the extent of the details given by the design specification and in view of existing regulation (see Task 1.7), manufacturers have a varying degree of freedom with regard to lift design. Within this freedom of action and limits in terms of budget, they may choose to manufacture or implement more or less efficient components and they thus affect the environmental performance of lifts.

- **Component manufacturers:** In addition to lift manufacturers, there are usually smaller manufacturers of components that focus on offering specific components for lifts such as control systems, brakes, motors, door movers, guide rollers, etc. As these components are part of the lift, they have an impact on the overall environmental performance of the lift.

- **Lift installers:** The task of lift installers is to assemble and install the lift on location, i.e. in the lift shaft/machine room of a building. This work is often carried out by lift manufacturers as part of the sales process. As the installation quality may affect the environmental performance of lifts (e.g. due to poorly installed guiding rails), lift installers may have an impact on the environmental performance, as well.

- **Notified bodies:** Notified bodies are organizations that verify the conformity of products with existing legal requirements before they are placed on the European market. As their task is to focus on assessing the conformity of lifts and their safety components, they have little direct impact on the overall performance of lifts and beyond to ensure that the lift is suitably equipped with all necessary safety precautions, e.g. light curtains.

- **Building constructors:** Building constructors develop the idea and set the conditions for building construction and rehabilitation projects. They give the impetus for such projects and contract architects and planners for detailed project planning. They might also set requirements on the design and operation of the building and its lifts.

- **Bank:** This group usually provides funding on the level of entire building projects, i.e. for constructing new buildings or for retrofitting existing ones. Banks typically focus on construction projects in their entirety and rarely deal with individual details such as lifts. Yet they may indirectly have an impact on the environmental performance of lifts by setting budgeting limits, by defining requirements to the project or by setting minimum requirements in terms of environmental impact or energy performance, thereby potentially also affecting lifts. Yet in sum, their direct impact on the environmental performance of lifts is rather limited.

- **Architects/planners:** Architects and planners define the layout of building projects and thereby also influence the need for vertical mobility. Thus, they determine many aspects relevant for the environmental performance of lifts, for example by setting the framework conditions which influence the number, size or usage of lifts.

- **Building owner:** Owners of the buildings are stakeholders that own the lift respectively the building where the lift is located. Building owners are usually identical to the constructor if buildings are not sold after completion of the building. Depending on the situation, building owners may mainly view the building including its lifts as an investment opportunity. Operational tasks may be delegated to an independently operating building administration.

- **Building administration:** The building administration mainly deals with financial and organizational aspects of building operation, e.g. renting of space, organizing maintenance, invoicing, etc. Regular maintenance works may be delegated to a building operator. Building administrators influence the performance of lifts by establishing maintenance and retrofitting schedules for the lifts, for example.

- **Building operator:** Building operators, e.g. caretakers, can be considered as stakeholders dealing with all organizational on-site aspects. They are responsible for ensuring the proper operation of the building including its technical equipment such as lifts. They usually ensure that the lift is working properly, for example, by performing routine checks. They may influence the performance of lifts among other means by identifying malfunctions of the equipment, e.g. based on unusual noise or contamination of the equipment. They may also respond to operational needs, e.g. by modifying standby modes.

- **Maintenance company:** Lifts need regular maintenance and inspection. Therefore, maintenance companies regularly intervene on any lift installation. The inspection intervals vary depending on several factors, among others their utilisation. Typical maintenance intervals are in the range of 1 to 3 months for many installations, yet it has been pointed out by stakeholders that an interval of 1 month while some lifts are not maintained on a regular basis at all. Proper maintenance can help to improve the environmental performance of lifts, e.g. by ensuring proper lubrication, replacement of worn components, ensure proper equipment setting etc. Maintenance work is provided by specialized independent companies, but also by large lift manufacturers.

- **Inspection body:** The safe operation of lifts is ensured by regular inspections of third party inspection bodies. Their impact on the environmental performance of lifts is mainly focused on pointing out faulty equipment or non-conformity with existing regulations.

- **Lift users:** Lift users are actually all those who use lifts for vertical transportation. Thereby, they directly affect the energy consumption of lifts as the power reading in the phase of operation is higher than it is in standby. In residential buildings, a large group of the lift users are the inhabitants of the buildings. They typically “pay for the lift”. Either the investments are covered by the rent or they are allocated to the owners as a function of their ownership of floor space or a similar measure. The operational costs for operation, especially energy and maintenance, are usually payed as part of the reoccurring costs of the building.

Though some of the previously mentioned stakeholder groups may overlap, it becomes evident that many groups affect the overall environmental performance of lifts. Due to the interaction of several types of stakeholders, barriers to energy efficiency have been identified as a relevant topic for lifts.

### 3.1.2. Barriers for lifts

Following the definition of Sorrell et al. (2004), a barrier can be perceived as a mechanism that inhibits a decision or behaviour that is both energy-efficient and economically efficient. A structured in-depth investigation on barriers for lifts (and escalators) was carried as part of the e4-project (Dütschke/Hirzel 2010). This investigation was based on a triangulation process combining the results of 13 expert interviews, a written survey with 10 additional participants and an intermediate and subsequent discussion of preliminary results with industrial representatives. The results were presented along five categories of potential barriers, i.e. a) information and transaction costs, b) split incentives, c) bounded rationality, d) capital and e) risk and uncertainty. In the following text and in Figure 3-2, the main results for these categories are summarized.

#### 3.1.2.1. Findings on information and transaction costs

Findings on information and transaction costs indicate that a regular monitoring of energy consumption in lifts is rather uncommon. Usually, no technical means were installed that would allow such monitoring. Consequently, it has been concluded that energy consumption of lifts could not be discerned from other equipment in a building. This has been perceived as related to the observation that operators and users are seldom aware of the energy consumption of equipment. Due to this lack of sensitivity on the topic, no measurement equipment is installed and due to the lack of data, individuals hardly become aware of potentials to increase energy efficiency in the case of existing installations.

Obtaining information on energy-efficient technology was not perceived as especially difficult, yet limited to information from manufacturers and their sales representatives. However, it has been pointed out that sales representatives were not necessarily familiar with a broad spectrum of possible solutions beyond those offered by their own company.[1] It has also been found that clients were largely ignorant about energy-related topics of lifts, as well, and that they thus could not ask specific questions about the topic.

#### 3.1.2.2. Findings on split incentives

Concerning split incentives, it has been found that they are considered as barriers to energy efficiency between general contractors or building constructors, lift owners as well as those who pay for the energy consumption of the lifts. In the residential sector, the latter group usually consists of the inhabitants of the building and they are not necessarily identical to the building owners. It has also been pointed out that constructors often do not pay particular attention to the energy consumption of lifts. In addition, the end-users are generally not aware of the costs related to the energy consumption of lifts.

#### 3.1.2.3. Findings on bounded rationality

A lack of time for the selection of equipment was not identified as relevant with the exception of cases of equipment breakdown where quick replacement was needed. A focus on the initial investments as opposed to life-cycle costs, however, has been identified as a relevant barrier.

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[1] Given that additional sources of information, e.g. the findings from the e4-project, have been made publicly available since conducting the study, this issue can be considered as less relevant. It should also be noted that the more widespread use of energy labels for lifts might also have affected the ease of obtaining information on energy consumption. It seems plausible that there is more awareness among specifiers, lift companies and suppliers on energy-related issues in lifts.

### 3.1.2.4. Findings on capital

A general lack of capital was not identified as a barrier. Rather, the willingness to make bigger initial investments for energy-efficient equipment was seen as a challenge, particularly in the case where split incentives were relevant. Yet some experts also pointed out in this context that energy-efficient technologies were not substantially more expensive than default components. Furthermore, no barriers due to budgeting laws or regulations for public buildings were identified.

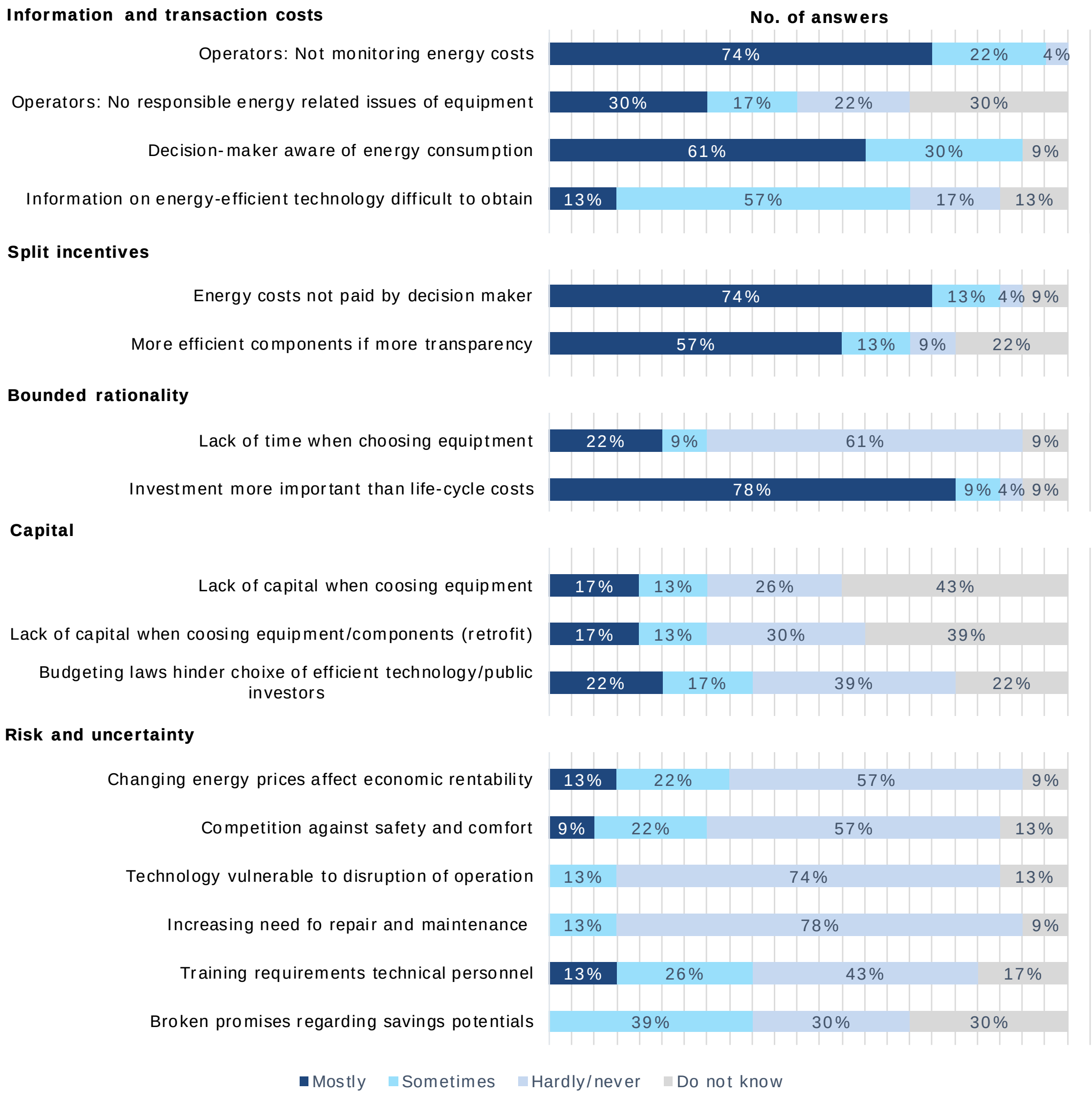



Figure 3-2: Overview of the results of the 23 expert interviews/questionnaires about the relevance of barriers to energy efficiency for lifts (and escalators) from Dütschke/Hirzel (2010)

### 3.1.2.5. Findings on risks and uncertainties

Risks and uncertainties could neither be identified as major barriers for the utilization of energy-efficient technologies for lifts. Neither has more efficient technology been identified as more susceptible to disruption of operations, nor has it been found to increase needs for repairs and maintenance or to increase substantially training requirements for technical personnel. Comfort or safety issues or uncertainties about promised/potential energy saving were not seen as barriers, either.

#### 3.1.2.6. Conclusions from the analysis in 2010

Based on these findings, the analysis in Dütschke/Hirzel (2010) gave the following main conclusions:

- Major barriers to energy-efficient technologies identified were related to information and awareness. A lack of monitoring of energy consumption and a lack of awareness about energy-efficient technologies especially with the operators/users has been identified. An important role was further attributed to the situation that a main source of information were manufacturers and their sales departments, encouraging situations where installations where usually chosen without any detailed assessment of energy demand or its life cycle impact.

- Split incentives were furthermore discussed as a challenge for implementing energy-efficient solutions. This is particularly the case when several building users/inhabitants share the overall energy costs of a lift, especially since only between 3 and 10% of the overall energy consumption of a building is caused by a lift. While manufacturers rather intensively discussed energy demand/energy efficiency, other stakeholders were not engaged by the discussion and investors focus on low investment costs

- Other barriers, next to those related to information and split incentives, were only identified as playing a minor role. A general lack of capital was not identified as a barrier, yet a focus on investments could be observed and the economic efficiency of energy-efficient technologies was the subject of a controversial debate.

## 3.2. Subtask 3.1 - System aspects in the use phase affecting direct energy consumption

The aim of this subtask is to report on the **direct impact** of lifts on the environment and resources during the use phase. Direct impact means here any impact that is directly related to the lift itself. The analysis is based on different scoping levels, starting with at the strict product scope, and then extending this perspective to an extended product approach, thereafter proceeding to a technical system approach and finally discussing lifts from a functional system approach. For the remainder of Task 3, the “lift users” are considered as main “users” in the sense of the MEERP methodology.

These different scoping levels can be sketched as follows (Figure 3-3):

- **Strict product approach:** In the strict product approach, the system boundary just contains the lift installation with its components. The operating conditions are nominal as defined in traditional standards.

- **Extended product approach:** In the extended product approach, the influence of lift usage and real-life deviations from the test standard will be discussed.

- **Technical system approach:** When viewed from the technical system perspective, the lift is embedded in the surrounding building system.

- **Functional approach:** In the functional system approach, the basic function of a lift, i.e. vertical transportation of goods or people in buildings, is maintained, yet other ways to satisfy this basic function are reviewed, as well.

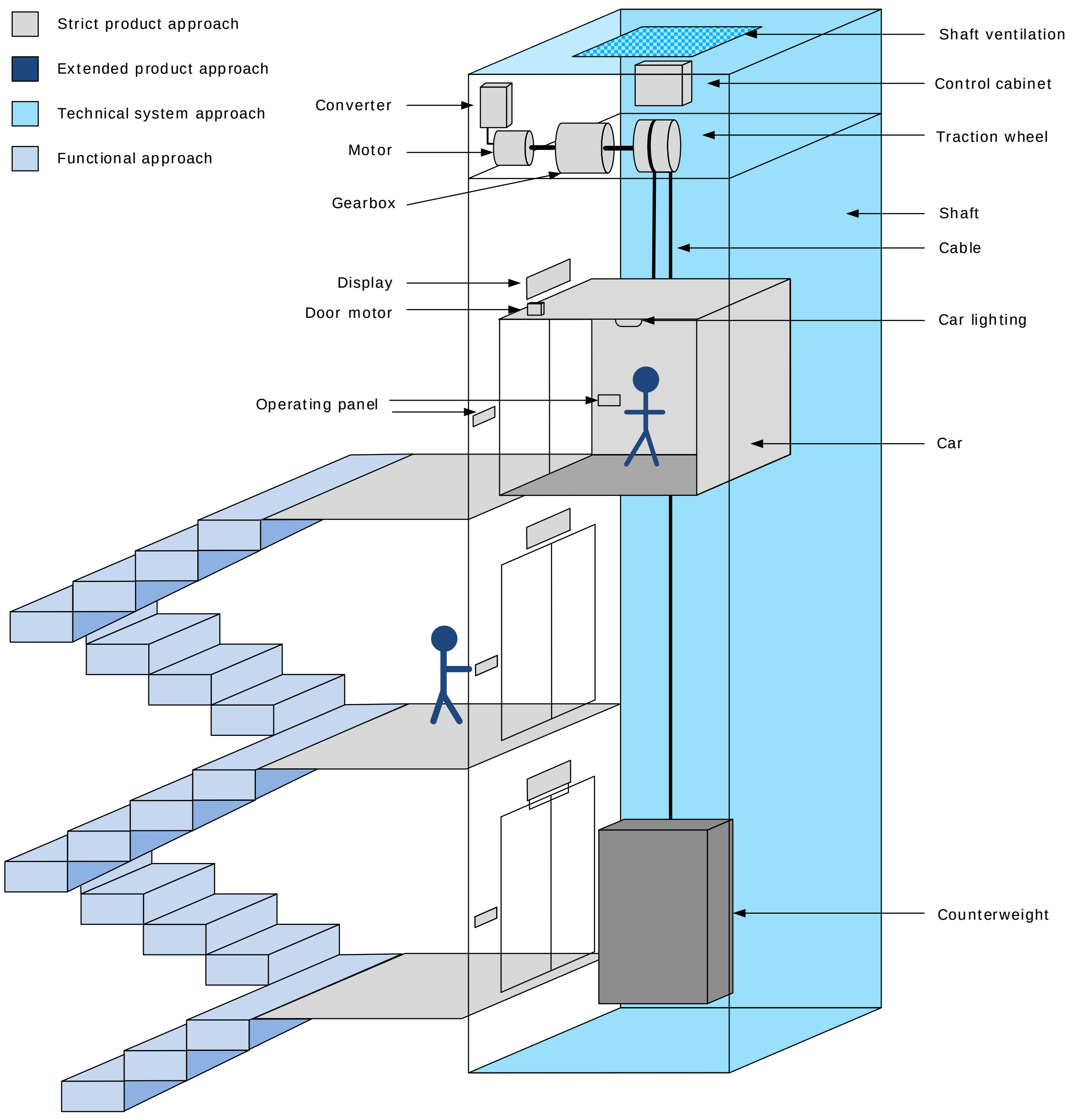



Figure 3-3: Illustration of the different scoping levels in this study (source: Fraunhofer ISI).

### 3.2.1. Strict product/component scope

The strict product approach is the most restrictive point of view with regard to user influence on product performance as it is based on nominal operating conditions as defined in energy-related standards. The review of existing standards in Task 1 shows that there are two families of standards for assessing the energy performance of typical lifts Both sets focus on the usage phase. The ISO 25745 family is a set of global standards concerning the energy efficiency of lifts and escalators. In addition, there is the family of national German VDI 4707 guideline documents which also deals with energy efficiency in lifts. The first VDI4707-1 was officially published a few years earlier than the corresponding ISO 25745 standards. Therefore, it has been used in some countries as a reference to analyse the energy performance of lifts prior to the release of ISO 25745. To provide a full picture, this section relates both to the ISO standards but also to the methodology of VDI.

Presenting VDI and ISO in this section does not mean that both lines of documents have the same relevance. The ISO 25745 standards clearly takes precedence over the VDI guidelines for considerations across the EU as carried out within this preparatory study. Furthermore, stakeholders have pointed out that VDI 4707-1 is to be fully harmonized with ISO 25745 in an upcoming revision.[2]

The aim of the following analysis is to point out the underlying assumptions concerning the role of the user both in the ISO and VDI documents. Due to the broad range of different lifts and utilizations, these standards require simplifications and assumptions to be made. This section focuses only on the simplifications that concern user behaviour. For general descriptions of the standards, the reader is referred to Task 1. Note that both VDI 4707-1 and ISO 25745-2 refer to the measuring procedures laid down in ISO 25745-1. These technical procedures will not be dealt with here.

To understand the impact of user behaviour on energy demand of a lift according to both standards, it is helpful to review how they calculate energy consumption. In the following text, a brief summary of the calculation procedures for determining energy demand according to VDI 4707-1 and ISO 25745-2 are given first. Thereafter, the simplifying assumptions on user behaviour are further discussed.

Note that some of the nomenclature has been modified from the standards to facilitate reading and to allow a better comparison of VDI and ISO calculation models. Note further that where necessary, some unit conversions have been added to ensure consistency of the equations.

#### 3.2.1.1. Energy demand calculation according to VDI 4707-1:2009

Generally, VDI 4707 specifies two general types of energy demand values: On the one hand annual energy demand values help to indicate how much electric energy is required to operate the lift per year. On the other hand, specific energy and power consumption values are used to compute an energy label for the lift.

In VDI 4707-1, the overall annual energy demand $\mathrm{E_{year}}$ in kWh/year is computed from a daily energy demand $\mathrm{E_{day}}$ in Wh/day multiplied by a factor $\mathrm{n}$ which accounts for the 365 days in a year. Thus:

$$\mathrm{E_{year}} = \mathrm{E_{day}} \cdot \mathrm{n} \cdot 0.001 \, \frac{\mathrm{kWh}}{\mathrm{Wh}}$$

The daily energy demand $\mathrm{E_{day}}$ consists of the daily energy demand in standby mode $\mathrm{E_{standby}}$ in Wh/day and the daily demand for travelling $\mathrm{E_{travel}}$, also in Wh/day:

[2] More specifically it has been pointed out that VDI 4707-1 is expected to be transformed into an application guideline for calculations according to ISO 25745. The publication of the draft for this revision is expected soonest by the end of 2018.

$$E_{day} = E_{standby} + E_{travel}$$

Daily standby $E_{standby}$ is determined by measuring the average standby power $P_{standby}$ in W multiplied by the daily standby within the period $t_{standby}$ expressed in h/day:

$$E_{standby} = P_{standby} \cdot t_{standby}$$

The daily standby is computed based on the 24 h/day minus the travelling time $t_{travel}$ in h/day:

$$t_{standby} = 24\,\frac{h}{day} - t_{travel}$$

The daily energy demand $E_{travel}$ is computed from the specific travel demand $E_{travel,spec}$ in mWh/(kg·m) multiplied by the daily travel distance $s_{travel}$ in m/day and the nominal load $m_{load}$ of the lift in kg:

$$E_{travel} = E_{travel,spec} \cdot s_{travel} \cdot m_{load}$$

The daily travel distance $s_{travel}$ is based on the nominal travelling speed of the lift $v_{travel}$ in m/s and the daily duration of use $t_{travel}$ in hours/day.

$$s_{travel} = v_{travel} \cdot t_{travel} \cdot 3600\frac{s}{h}$$

The specific travel demand $E_{travel,spec}$ is derived from the measured energy demand for an average reference trip $E_{cycle}$ in Wh divided by twice the lifting height $s_{lifting}$ in m, i.e. the travelled distance during one cycle, and the nominal load $m_{load}$.

$$E_{travel,spec} = 0.5 \cdot \frac{E_{cycle}}{m_{load} \cdot s_{lifting}} \cdot 1000\,\frac{mWh}{Wh}$$

The previous equation assumes that the energy consumption for the reference trip is measured for a car loaded with a predefined load spectrum. As a simplification for certain types of lifts, it is possible to measure the car empty and then scale the energy demand using a dimensionless adjustment factor $k$ as follows:

$$E_{travel,spec} = 0.5 \cdot k \cdot \frac{E_{cycle}}{m_{load} \cdot s_{lifting}} \cdot 1000\,\frac{mWh}{Wh}$$

For the sake of completeness, the calculation of the specific energy demand required for determining the energy label is briefly described. Based on the previously mentioned variables, the specific travel demand $E_{travel,spec}$ and the standby power $P_{standby}$ are merged into an overall specific energy demand value $E_{spec}$ in mWh/(kg·m):

$$E_{spec} = E_{travel,spec} + \frac{P_{standby}}{v_{travel} \cdot m_{load}} \cdot \frac{t_{standby}}{t_{travel}} \cdot \frac{1000\,\frac{mW}{W}}{3600\,\frac{s}{h}}$$

For determining the labelling value, this result is compared to maximum admissible values which depend on lift usage (i.e. $t_{standby}$ and $t_{travel}$) and maximum load (i.e. $m_{load}$).

An overview of the calculation scheme for the overall annual energy demand is given in Figure 3-4. All eight input variables necessary to perform the calculation are highlighted in blue.

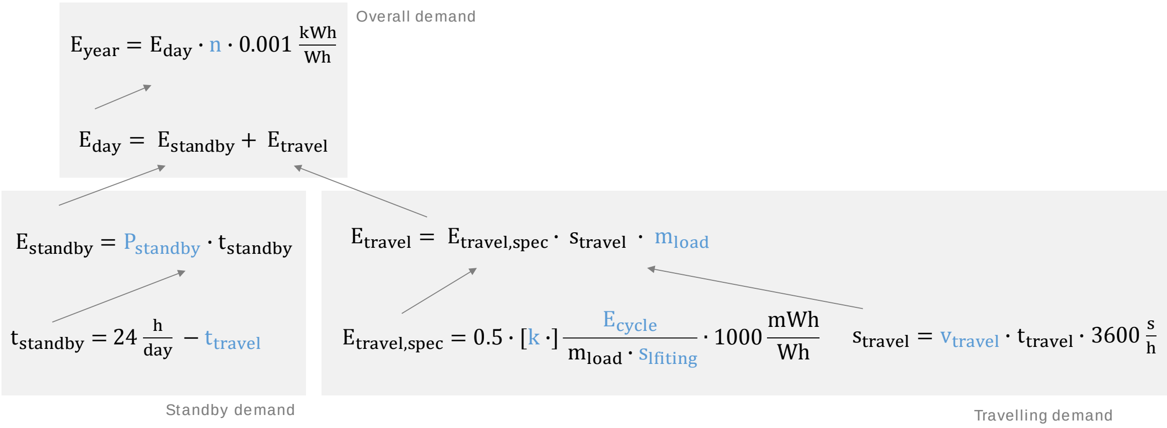



Figure 3-4: Overview of the calculation scheme for annual energy demand based on VDI 4707-1:2009 with input variables marked in blue (factor k in square brackets depends on configuration)

### 3.2.1.2. Energy demand calculation according to ISO 25745-2:2012

In terms of how to determine energy demand, ISO 25745 and VDI 4707 are similar. Yet ISO 25745-2 offers a more sophisticated calculation model for energy demand as will be outlined in the following discussion. Like in the previous subsection, some of the nomenclature has been modified to facilitate reading.

According to ISO 25745, the overall annual energy demand $E_{year}$is expressed in Wh/year and is computed from the daily energy demand $E_{day}$ expressed in Wh/day multiplied by the number of operating days $n$ per year. Thus:

$$E_{year} = E_{day} \cdot n$$

The daily energy demand $E_{day}$ is again split into the daily energy demand in standby mode $E_{standby}$ in Wh/day and the daily demand for travelling $E_{travel}$ in Wh/day:

$$E_{day} = E_{standby} + E_{travel}$$

The standby demand $E_{standby}$ is derived from standby readings in different modes of operation. More specifically, three standby values are distinguished: The standby power in idle mode $P_{<5min}$ in W covers the 5 minute period after the last movement, the 5 minute standby $P_{5-30min}$ in W covers the standby between 5 and 30 minutes after the last movement and the 30 minute standby power $P_{>30min}$ in W covers the period thereafter. Each of the phases is weighted by a typical share $r_{<5min}$, $r_{5-30min}$ and $r_{>30min}$ in percent. This weighted value is multiplied by the standby duration $t_{standby}$ in h/day:

$$E_{standby} = t_{standby} \cdot (P_{<5min} \cdot r_{<5min} + P_{5-30min} \cdot r_{5-30min} + P_{>30min} \cdot r_{>30min})$$

The standby time $t_{standby}$ in h/day is the time with the car stopped while the doors are opened and users enter or leave the car or while the doors are closed and the lift is in one of the non-running modes. It is usually equal to 24 h/day minus the travelling time $t_{travel}$ in h/day:

$$t_{standby} = 24\,\frac{h}{day} - t_{travel}$$

The overall travelling time $t_{travel}$ depends on the average travel time per trip $t_{trip}$ in s and the number of trips $n_{trip}$ per day.

$$t_{travel} = n_{trip} \cdot t_{trip} \cdot \frac{1}{3600}\frac{h}{s}$$

The variable $t_{trip}$ is based on the sum of the following variables: The time for the door movements including keeping the doors open $t_{door}$ in s, the average travel distance per trip $s_{trip}$ in m divided by the nominal speed of the lift $v_{travel}$ in m/s, the nominal speed divided by the nominal acceleration $a_{nominal}$ in m/s² and the nominal acceleration divided by the average jerk $j_{travel}$ in m/s³:

$$t_{trip} = t_{door} + \frac{s_{trip}}{v_{travel}} + \frac{v_{travel}}{a_{travel}} + \frac{a_{travel}}{j_{travel}}$$

The average travel distance per trip $s_{trip}$ is derived from the lifting height $s_{lifting}$ in m multiplied by an average adjustment factor $i$ as a percentage:

$$s_{trip} = i \cdot s_{lifting}$$

With regard to travelling consumption, the daily energy demand $E_{travel}$ is computed from the dimensionless load factor $k$, the number of trips $n_{trip}$ per day and the energy demand for an average cycle $E_{cycle}$ in Wh:

$$E_{travel} = 0.5 \cdot E_{cycle} \cdot k \cdot n_{trip}$$

The average energy demand per cycle $E_{cycle}$ is twice the specific average consumption $E_{travel,spec}$ in Wh/m multiplied by the average trip distance $s_{trip}$ plus the energy demand for each start and stop $E_{start-stop}$ in Wh:

$$E_{cycle} = 2 \cdot s_{trip} \cdot E_{travel,\,spec} + 2 \cdot E_{start-stop}$$

The specific average travel consumption $E_{travel,spec}$ is computed as an average from the specific energy demand of a reference cycle minus the energy demand of a short cycle. For the calculation, the energy consumption for a reference cycle $E_{run}$ in Wh according to ISO 25745-1 is diminished by the consumption for a short cycle $E_{short}$ in Wh and divided by the travel distance of the car during the reference cycle $s_{lifting}$ in m, i.e. the lifting height, minus the travel distance in the short cycle $s_{short}$ in m:

$$E_{travel,spec} = 0.5 \cdot \left(\frac{E_{run} - E_{short}}{s_{lifting} - s_{short}}\right)$$

This means that the specific energy consumption per meter is an average value for steady-state operation where the standing, start and stop parts of the reference cycle are eliminated from the specific consumption by subtracting the demand for a short cycle, this means only the steady-state running consumption is used here. Note the difference with the consumption value in VDI 4707, which is specific per weight and also includes other parts of the cycle next to steady state operation as part of the running consumption, i.e. acceleration/deceleration, door movements and loading/unloading).

The average energy consumption for each start and stop $E_{start-stop}$ is based on the energy demand for the reference cycle $E_{run}$, the average travel consumption $E_{travel,spec}$ and the lifting height $s_{lifting}$ of the car during the reference cycle:

$$E_{start-stop} = 0.5 \cdot (E_{run} - 2 \cdot E_{travel,spec} \cdot s_{lifting})$$

This means that the consumption for the constant movement is removed from the cycle consumption, thus leaving the acceleration and deceleration parts as well as the door movements in the overall energy demand value for start and stop.

The load factor $k$ for determining the travel demand is a function of the average load $l$ expressed as a percentage of nominal load as well as a type-specific dimensionless adjustment factor $k^*$ that depends on the balancing load:

$k = 1 - l \cdot k^*$ (traction lifts)
$k = 1 + l \cdot k^*$ (hydraulic lifts)

The energy label is then attributed based on the daily energy consumption. This is based on a comparison with maximum admissible energy values per class which depend on the nominal load $m_{load}$ , the number of trips $n_{trip}$, the average travel distance $s_{trip}$ and the time in standby $t_{standby}$.

An overview of the calculation scheme for the overall annual energy demand for ISO 25745-2 is given in Figure 3-9 with the input variables highlighted in blue. The ISO calculation model requires 18 distinct input variables and thus more than twice as many as VDI 4707-1 with its simplified calculation scheme.

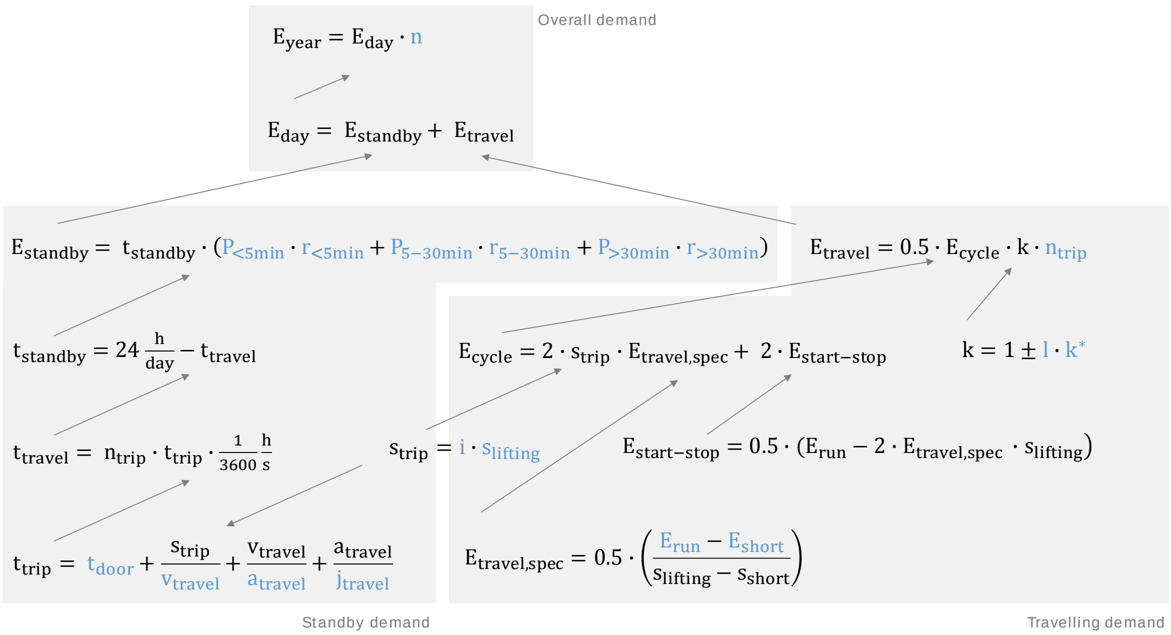



Figure 3-5: Overview of the calculation scheme for annual energy demand based on ISO 25745-2:2012 with input variables marked in blue.

An overview of all input variables used in ISO 25745-2 and VDI 4707-1 is given in Table 3-1. Note that not all variables match exactly but they have been denoted with similar letters to underline the similarities of the approaches.

Table 3-1: Overview of variables used in ISO 25745 and VDI 4707. Note that the delineation of variables may vary between the standards.

| **Variable** | **Description** | **ISO 25745** | **VDI 4707** |
|---|---|---|---|
| $E_{year}$ | Overall annual energy demand | Wh/year | kWh/year |
| $E_{day}$ | Daily energy demand | Wh/day | Wh/day |
| $E_{travel}$ | Daily travelling demand | Wh/day | Wh/day |
| $E_{standby}$ | Daily standby demand | Wh/day | Wh/day |
| $E_{cycle}$ | Energy demand for a cycle[1)] | Wh | Wh |
| $E_{run}$ | Running demand for reference cycle | Wh | - |
| $E_{short}$ | Energy demand for a short cycle | Wh | - |
| $E_{travel,spec}$ | Specific travel demand[2)] | Wh/m | mWh/(kg·m) |
| $E_{start-stop}$ | Energy demand for each start and stop | Wh | - |
| $E_{spec}$ | Specific energy demand for VDI label | - | mWh/(kg·m) |
| $n$ | Number of operating days per year[3)] | day/year | day/year |
| $n_{trip}$ | Number of trips per day | 1/day | - |
| $t_{standby}$ | Daily standby time | h/day | h/day |
| $t_{travel}$ | Daily travel time | h/day | h/day |
| $t_{trip}$ | Average travel time per trip | s | - |
| $t_{door}$ | Time for the door movements | s | - |
| $P_{standby}$ | Standby power | - | W |
| $P_{<5min}$ | Standby up to 5 minutes after stopping | W | - |
| $P_{5-30min}$ | Standby 5 to 30 minutes after stopping | W | - |
| $P_{>30min}$ | Standby 30 minutes after stopping | W | - |
| $r_{<5min}$ | Standby share up to 5 minutes | % | - |
| $r_{5-30min}$ | Standby share 5 to 30 minutes | % | - |
| $r_{>30min}$ | Standby share after 30 minutes | % | - |
| $s_{travel}$ | Daily travel distance | - | m/day |
| $s_{lifting}$ | Lifting height | m | m |
| $s_{trip}$ | Average travel distance per trip | m | - |
| $s_{short}$ | Short cycle travelling distance | m | - |
| $m_{load}$ | Nominal load of the lift | - | kg |
| $v_{travel}$ | Nominal speed | m/s | m/s |
| $a_{travel}$ | Average acceleration | $m/s^2$ | - |
| $j_{travel}$ | Average jerk | $m/s^3$ | - |
| $i$ | Adjustment factor for average trip distance | [1=100%] | - |
| $k$ | Adjustment factor for empty car measurement[4)] | [1=100%] | [1=100%] |
| $k^*$ | Type-specific constant for different load situations | const | - |
| $l$ | Average load as share of nominal load | [1=100%] | - |

1) Note that in VDI 4707-1, the cycle is measured for the full length of the shaft while in ISO 25745-2, the cycle is an averaged value.
2) Note that the specific travel demand in VDI 4707-1 is given as specific consumption per kg and m and also contains variable travelling shares whereas ISO 25745-2 gives a consumption value per m and only for steady-state travelling.
3) Note that VDI 4707-1 defines a default of 365 operating days whereas ISO 25745-2 suggests to use the number of operating days.
4) Note that the adjustment factors are defined differently in the standards and that the application domain varies too.

#### 3.2.1.3. Review of the input variables in the strict product definition case

In the following discussion, the highlighted input variables according to the standard are discussed to clarify how they are treated in the models. Due to the general similarities in VDI 4707-1 and ISO 25745-2, the input variables for both standards will be discussed together.

#### 3.2.1.4. Usage categories

Usage categories are not explicitly used as input variables in the previous calculation models for annual energy demand. Yet they are fundamental as they define typical values for several of the key parameters determining the overall energy calculation. Usage categories define several classes of lifts based amongst other factors on building characteristics, intensity and frequency of use or number of trips as well as typical running and standby times for the categories concerned.

The usage categories defined in VDI 4707-1 are shown in Table 3-2. Here, different types of buildings are defined with a rough description of their typical setting, e.g. small residential buildings as well as large and high office buildings. The bold variables are directly used as input variables in the calculation model while others mainly serve as orientation for the selection of the appropriate categories. In case of energy demand calculations specified according to the VDI standard, these categories determine the travel time $t_{travel}$.

The usage categories for ISO 25745-2 are given in Table 3-3. Similar to the VDI standard, different building categories and their typical usage intensities are described here. Variables directly depending on these usage categories are the number of trips per day $n_{trip}$ and the number of operating days $n$ per year marked in bold, while the others may be considered as mainly serving for the selection of the appropriate usage categories.

Table 3-2: Usage categories according to VDI 4707-1.

| Usage category | **Usage intensity / frequency** | Average travel time in hours per day[1)] | **Average standby time in hours per day** | **Typical types of buildings and use** |
|---|---|---|---|---|
| 1 | very low<br>very seldom | **0.2**<br>(≤0,3) | 23.8 | • residential building with up to 6 dwellings<br>• small office or administrative building with few operation |
| 2 | low<br>seldom | **0.5**<br>(>0,3–1) | 23.5 | • residential building with up to 20 dwellings<br>• small office or administrative building with 2 to 5 floors<br>• small hotels<br>• goods lift with few operation |
| 3 | medium<br>occasionally | **1.5**<br>(>1–2) | 22.5 | • residential building with up to 50 dwellings<br>• small office or administrative building with up to 10 floors<br>• medium-sized hotels<br>• goods lift with medium operation |
| 4 | high<br>frequently | **3**<br>(>2–4.5) | 21 | • residential building with more than 50 dwellings<br>• tall office or administrative building with more than 10 floors<br>• large hotel<br>• small to medium-sized hospitals<br>• goods lift in production process with a single shift |
| 5 | very high<br>very frequently | **6**<br>(>4.5) | 18 | • office or administrative building over 100 m in height<br>• large hospital<br>• goods lift in production process with several shifts |

1) Can be determined from the average number of trips and the average trip duration

Table 3-3: Usage categories according to informative Annex A – Table A.1 in ISO 25745-2.

| **Usage category** | **Usage intensity / frequency** | **Number of trips per day** (Typical range) | **Typical rated speed** [m/s] | **Typical buildings and usage (operating days per year)** |
|---|---|---|---|---|
| 1 | Very low | **50**<br>(≤75) | 0.63 | • residential buildings up to 6 dwellings (**360**)<br>• residential care home (**360**)<br>• small office or administrative building with few operations (**260**)<br>• Suburban railway stations (**360**) |
| 2 | Low | **125**<br>(75 - <200) | 1.00 | • residential buildings up to 20 dwellings (**360**)<br>• small office or administrative building with 2 to 5 floors (**260**)<br>• small hotels (**360**)<br>• office car parks (**360**)<br>• general car parks (**360**)<br>• main line railway stations (**360**)<br>• library (**312**)<br>• entertainment centers (**360**)<br>• stadia (**intermittent**) |
| 3 | Medium | **300**<br>(200 - <500) | 1.60 | • residential buildings with up to 50 dwellings (**360**)<br>• medium-sized office or administrative building with up to 10 floors (**260**)<br>• medium-sized hotel (**360**)<br>• airports (**360**)<br>• university (**260**)<br>• small hospital (**360**)<br>• shopping center (**360**) |
| 4 | High | **750**<br>(500 - <100) | 2.50 | • residential buildings with more than 50 dwellings (**360**)<br>• large office or administrative building with more than 10 floors (**260**)<br>• large hotel (**360**) |
| 5 | Very high | **1500**<br>(1000 - <2000) | 5.00 | • very large office or administrative building over 100 m height (**260**) |
| 6 | Extremely high | **2500**<br>(>2000) | 5.00 | • very large office or administrative building over 100 m height (**260**) |

### 3.2.1.5. Number of operating days per year

In VDI 4707-1 the number of operating days per year $n$ is assumed to have a value of 365 days. In ISO 25745-2 there is a possibility to adjust the number of operating days according to the actual usage of the lift. If, for example, the lift is not operated on the weekend or during holidays, the number of days can be reduced. The standard offers a range of default values in its informative Annex A (Table 3-3). The suggested operating days vary from 260 to 360 days per year. For very large office buildings, for example, the typical default usage is given at 260 operating days per year while for residential buildings up to 6 dwellings, a value of 360 days is provided.

### 3.2.1.6. Number of trips

The number of trips per day is only used in ISO 25745-2. There, the number of trips per day serve to compute the average travel time. VDI 4707-1 follows a different approach and directly uses the daily travel time as an input variable. Therefore, the number of trips is only defined in ISO 25745-2. As previously mentioned, default values are provided in the informative Annex A (Table 3-3).

### 3.2.1.7. Travel and standby time

With regard to travel and standby times, both ISO and VDI sum up both travel and standby times to a default value of 24 hours per day. ISO 25745-2 allows for this overall running time to be adjusted for real conditions in case the lift is completely shut-off during some parts of the day. As the travel time is computed from technical parameters in ISO 25745-2, this corresponds to a reduction of standby time.

In VDI 4707, the average standby and travel times are directly specified as a function of the usage categories shown in Table 3-2.

### 3.2.1.8. Reference and short cycle consumption

The reference cycle is a full-round trip of the lift system that is used both in VDI 4707-1 and ISO 25745-2. During the reference trip, an empty car starts at the lowest stop, moves to the highest stop and then moves back to the lowest floor and also carries out two complete door cycles. An illustration of the individual elements of the cycle along with the power demand in case of a traction lift is shown in Figure 3-6. Note that the consumption is higher when travelling downwards as the heavier counterweight "pulls" the empty car upwards.

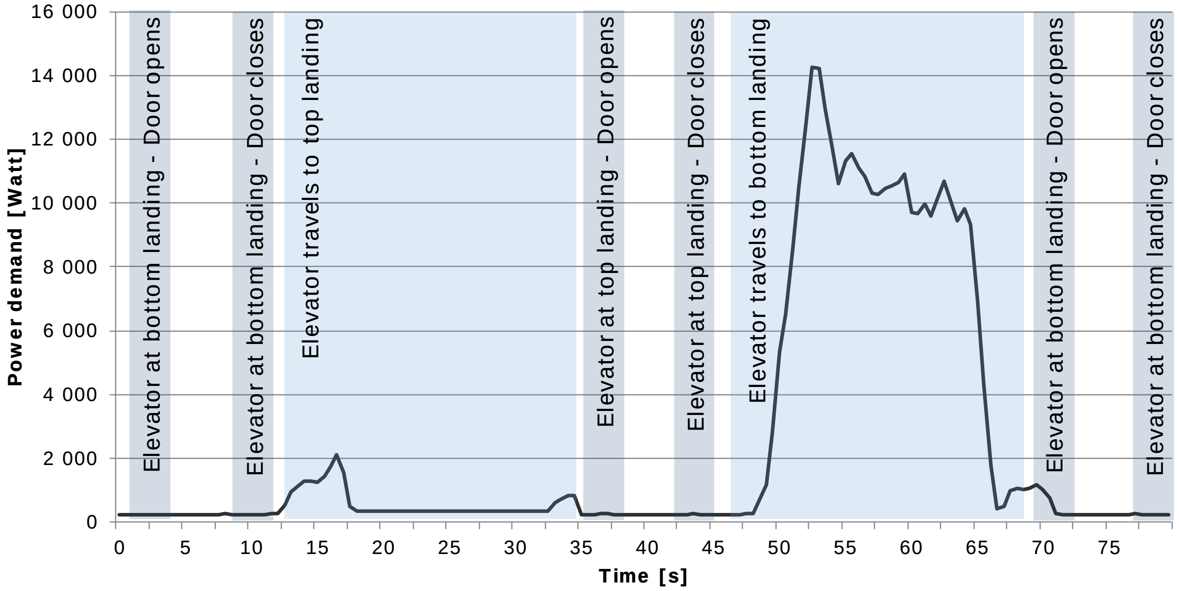



Figure 3-6: Sample diagram for the power drawn for the example of an (empty) traction lift (source: Hirzel/Dütschke 2010)

For the calculation of the specific energy demand per meter as per ISO 25745-1, a short cycle is used in addition to the (full) reference cycle. The short cycle is to cover at least a quarter of the full travel height while the lift shall reach the rated speed during this cycle. The short cycle is then used to compute travel consumption in the ISO standard as it is subtracted from the regular cycle, thus only leaving the steady state energy demand. An illustrative example of a short cycle is given in Figure 3-7.

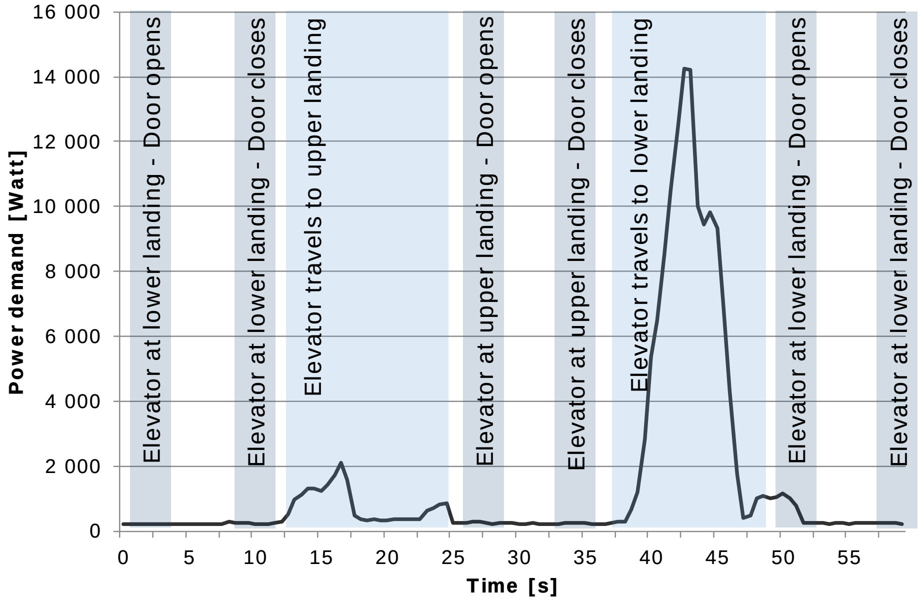



Figure 3-7: Sample illustration of a short cycle based on the previous diagram for the power drawn for the empty traction lift.

### 3.2.1.9. Load factors

The energy demand for travelling with a lift depends on the load to move the car and the load in the car. VDI 4707-1 characterises the car loads using the loads given in Table 3-4 and then weights the measurements with the different loads as a function of their share in the overall number of trips. As can be derived from the values, the majority of trips are expected to be carried out with relatively light loads. On average, the load spectrum implies an average of 12.5% of the nominal load. For special lift usages, a different load spectrum than given in the table can be used if this is also documented and justified.

Table 3-4: Load spectrum given in VDI 4707-1 (source: VDI 4707-1; last column own addition)

| Load in % of the nominal load | Trip ratio in % | Average load in % of nominal load |
|---|---|---|
| 0 | 50 | 0,0 % |
| 25 | 30 | 7,5 % |
| 50 | 10 | 5,0 % |
| 75 | 0 | 0,0 % |
| 100 | 0 | 0,0% |

For practical reasons, the use of a load spectrum as given in Table 3-4 is not required for certain types of lifts. In this case, the consumption for the empty reference cycle is adjusted by the factor k. This simplified method can be applied for lifts with a counter-weight equal to the weight of their cars plus 40 to 50% of the nominal load and for lifts without a counterweight or a counterweight of up to 30% of the car weight. In the former case, k is 0.7 and in the latter case it is 1.2. Though not detailed in the standard, these values can be derived from the previous Table 3-4 with few additional assumptions as illustrated in the information box below.

**Information box: Load factors in VDI 4707-1**

The load factor $k$ is used to scale the energy demand measures for a reference cycle with an empty car to actual load conditions. Typical traction lifts have a counterweight that balances the weight of the car plus approximately 50% of the nominal load. The counterweight reduces the amount of energy required for moving the car because only part of its mass respective to the load in the car has to be lifted.

If the car is loaded with 50% of the nominal load (“50% situation”), drive power will only be needed to accelerate/decelerate under ideal conditions, i.e. to overcome inertia. If the car is empty when it travels the cycle (“0% situation”), the energy consumption will be highest as the motor will have to lift the full weight of the counterweight, i.e. 50% of the nominal load, during the downward movement. If the car is travelling fully loaded (“100% situation”), the maximum load is also required for 50% of the nominal load as half of the car is balanced. This power will just be required when travelling upwards instead of downwards. Further assuming a linear scaling of motor power with the load means that in case of a 25% or a 75% load situation, the power required is half of the maximum power.

The following table shows this relative load compared to the empty car measurement which corresponds to 100% of energy demand. Multiplying the relative load with the trip ratio and adding up the individual components yields the value of 0.7.

| Load in % | Relative load in % compared to empty | Trip ratio in % | Load factor (Relative load * Trip ratio) |
|---|---|---|---|
| 0% | 100% | 50% | 0,50 |
| 25% | 50% | 30% | 0,15 |
| 50% | 0% | 10% | 0,00 |
| 75% | 50% | 10% | 0,05 |
| 100% | 100% | 0% | 0,00 |
| | | **Load factor** | **0,70** |
| | | Counterweight of nominal load: | 50% |
| | | Counterweight of car load: | 100% |

The same reasoning can be used for analysing a situation where the counterweight is equal to 40% of the load. In this case, the minimum power will be required to move a car that has a load of 40% of its nominal load. In case the car is fully loaded, 60% of the nominal load has to be lifted. Using the same trip ratios as for the previous calculation shows that the load factor has only slightly increased to 0.73, or rounded 0.7. If the weight of the counterweight is further decreased, the load factor will increase accordingly.

| Load in % | Relative load in % compared to empty | Trip ratio in % | Load factor (Relative load * Trip ratio) |
|---|---|---|---|
| 0% | 100% | 50% | 0,50 |
| 25% | 38% | 30% | 0,11 |
| 50% | 25% | 10% | 0,03 |
| 75% | 88% | 10% | 0,09 |
| 100% | 150% | 0% | 0,00 |
| | | **Load factor** | **0,73** |
| | | Counterweight of nominal load: | 40% |
| | | Counterweight of car load: | 100% |

Basically, the same reasoning can be applied if there is no counterweight or if only little of the actual weight of the car is balanced. Again, the energy demand for the empty car can be defined as 100%. If additional load is added to the car, the drive system will have to move both the weight of the car as well as the additional load. Consequently, more energy will be needed to move the car and its load upwards. The increase in energy demand depends on the ratio of the car weight to the additional load. Assuming that the weight of the car and the additional load are equal, this yields the results shown in the following table and a load factor of 1.2.

| Load in % | Relative load in % compared to empty | Trip ratio in % | Load factor (Relative load * Trip ratio) |
|---|---|---|---|
| 0% | 100% | 50% | 0,50 |
| 25% | 125% | 30% | 0,38 |
| 50% | 150% | 10% | 0,15 |
| 75% | 175% | 10% | 0,18 |
| 100% | 200% | 0% | 0,00 |
| | | **Load factor** | **1,20** |
| | | Counterweight of nominal load: | 0% |
| | | Counterweight of car load: | 0% |
| | | Weight ratio: Car/Nominal load | 1:1 |

ISO 25745-2 uses a similar yet more detailed calculation principle for determining the load factor. Here the typical load factor is a function of technological properties (Table 3-5) as well as the average load in the car (Figure 3-8). Note that due to the different calculation principles, the values cannot be compared directly.

Table 3-5: Technology dependent parameter for calculating the load factor in ISO 25745-2

| **Elevator type** | **Balance in % of weight of car** | **Balance in % of nominal load** | **Adjustment factor** |
|---|---|---|---|
| Traction | 100 % | 50 % | 0.0164 |
| | 100 % | 40 % | 0.0192 |
| | 100 % | 30 % | 0.0197 |
| Hydraulic | 0% | 0 % | 0.0071 |
| | 35% | 0 % | 0.0010 |
| | 70% | 0 % | 0.0187 |

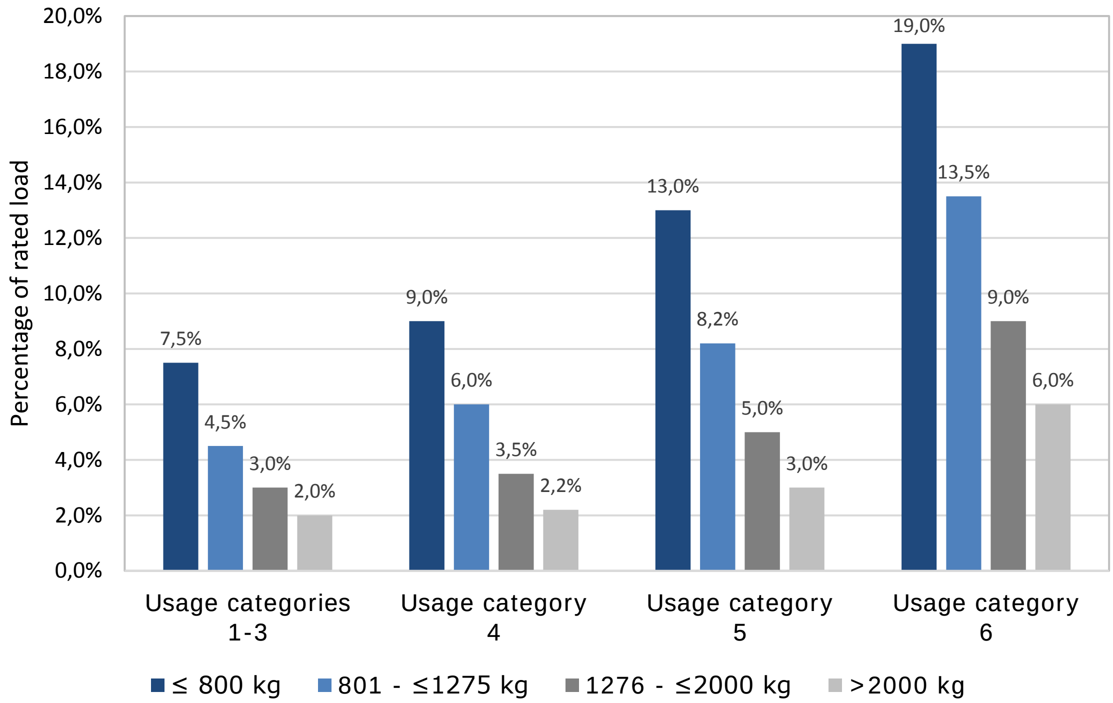



Figure 3-8: Average load by usage category and nominal load (source: based on ISO 25745-2)

#### 3.2.1.10. Standby power and standby power mix

Standby power in VDI 4707-1 is defined as the consumption of the lift in standby mode and it is to be determined five minutes after the last trip has ended. Only the electrical equipment is taken into consideration that is required for the operation of the lift or needed for keeping it in standby. Shaft and machine room lighting are for example excluded when determining standby power. The determination is to be carried out under actual operating conditions, i.e. all components that are switched on during real operation must be in on mode for the determination, as well.

The determination can take place either by adding up power demand values of individual lift components if they are “sufficiently known” or it can be derived from measurements. In the case where measurements are used, they shall be taken after the main switches for the power circuit and the lighting circuits, as illustrated in (Figure 3-9). For other related sources of energy consumption required to operate the lift (the examples given are for heating and cooling), the energy consumption values also have to be determined, as well, and shall be documented separately. In case of lift groups, standby has to be added proportionally to the standby consumption of the individual lifts.

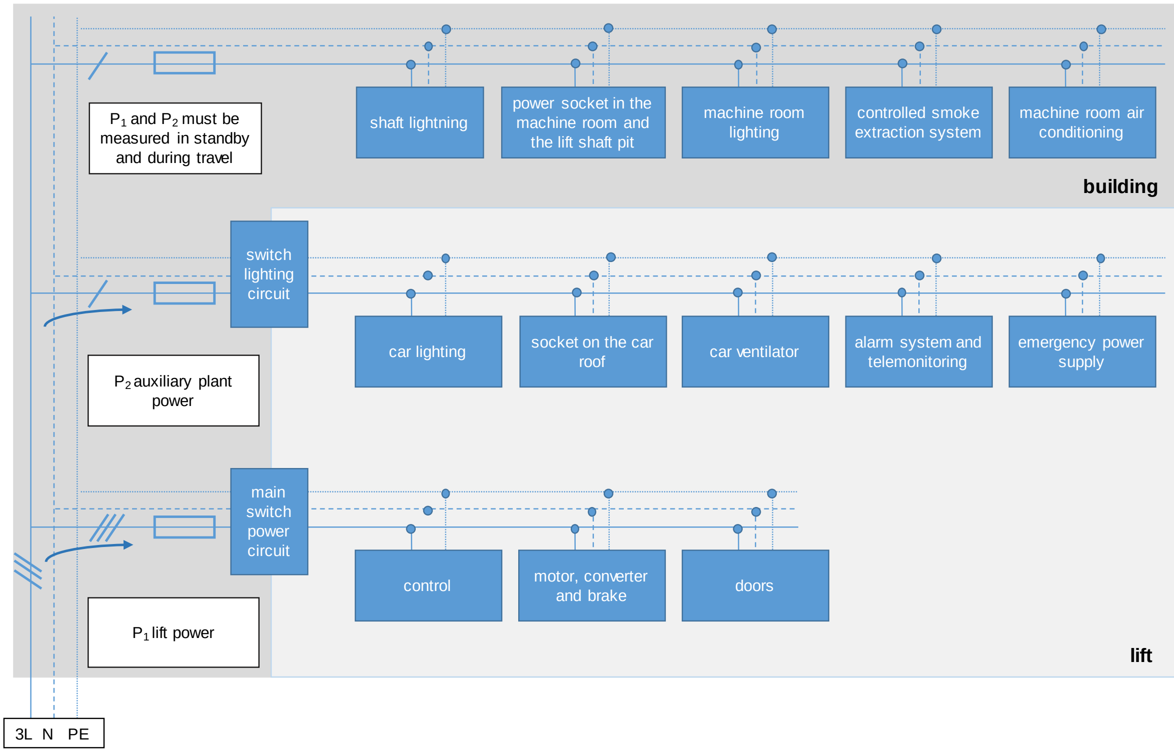



Figure 3-9: Schematic diagram for determining the energy demand of lifts according to VDI 4707 (source: own illustration based on VDI 4707-1).

Standby power in ISO 25745-2 requires the consideration of shutdown sequences of equipment. As shown in the previous review of the calculation model, ISO 25745-2 differentiates three of these non-running modes. Idle mode is the time until 5 minutes after the last movement, then there is a 5 to 30 minutes standby mode and another standby mode beyond 30 minutes. The consideration of the 30 minutes standby is only necessary if there are components that switch to a lower consumption mode after a time exceeding 5 minutes since the last movement. As in VDI 4707, the determination of annual energy demand can be based on measurements or it can be derived from calculations or simulations.

Compared to VDI 4701-1, ISO 25745-2 provides a more exhaustive list of items which are not be covered in energy demand considerations. These items are:

- Lifts including express zones
- Effect of lift group dispatch systems
- Heating and cooling equipment in the car
- Consumption through power sockets
- Components which are not part of the lift (e.g. non-lift display screen, surveillance cameras)
- Monitoring systems which are not part of the lift (e.g. building management)
- Hoistway lighting
- Machine room lighting, heating, ventilation, and air conditioning

Additionally, environmental conditions are not to be considered.

In addition, the ISO standard also specifies special conditions for lifts that draw energy from energy storage systems (excluding counterweights as energy storages). The basic principle for assessing energy demand for these lifts is to analyse energy demand for a

24 hour operation ensuring that the energy storage level is identical at the beginning and at the end of the analysis.

ISO 25745 defines a set of default shares for the three non-running modes which depend on the usage categories. The shares are shown in Figure 3-10.A general declining trend of standby between 5 and 30 minutes with higher usage can be observed. According to the introductory part of the standard, these values (and those in Figure 3-11) have been derived from “extensive research, which included the simulation of over 4 500 typical lift installations”. An average standby power is calculated based on this mix of shares.

Figure 3-10: Shares in the different operation modes by usage category (based on ISO 25745-2 with adaptations).

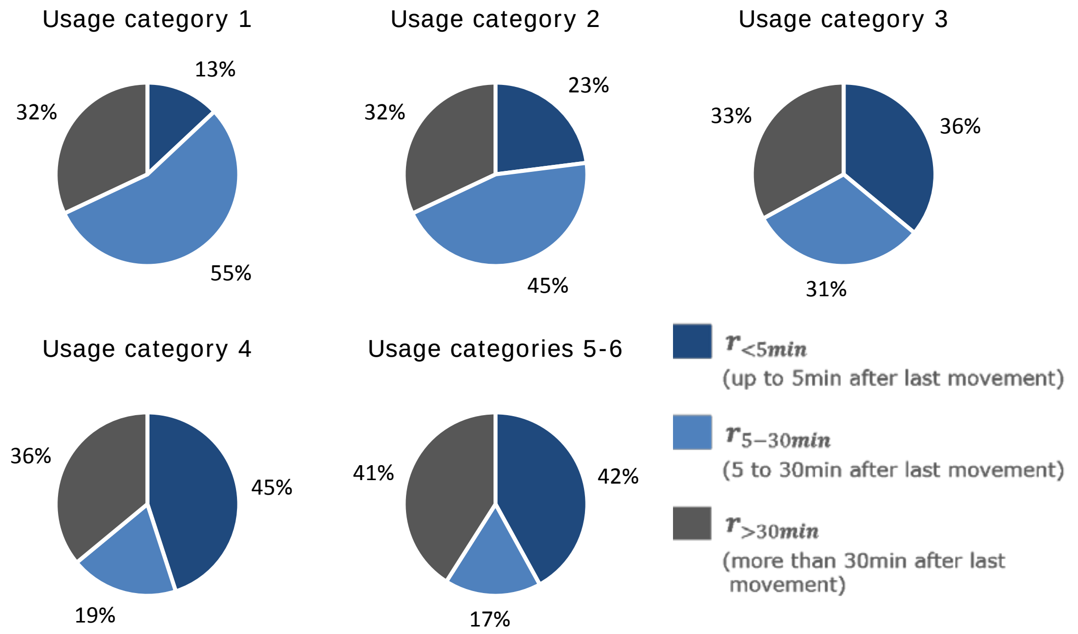
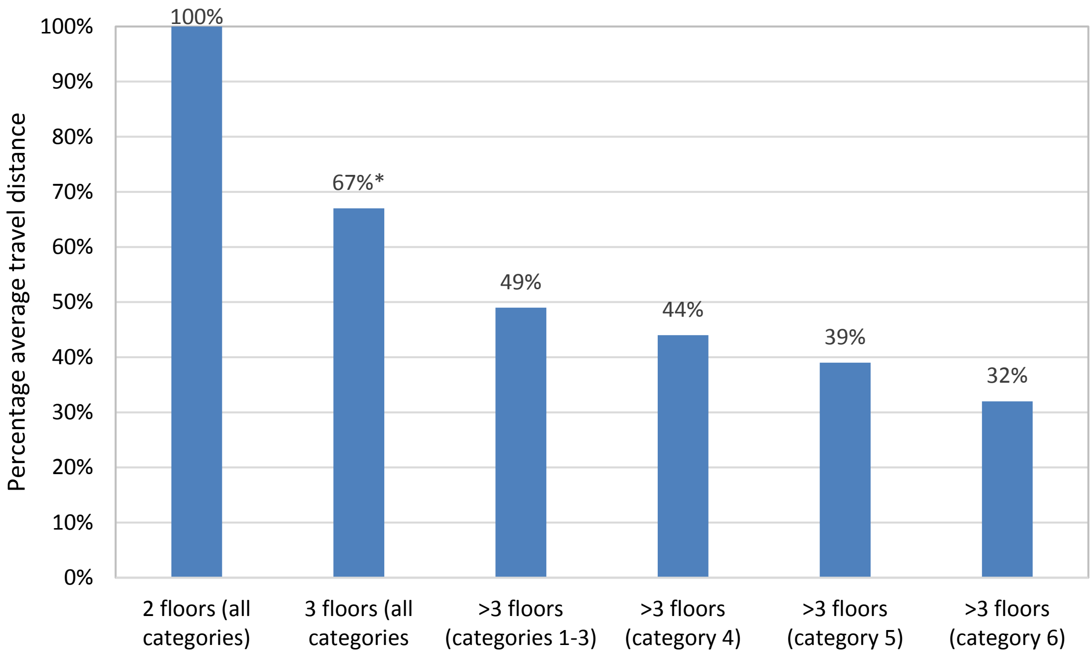


Figure 3-11: Percentage of average travel distance as a function of the number of stopping floors and the usage category (based on ISO 25745-2)




*For lift applications in which the traffic patterns are well known, a specific percentage of the average travel distance can be agreed between the involved parties for the assessment of the annual energy consumption. In this case, the selected percentage should be documented in Annex B.

### 3.2.2. Extended product approach

In the previous section a detailed review of the model for determining annual energy demand of lifts expressed in the form of the two main standards for estimating energy demand has been given. Both standards (necessarily) make simplifications of real-life lift usage through their scope, input variables and by how the variables are linked.

The aim of the extended product approach discussed in this section is to point out where real-life may deviate from the "ideal" conditions as given in the default calculation methods.

#### 3.2.2.1. Usage categories

Usage categories are proxies to help determine the energy demand where no current information or future predictions on lift usage are available. Especially for a newly installed lift, estimating its future usage is claimed to be challenging as many factors affect the actual usage. As shown previously, usage categories are, amongst other factors, based on the properties of the buildings. Specific factors related to the users are not explicitly considered in the categories. These include among others:

- the social structure of the inhabitants (e.g. families, elderly people, handicapped people, singles, young couples, etc.)
- the local culture in the building (e.g. intensive users, preferences of stairs)
- the location of the lift in the building (e.g. directly at entrance, located in a side-corridor)
- the availability of the lift (e.g. expected waiting time for lift)

- the location of the building (city centre, outskirts, country-side, socially troubled area)

Furthermore, the usage categories imply an average constant usage per day. Yet it should be noted that in practice the utilization can vary during the day, during the week, for specific types of days as well as seasonally.

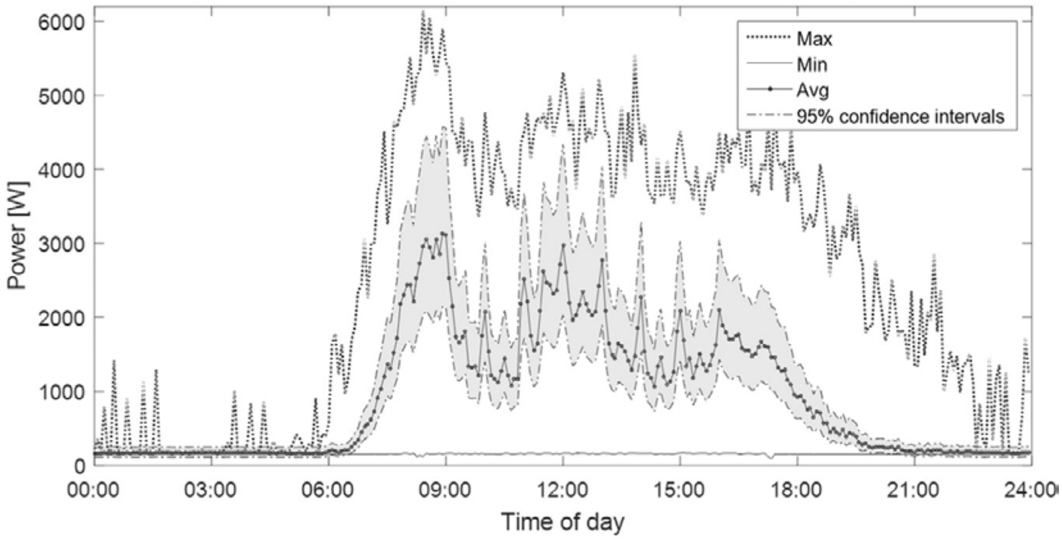



Figure 3-12: Intraday power demand by day of a lift located in a office building (source: Tukia et al. 2016).

For the purpose of illustration, Figure 3-12 shows the intraday electricity demand profile of a mid-rise office lift in Finland according to Tukia et al. (2016). It can be observed that during the early hours of the day, the average power demand is quite low while it peaks towards the beginning of office hours in the morning, peaks again around midday and finally shows some spikes later at the time the office closes.

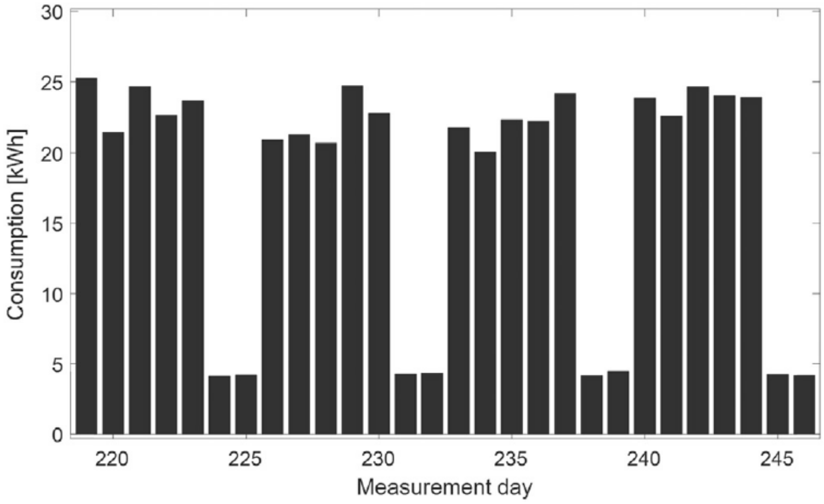



Figure 3-13: Electricity consumption by day of a lift located in a office building (source: Tukia et al. 2016).

With regard to weekly fluctuations, Figure 3-13 shows for example the energy consumption of a lift used in an office building over a period of four weeks. The low bars indicate a low usage during the week-ends while during the week-days, the overall energy consumption reaches a higher level but still shows some variation. Similar day-dependent measurement results for office buildings can for example also be found in Unholzer et al. (2015).

Further investigations by Tukia et al. 2016 illustrate the energy consumption of a lift by different types of day respectively season in the course of a year. Again, the differences between workdays and weekends can be identified. Additionally, the typology shows holidays during the week as well as the holidays in the holiday season. For both types of days, the energy consumption and thus usage tends to be considerably lower than during ordinary working days.

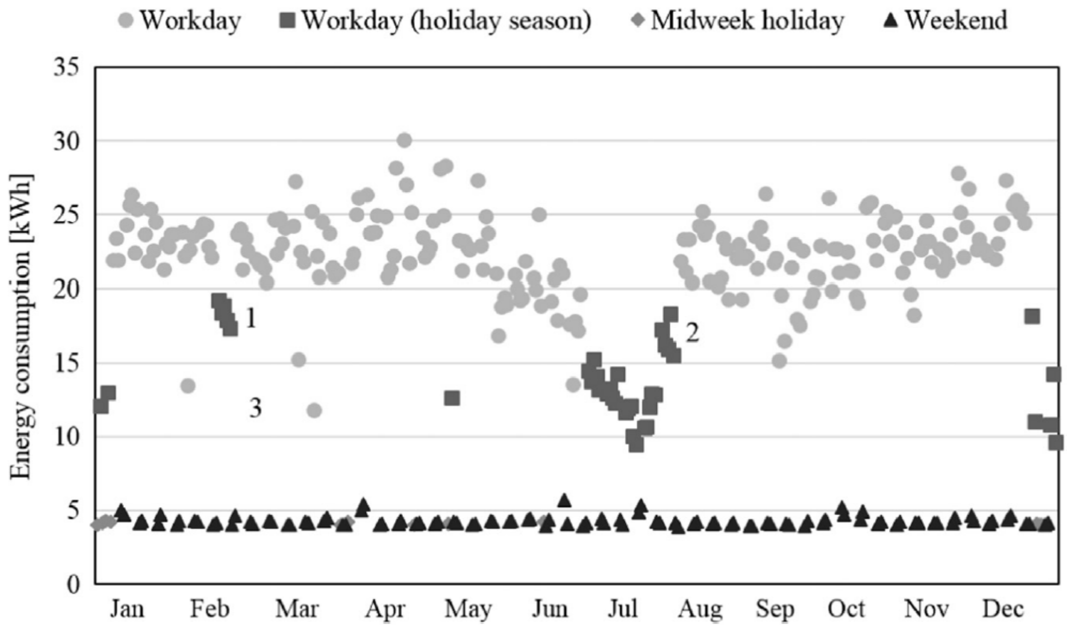



Figure 3-14: Daily energy consumption over a year by type of day (source: Tukia et al. 2016).

Though only illustrative, this underlines that the usage categories suggested in the energy demand standards are an approximation of reality. Under ideal conditions, this approximation meets well with reality or else real-life data can be used instead. For new installations, however, it is often challenging to determine the latter. Moreover, it needs to be taken into consideration that a change in building occupation (e.g. change from front-office with high number of visitors to back-office with little customer contact) may affect usage, as well.

#### 3.2.2.2. Number of operating days per year

Closely related to the usage categories is the number of assumed operating days per year. While 365 operating days can be a reasonable default value if the lift is constantly available during the year, longer maintenance or repair periods as well temporary shutdowns (e.g. during the weekend, holiday seasons) can decrease the number of operating days.

#### 3.2.2.3. Number of trips

A third factor related to actual lift usage next to the usage categories or the number of operating days are the number of trips. As pointed out in section 3.2.1.6, the number of trips is explicitly only relevant for the energy demand calculation in ISO 25745-2.

Figure 3-15 shows a comparison of the daily number of trips for the nine lifts in residential buildings as given in Annex C of VDI 4707-1 with the daily trips per category as in ISO 25745-2. For this illustration, only those lifts where chosen that operate in residential buildings and that had trip numbers. This overall annual trip number was divided by 360 days per year as per ISO 25745-2. The blue areas indicate the usage categories in the ISO standard with the default average values for each category as well as its boundary values (note that category 4 extends to 1000 trips).

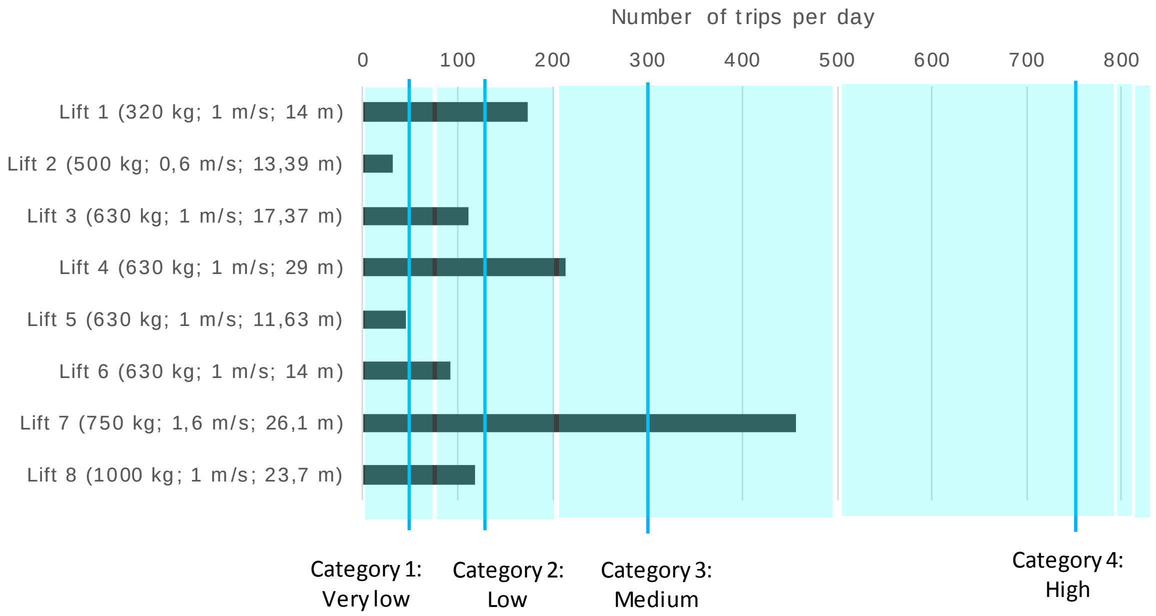



Figure 3-15: Illustration of the number of trips for nine residential lifts as compared to the usage categories according to ISO 25745-2 (source: own calculation based on data in Annex C of VDI 4707-1).

This illustration underlines again that there is a variation in the data and that the category averages can only be considered as proxies. Note further that the number of trips can also vary considerably for lift configurations that are quite similar in terms of size, speed and height (e.g. lifts 5 and 6 in Figure 3-15).

#### 3.2.2.4. Travel and standby time

With regard to travel and standby times, the default assumption for both standards is 24 operating hours per day. If lifts are not in operation the entire day, e.g. if there are several lifts in an office building and only few remain on outside regular office hours, this value could also be lower than 24 hours.

#### 3.2.2.5. Reference and short cycle consumption

Little direct impact of the user on the consumption in the reference cycle can be expected. Potential impacts might result from the operating state of additional equipment that is measured as part of the lift power demand and that can be operated from within the car (e.g. fan on the car).

The quality of maintenance can also affect the energy demand during the cycles. This includes for example the quality of lubrication. Yet the influence of the user on this is limited, unless he does not ensure proper and regular maintenance. The quality of the installation itself can also affect the energy demand (see also 3.5.3), but is also not directly affected by the user.

For the sake of completeness with regard to the consumption in the reference cycles, it should also be noted that several technical aspects affect energy consumption during the cycle. The efficiency of the drive system may vary from part-load to full-load operation. Whether the reference cycles correspond to a full-load or part-load situation depend on the actual system design. Furthermore, the lift should be measured under average temperature conditions, which do not necessarily apply regularly in all cases and can also affect the performance. In addition, the measurement equipment and power quality issues can affect the determination of energy consumption. Finally, the ability of a lift for energy recuperation can affect the energy demand in the reference cycle, as well. For these systems, ISO 25745-2 suggests a specific approach to determine the energy demand.

#### 3.2.2.6. Load factors

Where the impact of users is quite low with regard to the measurement of the empty car in the reference and short cycle, user practice may affect the actual load factors of a lift. As pointed out earlier, the load factors both used in the overall energy demand calculation in VDI and ISO are based on a set of assumption concerning actual lift load. If real-life utilization is different from these assumptions, e.g. if lifts are for example mainly only used by individuals instead of groups, this may affect the overall estimate of energy demand. Furthermore, different load conditions on the motor may affect its efficiency (e.g. Watson 2017). As with the number of trips, the actual usage is difficult to predict for new systems and thus using average values seems an appropriate way to deal with the complexity of actual systems.

#### 3.2.2.7. Standby power and standby power mix

Both ISO and VDI provide instructions on when to measure energy demand. While VDI 4707-1 requires the determination five minutes after the last trip has ended, ISO provides figures based on the usage categories.

The direct impact of the user on standby consumption is limited again. Yet he might indirectly affect the occurrence of the standby-times. As illustrated in Figure 3-12, the utilization of a lift may vary considerably during 24 hours and depends on the user. Idle periods of 5 minutes or longer will more likely happen during the night than the day. Consequently, more situations will occur in which the lift only stops briefly. During the night, substantially longer periods with no utilization can occur. Note that if components should enter a low-energy mode earlier than 5 minutes after the last stop, this might lead to an underestimation of standby demand for the overall estimation. Stakeholders pointed out that stand-by modes are implemented in modern control circuits. The actual point of time when components typically enter into a low energy-modes in practice depend on their design and the design of the system. It is expected that the durations based on ISO 25745-1 for idle and standby modes are used.

Note further that low-energy demand modes can cause delays in the availability of the lift. VDI 4707-2 defines several operating modes with different wake-up times. The shortened wake-up time for a component is referred to as mode S0 according to which the component should be operative after less than 250ms. In mode S1, this duration can take up to 3s. In the last mode S2, the wake-up can take up to 60s. If parts of the lift components are in S2 mode, it can thus take up to roughly 1 minute until a lift is operational again. Modern control systems allow for shutting down into a sleep mode sometime after the last trip. Yet evidence from practice suggests that these sleeping modes can be deactivated by request of the operator/user to avoid longer waiting times, especially during periods when the lift is not regularly used.

Based on the data of the e4 project (Almeida et al. 2010), an analysis of running and standby consumption for various lifts in Germany, Portugal, Poland and Italy was conducted. The analysis shows on the one hand that the electricity demand in the sample spans a considerable range from below 1 000 to more than 30 000 kWh/a. It further underlines that standby consumption varied from 15 to 710 Watts and that the relevance of standby consumption ranges from about 5 to 95% of overall electricity demand (Figure 3-16). It should be noted that analysis was conducted for elevators which were in actual operation in the period from 2008 to 2010. Further information on the state-of-the-art for new elevator installations as of the time of preparing this study is provided in later tasks.

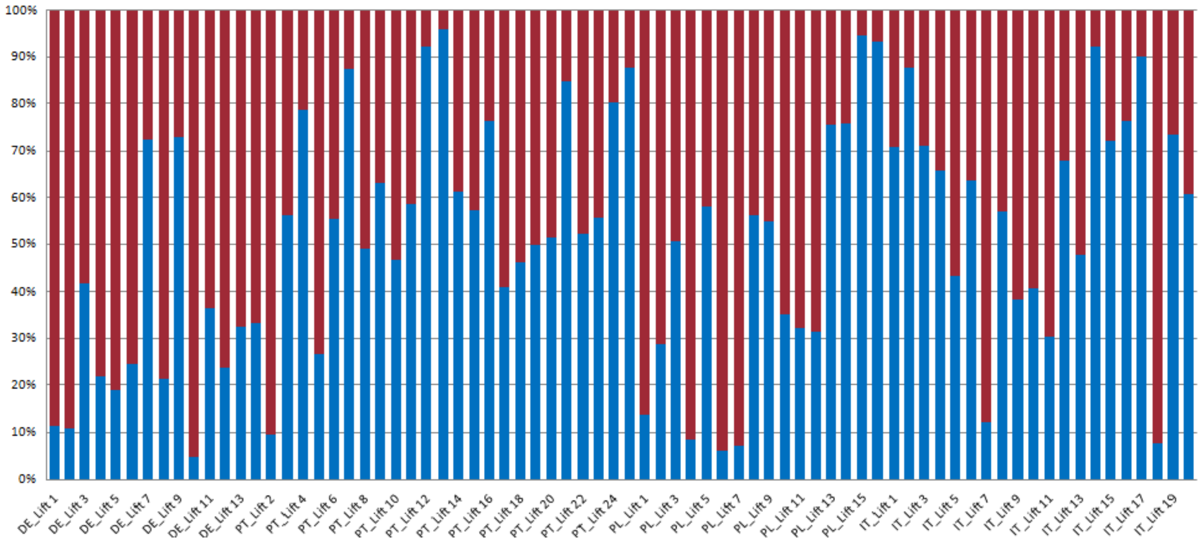



Figure 3-16: Shares in the energy demand of lifts by running (blue) and standby demand (red) (source: Almeida et al. 2010).

### 3.2.3. Technical systems approach

The technical system approach extends the scope of the analysis further and considers lifts as an embedded part in a building. Important aspects related to the indirect energy consumption in buildings through ventilation are discussed in section 3.3. When viewed from a technical system perspective, mainly the lift-related energy consumers excluded in the determination of energy demand can be mentioned. These include:

- Lift group dispatch systems: When several lifts are operated as a group, they can be used to optimize the operation of the vertical transportation system e.g. for throughput, energy demand or waiting times. Yet according to stakeholders, a standardized measurement, calculation and classification method is not available for lift groups. Therefore, their comparison is considered as restricted and not yet possible. The energy demand of a group is pointed out to be calculated as the sum of the individual lift energy demands

- Control strategy: The control strategy of individual lifts in a building can also affect demand, e.g. when the lift is automatically moved to some default landings to handle expected traffic/to reduce waiting times for passengers.

- Heating and cooling equipment in the car: This type of equipment is necessary, e.g. when the car is located outside the thermal shell of a building.

- Power sockets: Power sockets in the car or well can be used by maintenance personnel to operate electric tools if needed.

- Hoistway lighting: Hoistway lighting in the well is needed for maintenance purposes and to ensure safe working conditions for maintenance personnel.

- Components which are not part of the lift: Components such as non-lift display screen e.g. for information, entertainment or advertisement purposes and surveillance cameras can be energy consumers operated in or for the lift.

- Monitoring systems: Other monitoring system, e.g. for building management, might be linked to the lift system.

The use of such equipment, in turn, depends on the lift or building user/operator and/or maintenance personnel.

### 3.2.4. Functional systems approach

The functional systems approach is to take other means of transport into consideration that basically provide the same basic service as a lift. This functional view on lifts is to offer a broader view on the product.

There are various conceivable definitions of the "basic functions" of lifts. In a rather narrow definition, the basic function of a lift is to automatically and comfortably move people and solid or packaged goods vertically in buildings. From a broader perspective, the basic function is to ensure vertical accessibility in buildings. The former perspective has an emphasis on automated transport while the latter focuses on accessibility. Depending on which basic function is chosen, different functional alternatives to lifts can be discussed. As already mentioned in Task 1, various specific applications provide similar services to lifts but which are excluded from the Lift Directive:

- Lifting appliances whose speed is not greater than 0.15 m/s
- Construction site hoists
- Cableways, including funicular railways
- Lifts specially designed an constructed for military or police purposes
- Lifting appliances from which work can be carried out
- Mine winding gear
- Lifting appliances intended for lifting performers during artistic performances
- Lifting appliances fitted in means of transport
- Lifting appliances connected to machinery and intended exclusively for access to workstations including maintenance and inspection points of the machinery
- Rack and pinion trains
- Escalators and mechanical walkways.

Several of these applications are designed for very specific purposes. Based on the broader perspective of lifts mentioned above, a few relevant ways to ensure vertical mobility in buildings can be further discussed:

- **Lifts according to the Machinery Directive**: The Machinery Directive 2006/42/EC cover various types of lifting equipment that is different to lifts according to the Lift Directive 2014/33/EU. The distinctive criterion of these usually "simplified" lifts is their lower admitted maximum travel speed of up to 0.15 m/s. Thus, these lifts travel considerably slower than lifts according to the Lift Directive. They are therefore limited in terms of practical use to smaller buildings with few, typically up to 4 or 5 stops. These lifts are also subject to relaxed safety standards due to their lower traveling speed. There are many different types of lifts according to the Machinery Directive. Examples include home lifts, stair lifts or platform lifts. Depending on the specific configuration, these lifts are limited to one or very few persons and no or little additional goods.

- **Escalators and inclined moving walks**: Escalators and inclined moving walks are designed to transport people between a bottom and a top landing. Escalators and moving walks are especially used in commercial buildings, railway and metro stations or at airports. While escalators are mainly used for transporting people, inclined moving walks can also be used for transporting shopping carts between the two landings. Both escalators and inclined moving walks are mostly used to travel between two stories only; they are thus restricted in terms of vertical height. Note that escalators and moving walks are usually not suited for transporting larger quantities of goods and they are not suitable for transporting all kind of disabled people.

- **Fork lifts and cranes**: Fork lifts are used for sorting goods into shelves, transporting them between shelves or for loading and unloading trucks. Though they are a means of vertical transport for goods, their purpose is mainly to move heavy loads horizontally while the vertical movement is only a necessary addition. Cranes are also used to transport goods and they are mainly found on construction sites, in industrial applications or in logistics.

- **Stairs and ladders**: Stairs and in exceptional cases ladders can be used to gain access to higher stories. As opposed to the previously mentioned alternatives, they are “manually operated”, i.e. the user needs to climb the stair or the ladder. Thus, it is less comfortable for the user than to use lifts and the maximum vertical distance is either limited by the height of the ladder or the fitness of the user and for longer distances, the users available time.

In sum when viewed from a functional perspective, there are no directly competing alternatives to lifts, especially when it comes to larger vertical distances: Lifts according to the Machinery Directive still come closest to lifts. Escalator and inclined moving walks are limited to special purpose buildings, forklifts or cranes are mainly used for transporting goods and stairs and ladders do not operate automatically.

## 3.3. Subtask 3.2 - System aspects use phase with indirect energy consumption effect

The aim of this subtask is to report on any indirect consumption effects during the use phase that impact the environment and resources. From the perspective of energy consumption, lifts may affect energy consumption in the local electrical supply grid on the one hand (see section 3.5.1) and in the heating/cooling system of the building due to ventilation on the other hand.

Ventilation of lifts concerns the car, the shaft as well as the machine room. Ventilation serves three purposes: under normal operation, it is to ensure that waste heat from the system is removed first; the second purpose is to provide the system with fresh air; the third purpose is to remove smoke in case of fire.

The harmonized safety standard EN 81-20:2014 generally assumes that the well is sufficiently ventilated according to national legislation. In its informative Annex E, further information on building interfaces are provided which also cover ventilation. Generally, it is stated there that the ventilation of the well is subject to national requirements as specific rules for lifts or general requirements are relevant for buildings.

With regard to the ventilation of the well and the car, it is pointed out in EN 81-20 that the safety and well-being of people using the car, working in the well or being enclosed in a car depends on numerous factors. These include the ambient temperature, solar radiation, dimensions of the well, and the properties of the doors and the availability of fresh air. The car itself should have a sufficient number of openings to ensure an adequate airflow in case of a fully used car. In case of normal operation, the gaps of the doors at the landings, the opening and closing operation and the pump effect of the moving car are also considered to be suitable to ensure the necessary exchange of air. Yet for technical reasons and human needs, it might be required as a case-by-case decision to ensure a permanent or on-demand ventilation aperture, forced ventilation and/or supply of fresh air. Also, in case of longer stops of the car, a sufficient ventilation needs to be ensured and lift wells are not intended to ventilate other areas of the building, among others due to safety reasons. With regard to the machine room, the role of ventilation is to ensure suitable working conditions for maintenance personnel as well as the proper function of the technical equipment (cp. in more detail EN 81-20).

Ensuring the ventilation of the shaft lies within the responsibility of the building designer. The role of the lift manufacturer is to provide the necessary data for ventilation, e.g. on heat emissions of lift components. The working conditions for personnel working in the lift well and the comfort for the passengers in the car also need to be taken into consideration. Based on this data, the building designer then can determine an energy-efficient solution (KONE 2015).

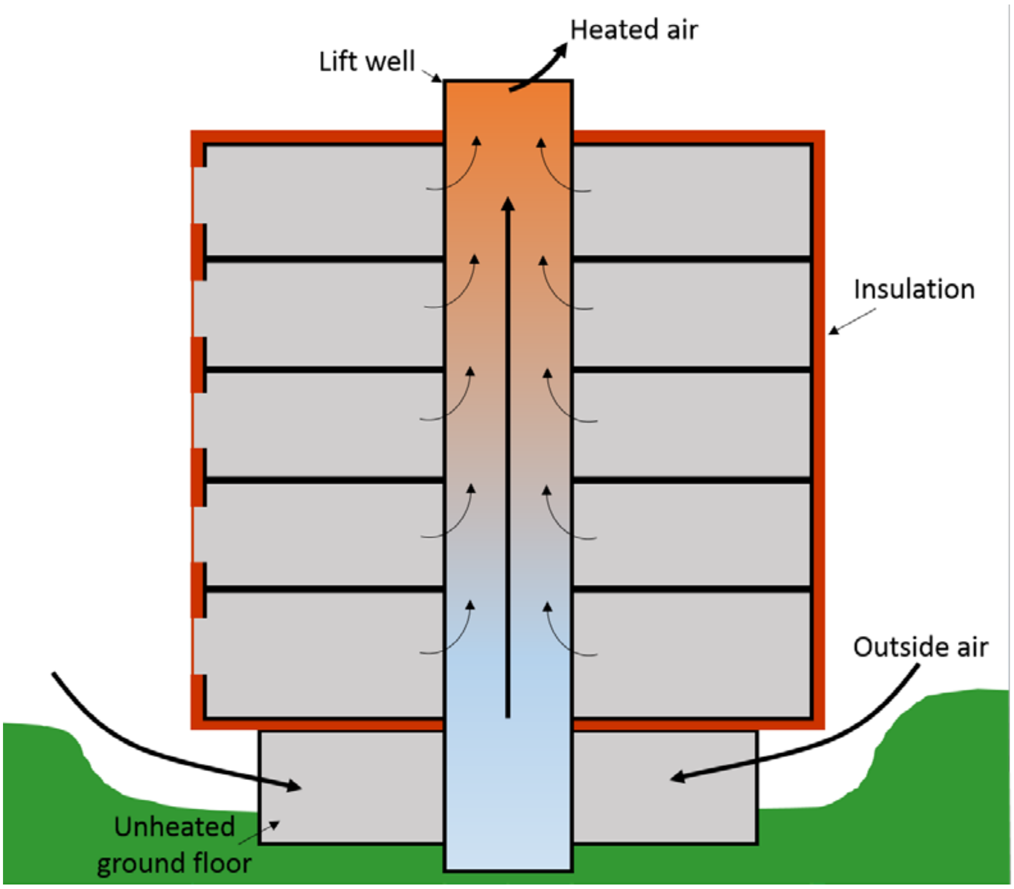


Figure 3-17: Illustration of heat losses due to uncontrolled shaft ventilation (source: with modifications from BfE 2004).

Ventilation can lead to considerable energy losses if the lift is installed within the heated area of a building, as is often the case. Lift wells have been identified as potential soft spots in building insulation when they bypass the insulation of the building. Under unfavourable circumstances, the bottom landing or air inlet is located on an unheated floor. Air flowing through leaks or open windows into the shaft is exposed to warmer walls of higher floors inside the well and then creates a draft towards the top-floor. There, the heated air leaves the shaft via ventilation openings (Figure 3-17). Traditionally, these opening have been designed as permanent holes in the building sheet, amongst other reasons to ensure that smoke can leave the shaft in case of fire and to ensure that surplus heat from the machine room can be removed from the building (BfE 2004).

To avoid these kind of losses, manually operated or automated ventilation systems have been developed. These systems allow for the ventilation shaft to be opened when needed instead of having a permanent opening to the outside of the building, e.g. by detecting temperature peaks or smoke in the well or in the machine room (see also Task 4). In Germany, the national building code, for example, requires that the building envelope is airtight in new buildings, thus requiring automated ventilation systems. Furthermore, it’s been suggested to that the lowest floor level should be properly insulated (BfE 2004).

If manually operable ventilation systems are put in place this could result in a situation where users, operators or other persons in place permanently lock the systems in an opening position, e.g. due to a lack of knowledge on the operation of the system or because they forget to re-close after manual aeration. From an impact of user behaviour perspective, it has to be ensured that it is not possible to permanently override automatic operating features.

While there is no systematic analysis of heat losses due to ventilation in lifts, some examples and indications on annual heat losses have been reported in several documents:

- BfE (2004) provides an estimate of heat losses by an opening ventilation hole sized 35 x 35 cm for a lift with a 12 m well at an average outside temperature of 4°C and an average inside temperature of 20°C. The estimated thermal losses are estimated at about 3 kW or 15 000 kWh per year.

- Base (2016) as a manufacturer of ventilation solutions provides a sample calculation for a 19 m lift and a car for 1000 kg at approximately 15 500 kWh per year.

- ZVEI (2012) also gives a similar example for a 19 m lift and estimates the thermal losses at approximately 15 200 kWh per year. Furthermore, it is reported that 10 lift ventilation systems of the Süddeutsche Verlag in Munich have been equipped with modern smoke ventilation systems. Energy savings of 550 000 kWh in heating power have been achieved by closing the permanent openings accordingly.

- Nickel (2011) conducted a 93 hours measurement of thermal losses of a 17.8 m and 1000 kg lift at Lufthansa Technik in April 2011. The average losses where determined at 3.67 kW.

- Another indication of thermal losses through lift wells – though for New York in the United States with its specific legislation and situation - is presented in Urban Green Council (2015). Various buildings with six to 50 stories were investigated in 2013 and 2014, indicating considerably higher losses in these larger buildings.

It should be noted that these losses are highly dependent on the ambient conditions of the respective installations. In countries with higher ambient temperature, heat losses will be lower, yet an additional energy demand for cooling might be relevant, as well. Thermal losses due to ventilation can be considerably higher than the electrical energy demand of lifts - note, for the purpose of comparison that the limit to attribute the worst standby class for electricity demand in lifts' power is at 1.6 kW according to ISO 25745 and VDI 4707. In practice, lifts have been found to usually have lower standby demand values (see for example Almeida et al. 2012). This means that the indirect energy consumption from thermal "standby" losses due to ventilation seem to exceed electricity demand if no measures against heat losses are taken.

Thus, it is advisable to also consider these thermal losses in the subsequent analysis.

## 3.4. Subtask 3.3 - End-of-Life behaviour

The aim of this subtask is to identify, retrieve and analyse data and to report on consumer behaviour regarding end-of-life aspects from an average European perspective.

### 3.4.1. Product use & stock life

Generally, the lifetime of lift installations can vary considerably. Economic depreciation models assume, for example, 15 years. Estimates suggest that the technical life cycle of a lift is roughly 20 to 25 years, while some lifts may need upgrading and modifications after 10 years whilst others operate satisfactorily for 30 to 40 years (Gray 1991). Other sources indicate similarly that under normal conditions, a lift will reach the end of its cost effective live after 20 to 25 years, but that a lift that is insufficiently maintained may need renovating after 10 to 15 years (ElevatorSource 2016).

Yet there are still many considerably older lift installations in place in Europe. A survey (Lindegger 2009a) carried out among ELA member organizations during the e4 project in 2009 yielded estimates on the stock distribution in Europe. For some countries, it was possible to obtain estimates on the age distribution of lifts, as well. With regard to the situation of lifts in 2009 in residential buildings as an example, the figures indicate that roughly 20% of these residential lifts in Finland, 25% in the Netherlands and 40% in Italy where installed prior to 1970 and thus roughly at least 40 years old. For Greece for instance, the age structure was broken down even further and pointed out that approximately 20% of the residential lifts even date back to the period from 1920 to 1960. Even though this data was collected approximately 10 years before the time of elaborating this preparatory study, it has to be taken into account that the stock renewal rates are quite low (see also Task 2). It underlines that lifts can be in operation for much longer than 15 years.

The longevity of some lift installations can be explained on the one hand by their traditionally very robust design. On the other hand, lifts consist of a set of replaceable components. Upgrades and replacements of selected components that need to be replaced due to wear and tear or to respond to new safety requirements help to maintain the bulk of the remaining components. Thus, the lift is usually still counted as an old installation even though some of its parts are more recent.

With regard to product use and stock life, it can be noted that the share of electricity consumption in lifts is expected to have shifted from running consumption to standby over time. Modern electronics allowed for new comfort and safety features, thus increasing power demand while improvements in drive technologies have allowed a reduction in energy demand over time.

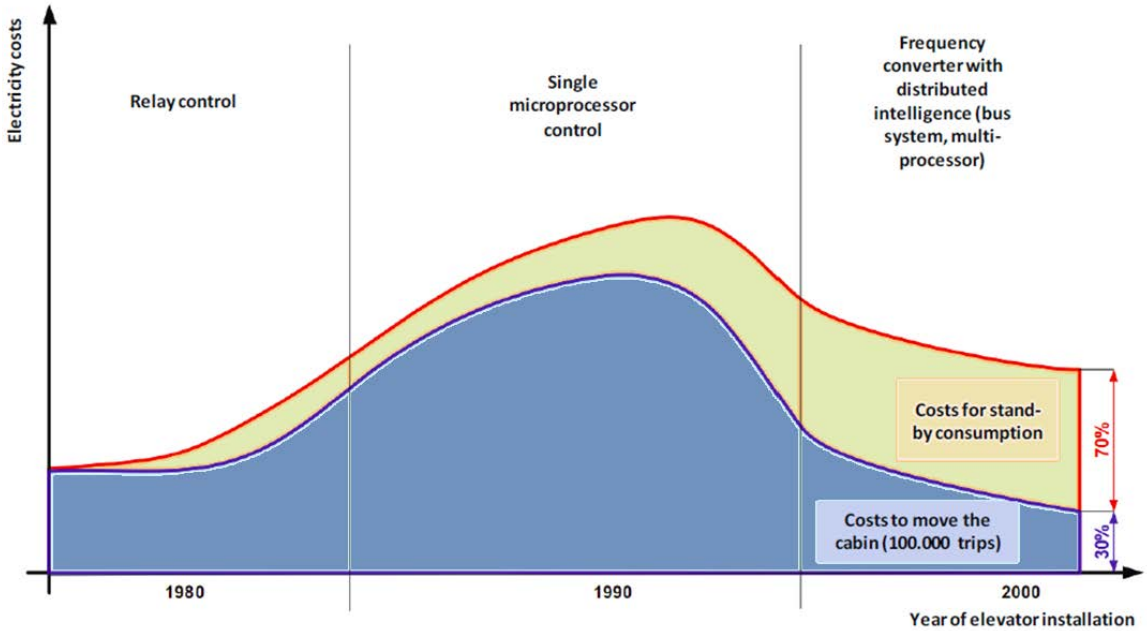



Figure 3-18: Energy consumption trends of residential lifts (source: Lindegger 2009b adapted from Hirzel et al. 2010).

### 3.4.2. Repair and maintenance practice

Maintenance is very important to ensure the reliable operation of lifts. Insufficiently maintained lifts can disrupt normal operations and reduce the availability of the lift. Additionally, lift components may deteriorate with a lack of proper maintenance and lose value (Unger 2015).

Maintenance activities typically include checks of the various components of the lifts (e.g. roping, brakes, doors, car, oil level, emergency intercom, control system, etc.). In many cases, maintenance takes place every 1 to 3 months.

Yet there is no general rule on the frequency of maintenance activities, there are values from experience that depend on a number of criteria such as the number of trips, the area the lift is located in (e.g. residential area, industrial area, schools), the age of the installation and the expected likelihood of disruptions. The latter usually decreases after the installation of a new lift and rises again when the lift ages beyond roughly 15 to 20 years (cp. Unger 2015). After approximately 25 years, thorough repairs beyond regular maintenance or replacements might be necessary (KONE 2017).

There are different basic types (Figure 3-9) of maintenance contracts (Hirzel/Blepp 2017; Lenzner/Böhm 2016):

- Simple maintenance: In this case, a maintenance company performs routine checks on the lift in predefined intervals (depending on the requirements e.g. on a monthly, quarterly or semi-annual basis) for a fixed price. Additional services such as the elimination of faults, repairs and spare parts are separately invoiced.

- Maintenance including elimination of faults: Beyond routine checks, this model also covers the elimination of faults as well as small spare parts up to a certain ceiling. Larger repairs and spare parts are invoiced separately.

- Full service contracts: In this case, repairs and spare parts are covered by the contract in case of proper use (excluding force majeure, vandalism and improper usage). Maintenance intervals are often defined by the maintenance company as needed here.

New lifts equipped with remote servicing capabilities enable the operating conditions of the lift to be monitored from a distance using a set of sensor feedback, e.g. motor temperature, oil levels, number of trips or operating hours. This can help to select the number of on-location checks in accordance to the actual needs. Yet there are also limits to this type of remote diagnostics capability as monitoring mechanical problems is non-trivial because it requires sensors that can detect mechanical changes (cp. Unger 2015).

Table 3-6: Design of basic maintenance contracts (own translation from Hirzel/Blepp 2017)

| Aspect | Simple maintenance | Maintenance including fault elimination | Full service contract |
|---|---|---|---|
| Frequency of maintenance | Fixed time interval | Fixed time interval | Often determined as needed by the maintenance company |
| Routine maintenance | Yes | Yes | Yes |
| Elimination of faults and potentially small spare parts | No | Yes | Yes |
| Repairs and spare parts | No | No | Yes |

Next to an increasing occurrence of technical issues, other arguments for major upgrades or replacements can also be found (KONE 2017): a) It might become more difficult to obtain spare parts, thus increasing the duration for repairs. b) Old lifts might not comply with more recent safety and accessibility regulations. c) Energy consumption could be lower with modern solutions. d) An old lift installation might be perceived as unattractive. e) New installations might offer a higher level of comfort. f) Replacements might allow for increased car sizes.

There are different kinds of repairs that can be done on lift installations (see also KONE 2017) as follows:

- Component replacements: In the case of replacing components, individual components like lighting or door operators are replaced in the lift.

- Modular modernization: In case of a modular modernization, larger parts of the lift respectively selected from its subsystems are replaced.

- Full replacement: In case of the full replacement, the entire lift installation is removed first and then replaced by a completely new installation.

The degree of the intervention depends on the condition and age of the existing lift. KONE (2017) provides an indicative lift age of more than 10 years for component upgrades, of 15 to 20 years for modular modernization and of more than 25 years for a full replacement. Yet it has to be noted that the lifetime of individual equipment items can vary considerably. Figure 3-17 provides information published by ElevatorSource (2016) for various lift components with indications on recommended action. This underlines that the expected useful lifetime not only depends on the complete lift installation but also on the different components.

Table 3-7: Table of expected lifetimes according to ElevatorSource (2016) if maintenance is performed on a routine basis and the equipment originates from a major original equipment manufacturer (abbreviated table)

| Equipment type | Expected useful life in years | Recommended action |
|---|---|---|
| Electrical switchgear | 50+ | Retain |
| Electrical wiring | 30 | Replace |
| Controller, dispatcher | 20-25 | Replace |
| Cab interior | 15 | Refurbish interior |
| Machinery | 30 | Replace |
| Shaft Doors | 20-30 | Replace gibs & rollers |
| Shaftways | N/A | N/A |
| Hoist rails | 25 | Realign rails |
| Cables | 20 | Replace |
| Traveling cables | 20 | Replace |
| Hydraulic piston | 25 | Replace / Resleeve piston |
| Elevator call station | 15 | Replace |
| Elevator car operating panel | 20 | Replace |

It has been suggested in Gray (1991) that major refurbishments could be taken into consideration during the refurbishment of buildings to avoid downtime and thus inconvenience during the normal operation of the building, especially if there is only one lift available.

For the sake of completeness, it should be noted that lifts have to undergo regular statutory inspections to ensure their safe and secure operation.

### 3.4.3. Collection rates and estimated second hand use

As lifts are fixed installations in buildings, there is no direct re-utilization of the entire product by moving the product to a new location.

Manual dismantling of the product is considered as an important environmental-friendly approach of recycling. It has been pointed out that the separate removal of fractions with a high polluting and resource potential (e.g. batteries, screens, circuit boards and plastics) is important in this context. It has also been suggested that passenger lifts should be constructed to ensure that different fractions can be readily separated and recycled and that hazardous components and substances (e.g. oils, batteries, electronic circuitry) can easily be removed and disposed of in an environmentally compatible manner (Blepp et al. 2011).

It should be noted that the bulk material of lifts is steel (see also Task 5) which can be readily removed and recycled. Little information, however, is available on the extent of current design and dismantling activities and their accordance with the previously mentioned suggestions for environmentally-friendly recycling.

With regard to the second hand use of lift components, little information is publicly available. Given the long lifetime of lifts and that their components become technologically obsolescent, as well as the need to ensure safe operation of lifts, the fraction of second hand use of components appears rather low and is limited due to safety and security requirements.

For the provision of environmentally friendly lifts, some requirements concerning components and construction have been provided in Blepp et al. 2011. Due to the longevity of lifts that ranges from 20 to 40 years, it has also been suggested that the availability of spare parts should be ensured. The reason for this is that the use of non-original spare parts may lead to a deterioration of the lift, an increase in energy demand, shorter lifetimes and higher safety risks.

## 3.5. Subtask 3.4 - Local infra-structure

The aim of this subtask is to identify, retrieve and analyse data and thereby to report on barriers and opportunities relating to the local infrastructure needed for the operation of lifts.

### 3.5.1. Electric interface

As with many electric and electronic devices, the main issues with regard to the electric interfaces are the safe and secure operation of lifts. On the one hand, this concerns the electromagnetic immunity of lifts, i.e. their ability to operate normally in a given electromagnetic environment. On the other hand, this relates to electromagnetic emissions of lifts, i.e. their ability to minimise their impact on other devices so that these can operate normally in the environment of the lift.

Any electric and electronic devices that generate or transfer non-sinusoidal signals may cause electromagnetic distortions. Lifts have to comply with the European Electromagnetic Compatibility Directive 2014/30/EU. Specific interpretations for lifts in terms of electromagnetic compatibility are defined in EN 12015:2014 for emissions and in EN 2016:2013 for immunity.

Electromagnetic emissions within lifts primarily affect the control system of lifts, control signals on the control lines or the bus system. Consequences include a bad ride quality or aborted movements. Emissions from lifts may affect the operation of mobile phones, radio and TV devices, computers, medical equipment, etc. (cp. Lenzner/Böhm 2016). In lift construction, frequency converters with modern power electronics are seen as a main source of electromagnetic disturbances (Lenzner/Böhm 2016).

Various measures can be taken to avoid electromagnetic disturbances from lifts. They include for example proper shielding of cables and conductors, ensuring sufficient distances of cables and conductors running in parallel, the utilisation of filters before frequency converters and the control system (cp. in further detail Lenzner/Böhm 2016).

The drive system, which incorporates the lifts motor, is the component with the highest power demand. As pointed out in Almeida et al. (2014), the use of drive systems with reduced power demand may lead to a reduction in supply side electrical infrastructure and losses. Increases in harmonic distortions due to power electronics may increase losses while on the other hand, lower power demand may reduce the demand in transformers, cables and other transmission components. The utilization of soft-starting technology can reduce peak demand and it can offset the need for additional equipment in the case of local capacity constraints in the electricity distribution system.

With regard to the electrical interface, no major barriers have been identified if lifts are installed in line with existing regulations. Evidently, measures to minimise the electromagnetic compatibility of lifts may increase their costs, yet as these are legally compelling in any case, these do not seems to justify more in-depth considerations on barriers and opportunities with regard to the electric interface of the local infrastructure.

### 3.5.2. Telecommunications

Telecommunication equipment as a part of the local infrastructure is required in case of a lift malfunction. If a lift car is stuck with passengers inside the car, there is a need for a means to signal that the passenger are unable to leave the car.

A simple means to signal that passengers are trapped in a lift car in older lift installations is an acoustic device, e.g. a bell, that is located outside the lift and which can be activated from within the car. It has to be ensured that someone on the location outside the lift can hear and respond to this type of emergency signal.

The default approach today is an emergency intercom that is basically a phone device integrated into the lift car, which is connected to an emergency contact e.g. an emergency call centre or a person located nearby who is instructed for rescuing passengers from the car. While traditional solutions for emergency phone devices are based on a connection to the cable-based landline in the buildings, modern solutions allow for the use of a mobile GSM connection for emergency calls.

To ensure that emergency systems are also available in case of a loss of the electric supply in the building, lifts need to be equipped with an emergency electric supply to operate the communication system, i.e. a battery, unless it is based on an old analogue telephone line supplied by a telecommunication operator.

In terms of overall relevance, the telecommunication device itself including its power supply contributes to the idle consumption of a lift, but due to its relatively low power demand, it does not need to be explicitly considered further in this study. In addition, no specific barriers are known which can be considered as barriers relating to local infrastructure.

### 3.5.3. Installation

In the process of installing a lift, an interface between the building and the lift is created. The installation quality can affect the performance of lifts, both with regard to the comfort of use as well as the environmental performance.

Improperly installed guide rails, for example, may lead to lift cars travelling ungently with jolts and vibrations. Such unsteady movements and maladjusted guiderails requiring higher forces than necessary may also increase power demand on the drive system and thus affect the overall energy demand of lifts (see also ELA 2013). The quality of installation is also seen as having an important impact on lift energy demand in VDI 4707-2.

## 3.6. Subtask 3.5 - Recommendations

Based on the analysis in this task, several main observations can be made:

- First, lifts can be characterised as technical goods that are closely related to building operation. The planning and operation of lifts are thus influenced by many stakeholders. Findings on barriers to energy efficiency for lifts suggest that especially users and operators often lack information on the environmental performance of lifts and that they also tend to pay little attention to the topic. Furthermore, split incentive problems are identified as a challenge to the energy-efficient operation of lifts.

- Second, the lift utilisation of users strongly influences the energy demand and thus the environmental performance of lifts. Depending on this usage, both standby in infrequently operated lifts or running-mode consumption in intensively used installations can dominate the overall energy demand. The standards take these different usages into consideration by introducing different default classifications. As shown above, the underlying assumptions do not necessarily correspond in detail to specific situations, but on an aggregate level, they can be considered as a means to deal with the complexity of the real-life situation.
- Third, lifts are generally characterised by a relatively long lifetime. Unlike products such as white goods, they are subject to regular repairs and upgrades. Thus, measures to improve the environmental performance of new lift installations will only gradually impact the stock of installed lifts.
- Fourth, the ventilation of shafts has been identified as a particularly relevant consideration with regard to the indirect energy demand of lifts.

Based on these observations, the following conclusions for the scoping and subsequent analysis can be derived:

- First, the analysis and discussion of the energy-related standards have shown that lift usage considerably influences the environmental impact of lifts. This confirms the need to consider user behaviour next to functional parameters in the product categories as defined in Task 1.
- Second, given the relevance of barriers to the implementation of energy-efficient lifts, the encouragement of a demand-pull mechanism for energy-efficient equipment may be challenging. Doing so would entail giving users more information but also requires finding a means to overcome the existing split incentive problems. Furthermore, the annual energy costs for lift operation are rather limited, especially when the operation is financed by several parties, e.g. inhabitants. A further discussion of the policy implication of this observation will be part of later tasks.
- Third, ventilation has been identified as a relevant topic. Even if ventilation is not part of the product definition, available data suggests that it seems to be a non-negligible issue. Therefore, it should also be covered in the subsequent analysis.

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