Getting to the top floor: towards policy options to address the energy saving potentials of lifts

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Abstract

Lifts are nowadays considered an essential part of nearly all larger new buildings. They increase comfort and make buildings accessible to handicapped and elderly people. Due to their longevity, lifts determine the energy demand of buildings in the long run. While a considerable amount of lifts has been installed in the last decades, the bulk of them is considerably older. Some installations, though partially upgraded, still even date back to before the mid of last century. The aim of this paper is to further investigate how energy efficiency of lifts is currently addressed by European policy-making and to discuss how policy options on lifts might contribute to achieving energy savings for these installations. To underpin the analysis, a quantitative stock model for lifts is elaborated for this paper. Based on this model, different policy scenarios are discussed to analyse their potential impact on the energy consumption of lifts. The stock model indicates that there are currently approximately 4.6 million lifts in operation in the EU-28 consuming in total about 18.9 TWh of electricity each year. Due to gradual replacements of inefficient older lifts and technological progress, this consumption is expected to decline to 10.4 TWh until 2050. Policy options for new lifts could help to lead to a further reduction in electricity demand of about 2.3 TWh. These options could be based on the inclusion of lifts in the list of technical equipment in the next revision of the EPBD, by further investigating on implementing measures within the Ecodesign process and by considering a European energy label for lifts.

Introduction

Lifts are essential to make large buildings accessible and to increase comfort in multi-storied buildings. According to estimates, lifts in large buildings make more than seven billion trips each day (Al-Kodmany 2015) and approximately 500,000 units are constructed world-wide each year (Papanikolaou et al. 2017). There are varying indications on the relevance of lifts for energy demand. Some refer to the energy consumption of buildings and indicate a 2 to 10 % share in their consumption (Al-Kodmany 2015), a value of 4 % for high-rise buildings (Ahmed et al. 2014) or a shift beyond formerly 2 to 3 % (So and Li 2000). Others relate the consumption of lifts to the electricity demand of buildings and indicate a range of 5 to 15 % depending on the building configuration (Al-Sharif et al. 2004), a typical value of 3 to 8 % in building consumption (Almeida et al. 2012) or, with a different scoping, a value of 4 % in total electricity consumption in the tertiary sector (Almeida et al. 2009). It has furthermore been pointed out that lifts can cause up to 40 % of a building's energy demand during peak hours (Al-Kodmany 2015). Despite varying details, partially explained by varying delimitations, regions, building, lift types and limited data, these numbers underline the relevance of lifts for the energy demand of buildings.

Awareness of the energy efficiency of lifts increased during the last decade, also following the introduction of standards, i.e. the German VDI 4707 (e.g. Meermann 2009) and the more recent ISO 25745 series. Yet understanding, analysing and predicting the energy demand of individual lifts or groups of them is no recent development. Investigations on the energy consumption of lifts in tall buildings have already been an issue in the 1970s (e.g. Sweet und Duket 1976) and the decades to follow (Al-Sharif 2004). In recent years, models and simulations gained in importance, especially concerning energy-related aspects of individual

installations. Al-Sharif et al. (2004), for instance, outline a method for simulating and modelling lifts. Works that are more recent deal with integrated views of energy consumption and service levels. Adak et al. (2013), for example, propose an integrated simulator design to analyse the service quality and energy demand of a lift and Zhang and Zong (2013) deal with a method for energy-saving scheduling optimization for lift groups while keeping time performance acceptable. Then again, there are works that strive to improve the quality of energy demand projections. Tukia et al. (2016), for instance, propose a way for projecting the annual electricity consumption based on short-term measurements. A high-resolution model to determine the lift power consumption beyond using daily averages has been proposed in Tukia et al. (2018). Others focus on individual components of the lift such as the drive system. Ahmed et al. (2014), for example, suggest a model for calculating the energy consumption of lift motors as a major energy consumer in lifts and Chen et al. (2014) compare the energy input for different trajectories in systems with permanent magnet motors.

Next to these works with a stronger focus on individual installations, some also look at their aggregated energy demand and saving potentials. They include the works by Nipkow and Schalcher (2006) who conducted an analysis of 33 lifts in Switzerland and a later study with a related approach for Europe (Almeida et al. 2010). More recently, Papanikolaou et al. (2017) analysed the energy saving potentials in 15 commercial lifts by a specific manufacturer and indicated potential energy savings of 20 to 40 %. Many measures are available to contribute to these potentials. They include approaches addressing hardware and software (e.g. Al-Kodmany 2015), energy recuperation in roped lifts (e.g. Nobile et al. 2014) and hydraulic lifts (e.g. Yang et al. 2007), adjustable counterweights (e.g. Tukia et al. 2017), the integration of intelligent control systems (e.g. Zarikas et al. 2013), the utilization of sensors technologies (e.g. Kwon et al. 2014) or changes in user behaviour (e g. Rotger-Griful et al. 2017) to name a few examples.

Implementing energy efficiency measures is essential to contribute to the European long-term goals for reducing greenhouse gas emissions in the Union by 80 to 95 % as compared to 1990 levels (European Commission 2011) and for the transition towards a decarbonized building stock. Against this background, the aim of this paper is to investigate how the energy efficiency of lifts is currently covered by European policies, to seek an understanding of the energy saving potentials of lifts until 2050 and to discuss how European energy policies could tap these potentials. For this purpose, an introduction to the current legal framework for energy efficient lifts is followed by a modelling approach. Using a stock model, the energy saving potentials of lifts are estimated. Based on this analysis, policies to improve the energy efficiency of lifts are discussed.

Standards and policies relating to the energy efficiency of lifts

There is an abundant number of international and European standards applying to lifts. They nearly all focus on safety-related issues. The exception is the ISO 25745 family that addresses the energy consumption of lifts. More specifically, ISO 25745-1:2012 deals with the energy measurement and the verification of the energy performance of lifts, escalators and moving walks and ISO 25745-2:2015 deals with energy calculations for lifts including an energy classification scheme. In addition, the national German VDI 4707-1 from 2009 also deals with the energy efficiency of lifts. It was the first published guideline on this topic and helped to pave the ground for the more recent ISO 25745 family. In addition, there is a Product Category Rule (PCR) published in 2015 for developing Environmental Product Declarations (EPD) for lifts (PCR UN CPC 4354). The EPDs aim at showing the broader environmental impact of lifts using a Life Cycle Analysis (LCA). Within this analysis, the method to determine the energy demand of lifts in the usage phase yet still refers to the ISO 25745 calculation model.

When it comes to legal documents governing lifts, the main two texts harmonizing the requirements in the European Member States are the Lift Directive (Directive 2014/33/EU) and the Machinery Directive (Directive 2006/42/EC). The Machinery Directive (Directive 2006/42/EC) sets requirements to machines and is relevant for all lifting appliances. The Lift Directive has more specific requirements for safety components and certain types of lifts, especially those with speeds exceeding 0.15 m/s, i.e. "typical" lifts used in buildings. Both directives focus on safety and neither address energy nor environmental impacts.[1]

With regard to policies that could cover the energy demand of lifts, the most relevant documents are the Energy Performance of Buildings Directive (EPBD, Directive 2010/31/EU), the Energy Efficiency Directive (EED, Directive 2012/27/EU), the Energy Labelling Regulation (Regulation (EU) 2017/1369) and the Ecodesign Directive (Directive 2009/125/EC).

The EPBD addresses energy savings in buildings and includes the application of minimum requirements to the energy performance of technical building systems whenever they are installed, replaced or upgraded. Lifts were not covered by the EPBD of 2010, but their inclusion in the list of technical building systems was discussed for its 2018 amendment (Directive 2018/844/EU). Yet the most recent changes still do not cover them.[2] Therefore, the EPBD does currently not provide a strong legal framework for minimum requirements including lifts even if lifts could be taken into account there. On the level of individual countries, Portugal and Denmark seem to be the only Member States to set requirements to lifts. Portugal has them for non-residential buildings while Denmark addresses buildings that are not solely intended for residential use. They require lifts to achieve an energy class B according to VDI 4707.

The EED, in turn, defines a more general framework for energy efficiency improvements in the European Union. It provides some mechanisms which could affect lifts, e.g. via requirements on general building renovation, via the exemplary role of public buildings, via the use of energy management systems or by

1. There are also requirements to the accessibility of buildings that concern lifts. In Germany, for example, state building codes specify when lifts are mandatory. Yet such requirements do not address energy either.

2. "'[T]echnical building system' means technical equipment for space heating, space cooling, ventilation, domestic hot water, built-in lighting, building automation and control, on-site electricity generation, or a combination thereof, including those systems using energy from renewable sources, of a building or building unit;" (Article 2.3 of 2018/844/EU).

Table 1. Overview of the EU regulations based on the Ecodesign Directive and/or the Energy Labelling Regulation concerning lift and wells equipment (x: impact, (x): limited impact).

Product	Regulation	Lift	Well
Non-directional household lamps	EC 244/2009	x	x
Fluorescent lamps without integrated ballast	EU 247/2010	x	x
Directional lamps and LEDs	EU 1194/2012	x	x
Ventilation fans	EU 2011/327	x	x
Air conditioning	EU 206/2012	x	x
Local space heaters	EU 2015/1188; EU 2015/1186	x	(x)
Space and combination heaters	EU 813/2013; EU 811/2013	(x)	(x)
Air heating products, cooling products, high temperature process chillers and fan coil units	EU 2016/2281	(x)	x
Electrical Motor*	EC 640/2009	–	–

** Not applicable as lift motors, among others, do not fall under the continuous duty requirements as laid down in the motor regulation.*

energy efficient public procurement processes.[3] As a framework directive, however, it does not yield specific requirements on the level of individual products such as lifts.

The Energy Labelling Regulation sets a framework for labelling energy-related products during use and aims at enabling customers to choose more efficient products. However, it is explicitly stated in the preamble of the regulation that lifts are excluded from its scope, referring to other polices which directly or indirectly address the energy consumption of lifts. Due to the relevance of lifts for energy demand, their considerable energy saving potentials and in absence of specific legal requirements addressing the performance of lifts, the European Commission included lifts in its Ecodesign Working Plan for the period from 2016 to 2019 (European Commission 2016). The corresponding Ecodesign Preparatory Study[4] was initiated in September 2017. It aims at analysing the potential, feasibility and impact of measures for new lifts. As any Ecodesign Preparatory Study, the basic outcome could be minimum energy performance standards and/or information requirements, a voluntary agreement or a situation with no regulation. At the time of writing, this study was still on going. However, many components used for the lift or its well are subject to energy-related regulation (see Table 1).

On the international level, the US Energy Standard for Buildings Except Low-Rise Residential Building ASHRAE 90.1-2016 includes requirements on the energy performance of some lift components. According to a literature and policy review, Hong Kong and Singapore are the only additional regions with energy efficiency requirements addressing lifts, also due to the importance of vertical transportation in these urban regions. Furthermore, the voluntary labelling schemes BREEAM (Building Research Establishment's Environmental Assessment Method, a sustainability-rating scheme developed in the UK), Energy Star (in the USA) and LEED (Leadership in Energy and Environmental Design, a voluntary label for green buildings) take the energy efficiency of lifts to some degree into account.

Stock model and energy demand projection for lifts

In view of considerable saving potentials attributed to lifts, it seems relevant to investigate on the potentials that energy policies could trigger in the long run if aligned accordingly. Due to the long service life of lifts, it is necessary to take the age structure of the stock of lifts into account in this analysis. Stock models (e.g. Hirzel et al. 2012) are a modelling approach to do so.

DATA SOURCES AND DATA PREPARATION

In general, information on the current stock of lifts is limited. Various production-related databases like the European PRODCOM database or national statistics indicate production or sales volumes. Yet this information is often limited to recent years and the description of the lift types is generic. In the year 2009, a survey (Lindegger 2009) was led by the European Lift Association (ELA) within the FP7 project "e4" on energy efficient elevators and escalators (Almeida et al. 2010). The aim of this survey was to collect data to estimate the overall energy consumption of lifts in 2010. For this purpose, ELA distributed a survey to its member associations to obtain a structured overview of the stock of lifts and to answer some additional questions. In this survey, information by different technological characteristics was asked for. These included items such as the nominal load, rated speed, rise, annual trip number, motor power, age and information on pre-defined attributes like building types, drive and controller technologies. This survey produced results for 17 Member States and despite some limitations and the inclusion of estimates, the data provides a very detailed picture of the stock of lifts in these countries around the year 2010.

Due to the differences in terms of format and disaggregation, it was necessary to process this data prior to using it in the stock model. For this purpose, a set of harmonized categories (Table 2) were defined first. Then, the original data was sorted into these categories. As the original data from some countries did not contain information for all categories, the missing cat-

3. The German AMEV guideline (AMEV 2017) for the procurement of lifts for public buildings could serve as an example as it also addresses adequately considering energy efficiency as an award criterion.

4. See: www.eco-lifts.eu.

Table 2. Overview of the categories of the stock model.

Region	Eastern, Northern, Southern, Western Europe
Country	Each of the EU-28 Member States
Building	Commercial, hospital, industrial, office, residential
Controller	Electro mechanic, electronic
Drive	Hydraulic, geared traction, gearless traction
Nominal load	5 groups (up to 450 kg, 450 up to 630 kg, 630 up to 1,000 kg, 1,000 kg up to 1,600 kg, more than 1,600 kg)
Rise	4 groups (up to 12 m, 12 up to 20 m, 20 up to 30 m, more than 30 m)
Decade	7 groups (before 1950 and every decade thereafter until 2009)

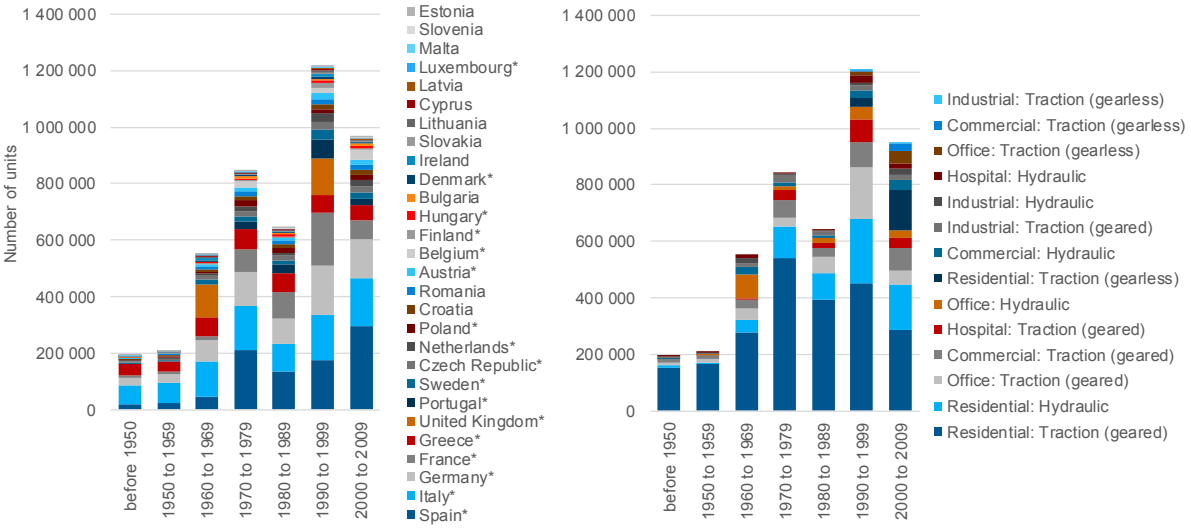

*Figure 1. Overview of the lift stock in 2010 by age and country (left) and by age, building type and drive technology (right). Note that the overall number of lifts for countries marked by * is directly based on the source data while for the others, extrapolations were necessary.*

egories were successively filled by using similarity assumptions from other countries where that breakdown was available. If, for example, the drive technology was just stated as "traction", it was assumed that the split into geared and gearless traction lifts was similar to that of other countries. Furthermore, as data was only available for 17 Member States, the countries were attributed to four European regions (Eastern, Northern, Southern, Western) with the assumption that the missing 11 Member States had a structure of lifts like the regional average. To obtain the absolute numbers of lifts from there, the structure was scaled by the number of inhabitants in the countries based on figures from Eurostat for 2010 (Eurostat 2019a). In sum, this resulted in more than four thousand configurations for the stock with lift numbers for the different decades.[5]

STOCK ANALYSIS FOR THE YEAR 2010

The results indicate a total stock of 4.62 million lifts for the EU-28 in 2010. This overall number seems in line with estimates by ELA (Gemici-Loukas 2015) which allows deriving an overall number of 4.78 million lift for 2010 in the EU excluding Croatia and Malta.

A disaggregation of the overall stock is illustrated in Figure 1. The left part shows the distribution by country and age. It underlines that lifts can be quite long-lived installations, since parts of them are regularly updated or replaced. Furthermore, it can be seen that the size of the major European countries is generally mirrored by the number of lifts. Limits in the resolution of the original data can also be observed: Values for the UK, for example, show that major lift installations are from the 1960s and 1990s. This reflects that the breakdown in the original survey only attributed data to these two decades. The right part shows the age structure by the building categories and drive technologies. It is obvious that residential lifts play a very important role in Europe and that traction lifts are the dominating technology in the stock.

STOCK PROJECTION UNTIL 2050

While the previous analysis only shows the situation for 2010, a discussion of future policies requires the projection of the stock until 2050. An important factor for the stock development are the lifetime assumptions. A particular challenge of lifts is that their components are successively replaced and up-

5. Note that not all potential permutations of categories are needed since some combinations were empty (e.g. no lifts before 1950) and some mutually exclusive (e.g. no hydraulic lifts with a rise beyond 30 meters).

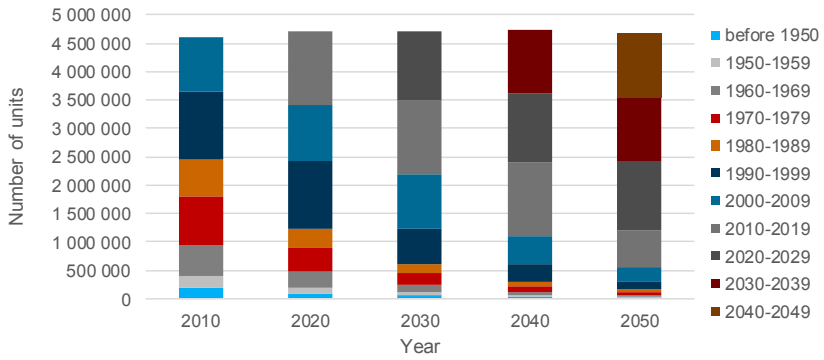

Figure 2. Projection of the lift stock in Europe in terms of numbers and age structure.

graded. There are, for example, indications that for a lift under routine maintenance, a refurbishment of the cab is needed after 15 years, its controller might need replacing after 20 to 25 years and its machinery could be used for 30 years (ElevatorSource 2019). While the actual values depend on the specific installation and its use, this successive replacement of components combined with the robust construction work from the last century are reasons for the long life of some lift installations. Therefore, it is difficult to determine one typical lifetime for a lift. For projections, it would also be necessary to obtain an indication on the future need for lifts. Many factors affect this need. They include the construction, refurbishment and deconstruction activities for buildings, changes in the age structure of the population, stricter requirements to accessibility, structural changes in the buildings stock due to urbanization or changing demand to comfort.

Evidently, additional assumptions are required. For the purpose of the analysis, two straightforward assumptions concerning the survival of lifts by construction year and concerning the overall need for lifts are made. The first assumption is that lift cohorts operate for an average of 30 years and thereafter, their number is reduced by half each decade. This means that the cohort from before the 1950s[6] is reduced by half from 2010 to 2020 and in 2030, it is only a quarter of its 2010 value. The cohort for the decade 1990 to 1999 remains unaffected in 2020 and only starts declining in 2030. This general assumption corresponds to the idea that lifts essentially remain unchanged during their first decades of operation and thereafter, they are gradually replaced by new lifts or they undergo ma<jor upgrades. The second assumption is that the development of the lift stock generally follows the development of the entire population in the country using the baseline projection from Eurostat (2019b). Based on these two assumption, new lifts are installed in the model to compensate for changes in population or to replace lifts from the older cohorts.

To judge the quality of these assumptions, the resulting number of new installations in the period from 2010 to 2019 can be compared to the current market situation. In total, about 130,000 new lifts on average would come into the market during that period in the EU-28. This corresponds to 2.84 % of the stock in the year 2010. This figure is higher but still similar to the approximately 93,000 unit average for the period from 2011 to 2013 that corresponds to 1.84 % of the 2010 market in 25 Member States which can be derived from Gemici-Loukas (2015). It is also in line with about 115,000 new lifts per year derived from ELA market statistics for 2005 for the EU-27, corresponding to 2.40 % or 4.8 million units in stock given in Almeida et al. (2012).

The resulting development of the European stock of lifts based on these assumptions is shown in Figure 2. The relative low dynamics with regard to the population development is reflected in the overall stock that only changes to some 4.67 million lifts in 2050. The figure shows further that the stock of existing lifts only gradually moves out of the market.

While the values seem in line with other sources, the estimated number of lifts can only be a proxy for reality. As pointed out, it should be noted that the projection does not take structural changes into account, e.g. an increasing trend towards urbanization or an ageing population, which will further add to the number of new installations. Using projections on buildings and their structure would be helpful, but an in-depth analysis of all the previously mentioned factors of influence would go beyond the scope of this paper. Furthermore, this would entail a number of additional assumptions. Finally, it can be discussed whether more recent lifts still achieve the considerable life spans of the old and quite robust installations.

ANALYSIS AND PROJECTION OF ENERGY DEMAND

With the information on the stock of lifts available, energy demand is calculated for each entry in the stock using the energy calculation model provided in ISO 25745-2. The standard foresees a calculation of the overall annual energy demand of a lift based on its stand-by and running demand. This is necessary because both the stand-by and the running demand can dominate the overall energy demand of a lift depending on its configuration and usage (e.g. Nipkow and Schalcher 2006; Almeida et al. 2010). The standard then allows to attribute one of seven overall Energy Efficiency Classes to a lift, ranging from A (the best one) to G (the worst one). Furthermore, there are also energy demand classes for the stand-by and running mode. Each mode can be attributed a class from class 1 (best) to class 7 (worst). Figure 3 shows the essential calculation model as provided in ISO 25745-2. Exogenous input parameters are depicted by italic letters; the other parameters are intermediary variables used in the standard.

6. Note that this will not correspond to a full original cohort from before the 1950s but rather what remains in 2010 of this original cohort.

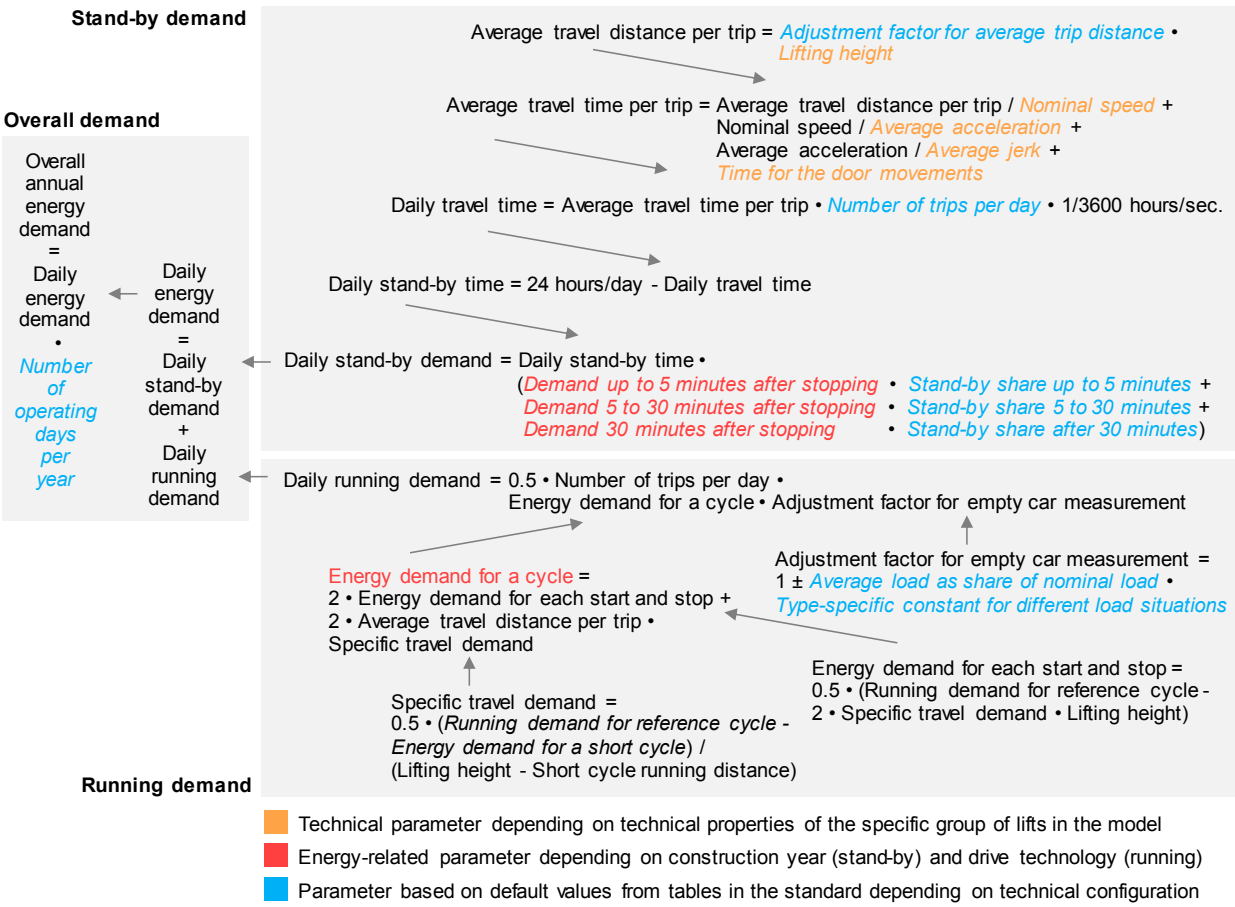

Figure 3. Overview of the calculation scheme for determining the energy demand of a lift based on ISO 25745-2 (italic parameters are exogenous input variables for the calculation).

The parameters used for the energy demand model can be attributed to different categories that are indicated by colours in Figure 3. While a full documentation goes beyond the limits of this paper, the general approach used for the model will be briefly explained. Orange parameters depend on the technological properties of the entries in the stock model. For example, the lifting height for lifts in the group with a rise of "20 up to 30 m" was assumed to be 25 meters on average. Blue parameters were determined from default tables in the standard that depend on the technical properties of the lift. For example, when a lift was located in a "residential" building with a maximum rise of "12 to 20 m", it was attributed to a "usage category 2" according to the standard. ISO 25745-2 suggests six of these so-called "usage categories". They describe the usage intensity of a lift (very low to extremely high) by providing an indicative number of trips per day (50 up to 2,500), a typical speed (0.63 m/s to 5 m/s) as well as the typical number of operating days per year. These categories span all types of lifts from small residential to very large office applications. The information on the usage category for the specific entry can then be combined with the nominal load of the car to obtain the "average load as a share of the nominal load" which is needed for further calculations. The red parameters are energy-related input parameters that serve as an input for the energy demand calculation. For the determination of running demand, we used assumptions on the energy classes, which in combination with the technical parameters, yield the running demand.[7]

In general, up-to-date information on the energy consumptions of lifts is scarce. Some indications can be drawn from previous studies (e.g. Nipkow 2005; Almeida et al. 2010; Papanikolaou et al. 2017), manufacturers' websites and available PCRs.[8] The available data, however, is limited and only provides a partial picture. Therefore, a set of assumptions was needed for the analysis. Among others, we assumed that old relay-controlled lifts have a lower stand-by demand than the electronically controlled lifts from more recent decades, but that they also have a higher running demand. For more recent lifts, we assumed further that the demand decreases again due to technological improvements following a higher awareness of manufacturers for energy efficiency. An overview of the detailed input assumptions for the baseline is available in Table 3. While these values draw on available data, their uncertain nature needs to be underlined. However, the results for 2010 can be compared to available data: The calculated overall demand for 2010 based on this input results in 18.9 TWh for today's EU-28 countries

7. In practical applications, the process is obviously the other way round, i.e. it starts from measurements to determine the class of a specific lift.

8. See: https://www.environdec.com/PCR/Detail/?Pcr=9211.

or about 0.6 % of the overall electricity demand (Figure 4). This seems very close to the value of 18.4 TWh for the EU-27 from Almeida et al. (2012). However, due to particular uncertain future improvements, a sensitivity analysis (ceteris-paribus) for new lifts after 2019 is carried out.

The resulting baseline demand until 2050 with no policy intervention decreases to 10.4 TWh (Figure 4). These considerable changes can be explained by the gradual phase-out of the old lifts, in particular those installed between 1980 and 2009, which are replaced by models that are more efficient. The sensitivity analysis in the left part shows that even a considerable change in the demand of new lifts does not change the generally declining trend. In total, running consumption will be higher than stand-by in the year 2050 as shown in the right part.

Discussion of policy options

ANALYSIS OF ADDITIONAL SAVING POTENTIALS UNTIL 2050

The additional impact of policies on energy demand in 2050 is analyzed by a set of scenarios (Table 4). Next to the previously described no policy scenario, four scenarios with successive policy options are explored, i.e. the options are added "on

Table 3. Summary of the assumptions for the no policy scenario and the sensitivity analysis for new lifts after 2019.

Age	Stand-by: Idle mode [Watt]	Stand-by: After 5 minutes [Watt]	Stand-by: After 30 minutes [Watt]	Running: Traction lift [Class]	Running: Hydraulic lift [Class]
before 1950	100	100	100	4	6
1950–1959	100	100	100	4	6
1960–1969	100	100	100	4	6
1970–1979	150	150	150	4	6
1980–1989	200	200	200	4	6
1990–1999	250	250	250	4	6
2000–2009	250	250	250	3	5
2010–2019	160	120	70	3	5
2020–2029*	120	80	40	2	4
2030–2039*	100	70	30	2	4
2040–2049*	100	70	30	2	4

***Sensitivity analysis:**
Stand-by increased: Stand-by demand for new lifts after 2019 increased by one third
Stand-by decreased: Stand-by demand for new lifts after 2019 decreased by one third
Running increased: Running demand for new lifts after 2019 increased by one class, i.e. by fifty percent
Running decreased: Running demand for new lifts after 2019 decreased by one class, i.e. by one third

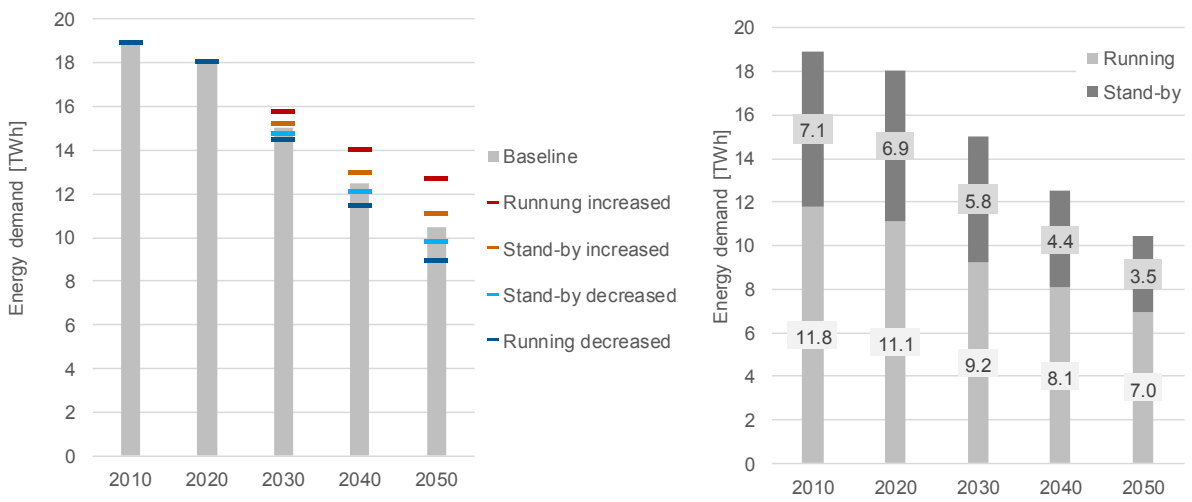

Figure 4. Energy demand projection in the baseline scenario including a sensitivity analysis concerning the running and stand-by demand for new lifts built after 2020 (left) and split by running and stand-by demand (right).

top" of each other. Though the options do not interact, this approach was chosen because it is easier and more cost-effective to address new installations and it can be expected that setting requirements to running demand is more complicated as the drive technology comes into play. Accordingly, the first two scenarios apply to new lifts put onto the market after 2019; the second set of scenarios addresses existing lifts. The first scenario follows the idea that consumption would be reduced by approximately half as compared to the no policy scenario. This could, for example, correspond to a situation with minimum energy performance standards on the stand-by consumption of lifts. The running policy yields additional saving in the running demand of new lifts. In the further scenarios, the assumption is that relevant parts of existing lifts are in addition replaced by new energy-efficient equipment. Yet some parts of the installations will not be replaced, leading to performance levels generally below those of completely new lifts.

The left part of Figure 5 shows the cumulated effect of applying the different scenarios in the year 2050. It can be seen that the policy measures all have a relatively similar effect on the achieved savings with the exception of the additional running policy for new lifts. If can further be observed that under the assumed development, lifts from the last century will only have a limited effect on overall consumption in 2050. The right part of Figure 5 shows the impact of the different policy scenarios on overall consumption. If policymaking would address the stand-by and running consumption of new lifts according to the assumptions, this would yield additional savings of 2.3 TWh per year in the year 2050, leading to an overall demand by lifts of 8.1 TWh. It can also be observed that addressing the currently existing lifts by the stand-by and running policies could yield the highest savings in 2030. However, it should be kept in mind that these savings are unlikely to be realized, on the one hand due to the comparatively high costs of such modifications, and on the other hand due to the very high number of existing lifts that would have to be addressed. That means that while the measures on new lifts reflect a technical potential, the impact of the measures on the existing lifts should therefore be rather considered as a theoretical potential that is unlikely to be realized.

FUTURE POLICY OPTIONS FOR LIFTS

There are various ways how policies could help to further decrease energy demand in line with the previously discussed scenarios.

A first kind of policy instrument would consider the performance of lifts installed in new buildings by taking the energy consumption of a lift and the well into account when the building energy consumption is assessed. Such a holistic approach could provide more attention of building planners, investors

Table 4. Summary of the scenario assumptions.

Scenario	**Description** (energy classes according to ISO 25745-2)
Stand-by policy (new lifts)	**Stand-by:** Lifts built after 2019 achieve roughly half the stand-by of the no policy scenario
+ Running policy (new lifts)	**Running:** Lifts built after 2019 improve by one class as compared to the no policy scenario
+ Stand-by (existing lifts)	**Stand-by:** Earlier lifts achieve class 2 in idle and 1 in sleep or deep sleep mode
+ Running (existing lifts)	**Running:** Earlier lifts improve by one class as compared to the no policy scenario

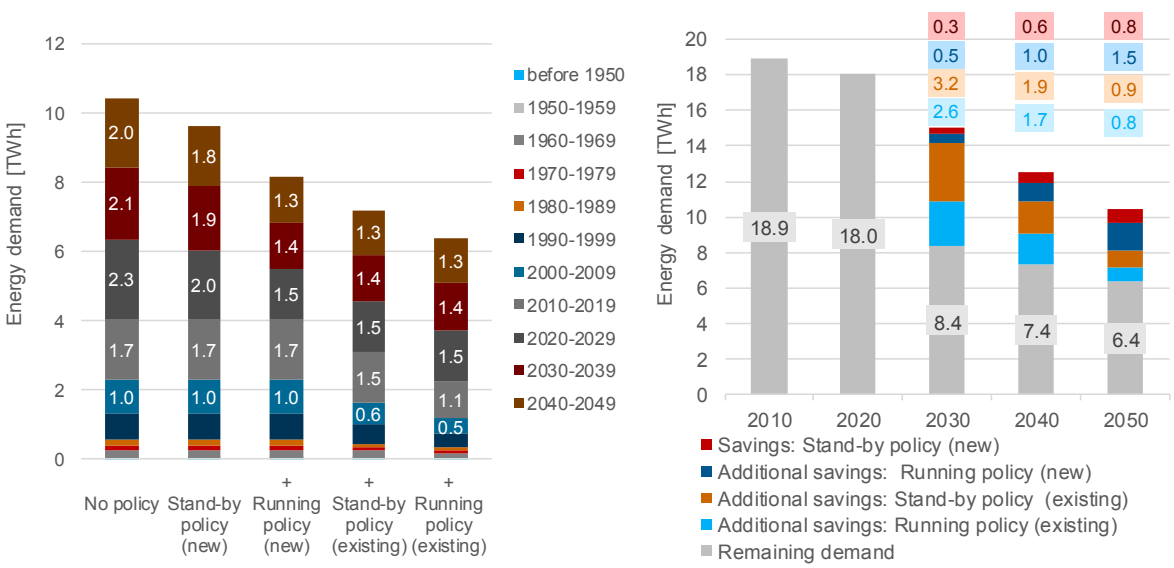

Figure 5. Energy demand in 2050 for the different scenarios (left) and savings from the different policy scenarios in the different years (right).

and potentially users to the energy efficiency of lifts. In practice, this is already possible within the current EPBD, but only if Member States systematically include lifts in their national building code. The next recast of the EPBD could ideally include lifts in the list of the technical building systems – as it is already the case for heating systems for example – so that the lift and the well would be part of the overall assessment of the building energy consumption. Concerning wells, no in-depth investigations on their relevance for energy demand are available. Yet results from some works (BfE 2004; ZVEI 2012; Urban Green Council 2015) indicate that thermal losses could be quite substantial as compared to the mere electricity demand of a lift.

Complementary to the EPBD approach, a second kind of policy instrument for new lifts could be minimum energy performance requirements set through an implementing measure within the Ecodesign Directive. Yet the process by the European Commission is still on-going.

Transparency on energy demand is also a crucial issue for lifts. ISO 25745 provides an accepted methodology to assess energy efficiency classes, but it is voluntary. Furthermore, according to the most recent Energy Labelling Regulation (2017/1369/EU) "labels that mimic the energy label should not be allowed to be used for energy-related products and non-energy-related products". Therefore, legal reasons might limit the applicability of such a rating scheme on the EU level now. Independently of the legal discussion, however, energy efficiency classes could help to identify well-performing configurations and facilitate financial instruments for fostering very efficient solutions. Therefore, adding an information requirement could contribute to raise the awareness and to improve the market transparency for energy efficient lifts.

Furthermore, the refurbishment of existing lifts presents a considerable energy saving opportunity, at least in the medium run. Though this paper does not analyse costs, it should be noticed that electricity costs especially for smaller lifts are limited and the life cycle costs are dominated by the initial investment, repair and maintenance. Extensive modifications for energy-saving reasons alone are therefore unlikely to happen on their own, also because longer construction activities might be inconvenient for users. If policies addressing the existing stock of lifts were to be implemented, different options would be available. They could include independent mandatory upgrades/replacement of very old lifts, mandatory upgrades of inefficient lifts in case of modernizations due to safety requirements or incentive programmes to encourage the modernization or replacement. Such policies to boost energy-efficient modernizations of older installations could be an option, yet it seems important to focus on new lifts first as they will determine the energy demand in the long run and because improvements are likely to provide more technically efficient and cost-effective solutions.

Conclusions

The aim of this contribution was to investigate how the energy efficiency of lifts is currently covered by European policies, to seek an understanding of the energy saving potential from lifts until 2050 and to discuss how European energy policies could tap these potentials. For this purpose, a stock model was developed and several scenarios were elaborated. The bottom-up approach used in this paper is quite data-intensive, but it also allows a detailed analysis of energy demand following the ISO 25745 standard. A review of existing policies indicates that the energy demand of lifts is currently not explicitly covered by European legislation. Further investigation based on the stock-model indicate, in line with previous findings, that there are currently approximately 4.6 million lifts in the EU-28 and that they consume approximately 18.9 TWh of electricity each year. This consumption could decline to 10.4 TWh in the year 2050 due to gradual replacements of inefficient older lifts. Under the assumptions made, policy options for new lifts could help to achieve annual savings of about 2.3 TWh of electricity in addition. These options could be based on the inclusion of lifts in the list of technical equipment in the next recast of the EPBD, by further investigating on implementing measures within the Ecodesign process and by opening up the possibility to have a European energy label for lifts that is currently not allowed. By selecting a suitable combination of these policies, it could be possible to bring passengers, goods and energy efficiency to the top floor at the same time.

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