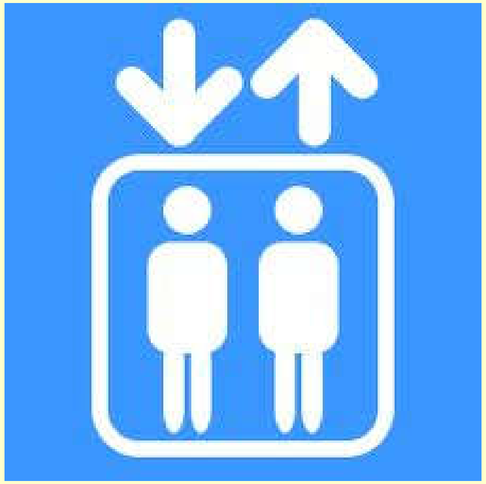
International Association of Elevator Engineers (IAEE) (HK-China Branch)
CPD Webinar, 30 Apr 2021 (Fri)



Recent technological advances for energy efficiency of lift and escalator systems

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(http://ibse.hk/cmhui/210430_IAEE-HK-China_CPD_Webinar_EE.pdf) Apr 2021

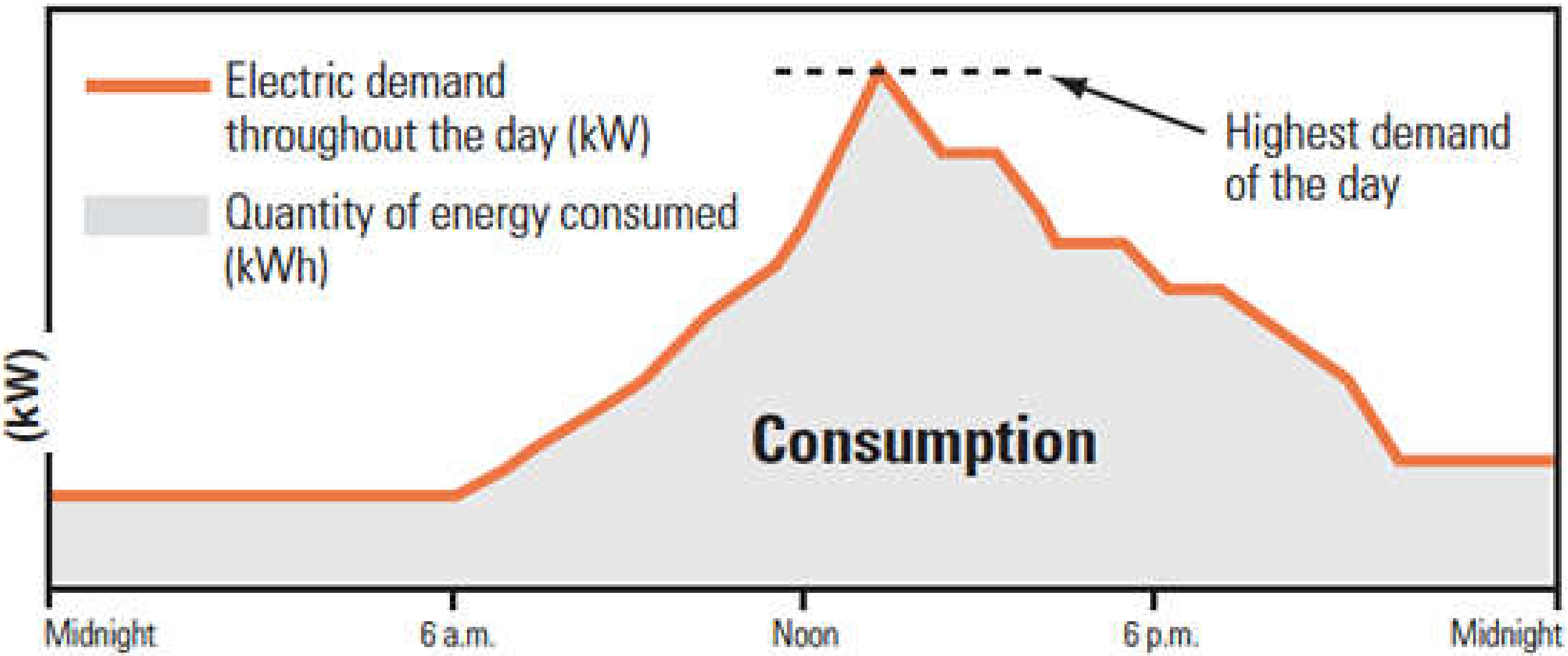
Contents

Introduction

- Lifts (elevators) and escalators
  - Very important for urban cities like HK
  - Constitute a significant part of electrical power demand & energy consumption
    - Typically consists 5-15% of electricity in high-rise commercial & residential buildings
    - Also affects peak energy demand & power factor
  - Good potential for energy saving
    - Research in Europe (the E4 Project*) indicated large saving potential for lifts (> 60%) & escalators (~30%)

(* E4 - Energy Efficient Elevators and Escalators http://www.e4project.eu/)

Electricity consumption & maximum/peak power demand

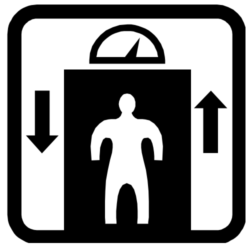


Total electricity charge
= Electricity consumption charge (kWh)
+ Peak demand charge (KW)

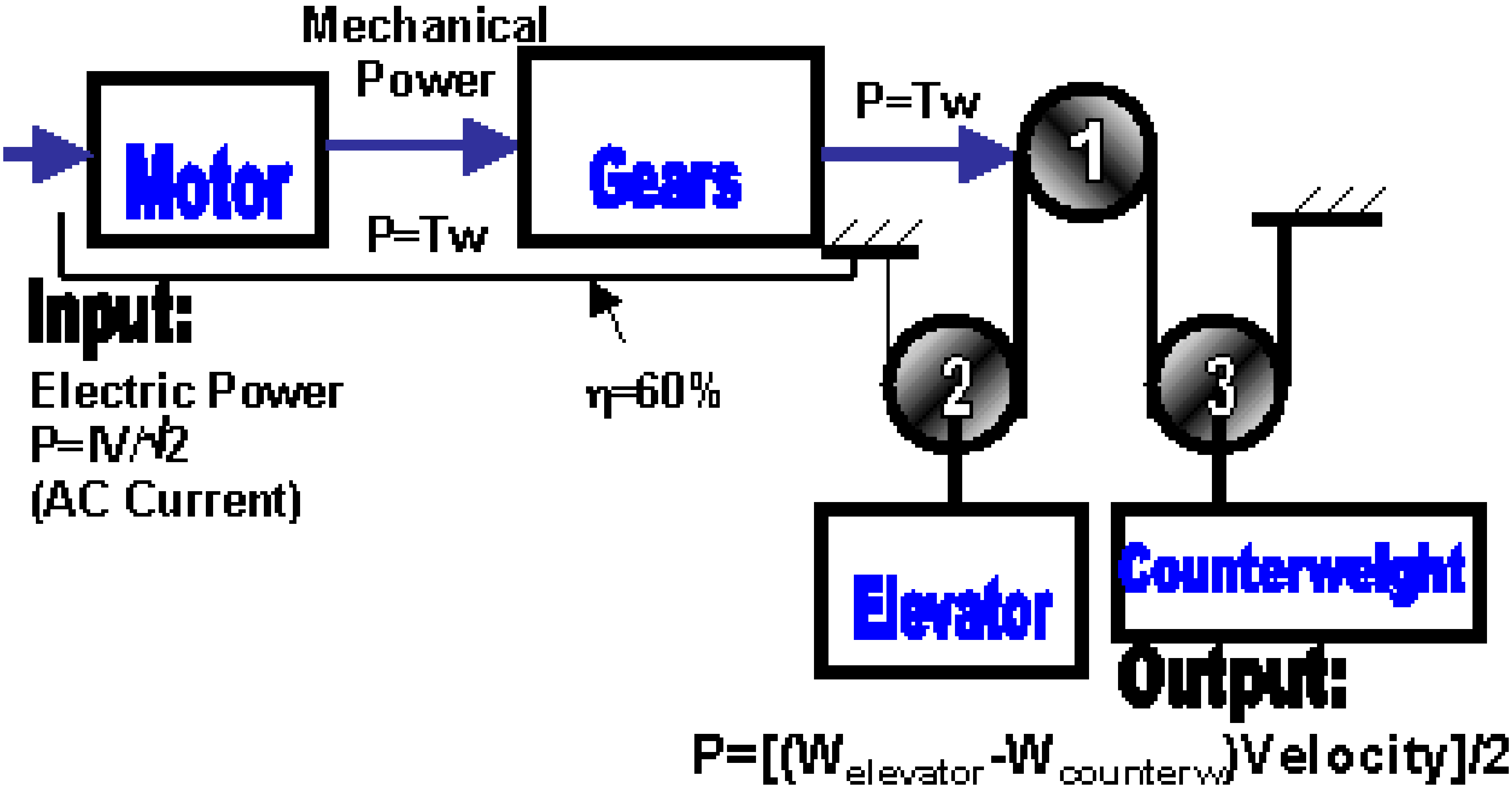
(Image source: https://www.energyly.com/blog/electricity-maximum-demand/)

Introduction

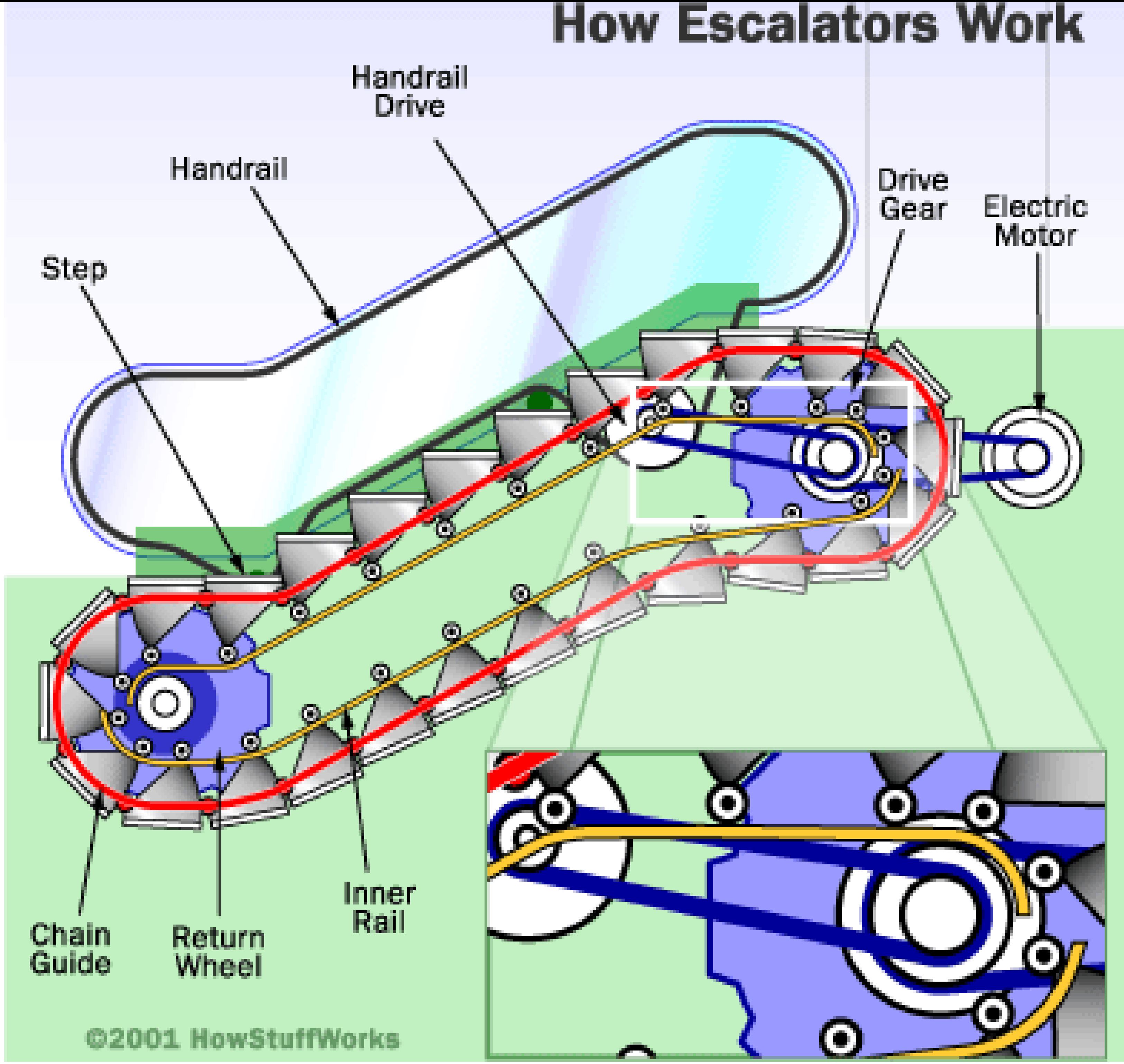
- The energy use of lifts & escalators depends on the device type, location of installation & usage intensity connected to passenger traffic
- Construction factors (motor type, drive & control, roping ratio & overbalancing of the system, etc.) & operation parameters (e.g. rated speed, acceleration/deceleration, travel distance, travel direction, nominal load, number of trips) influence energy efficiency



Power flow through a typical elevator

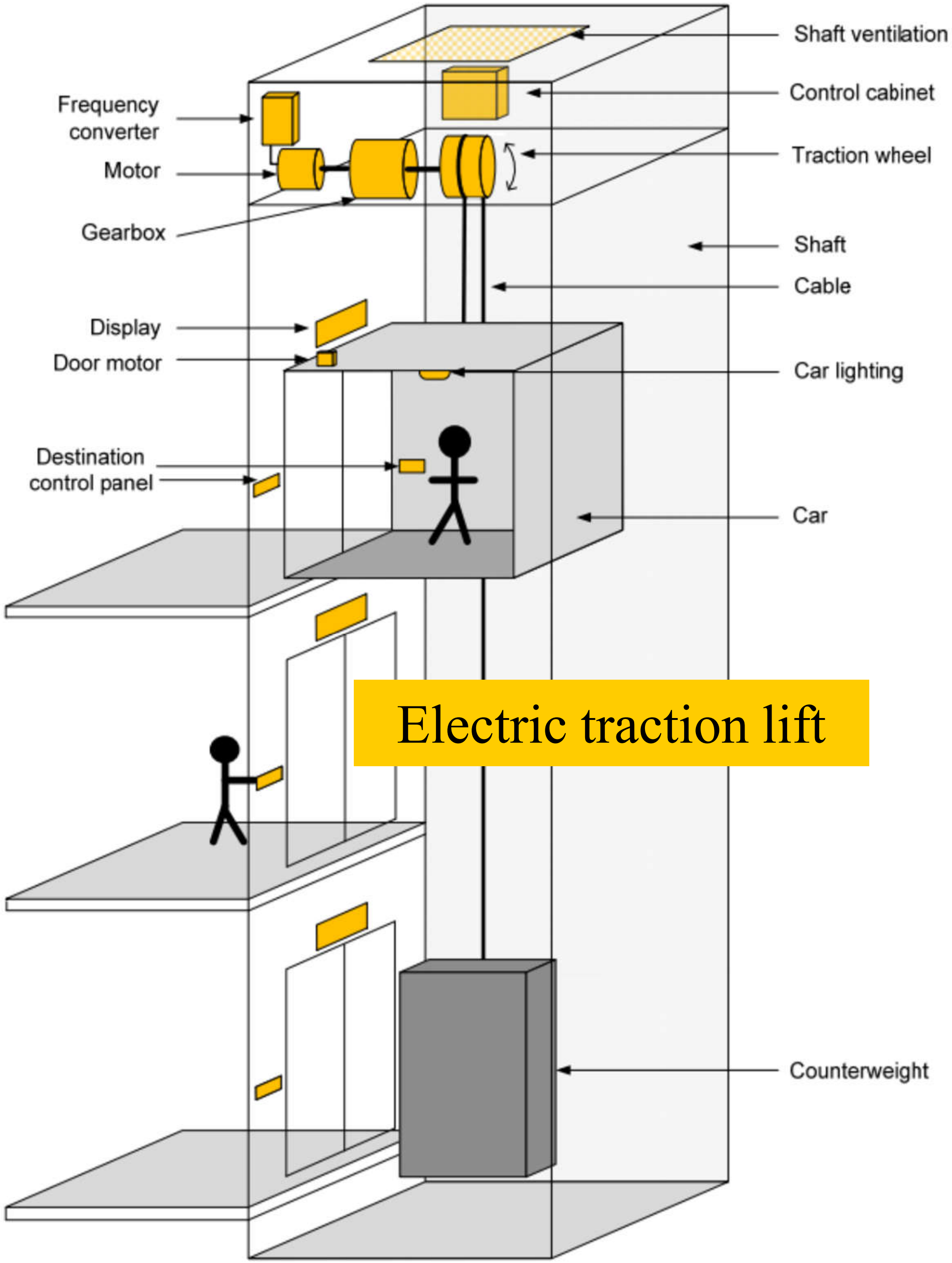


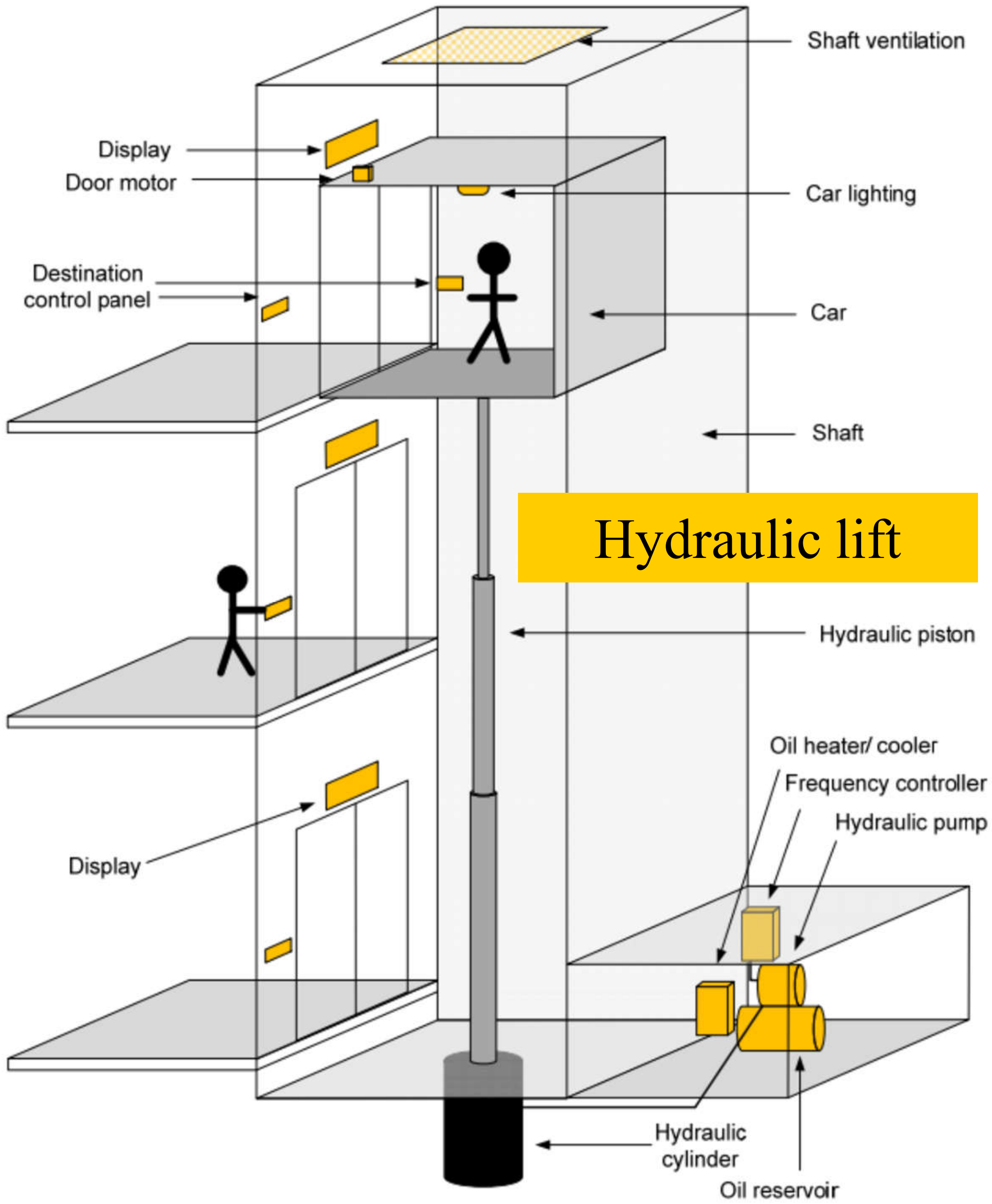
[Source: How an elevator works http://web.mit.edu/2.972/www/reports/elevator/elevator.html]



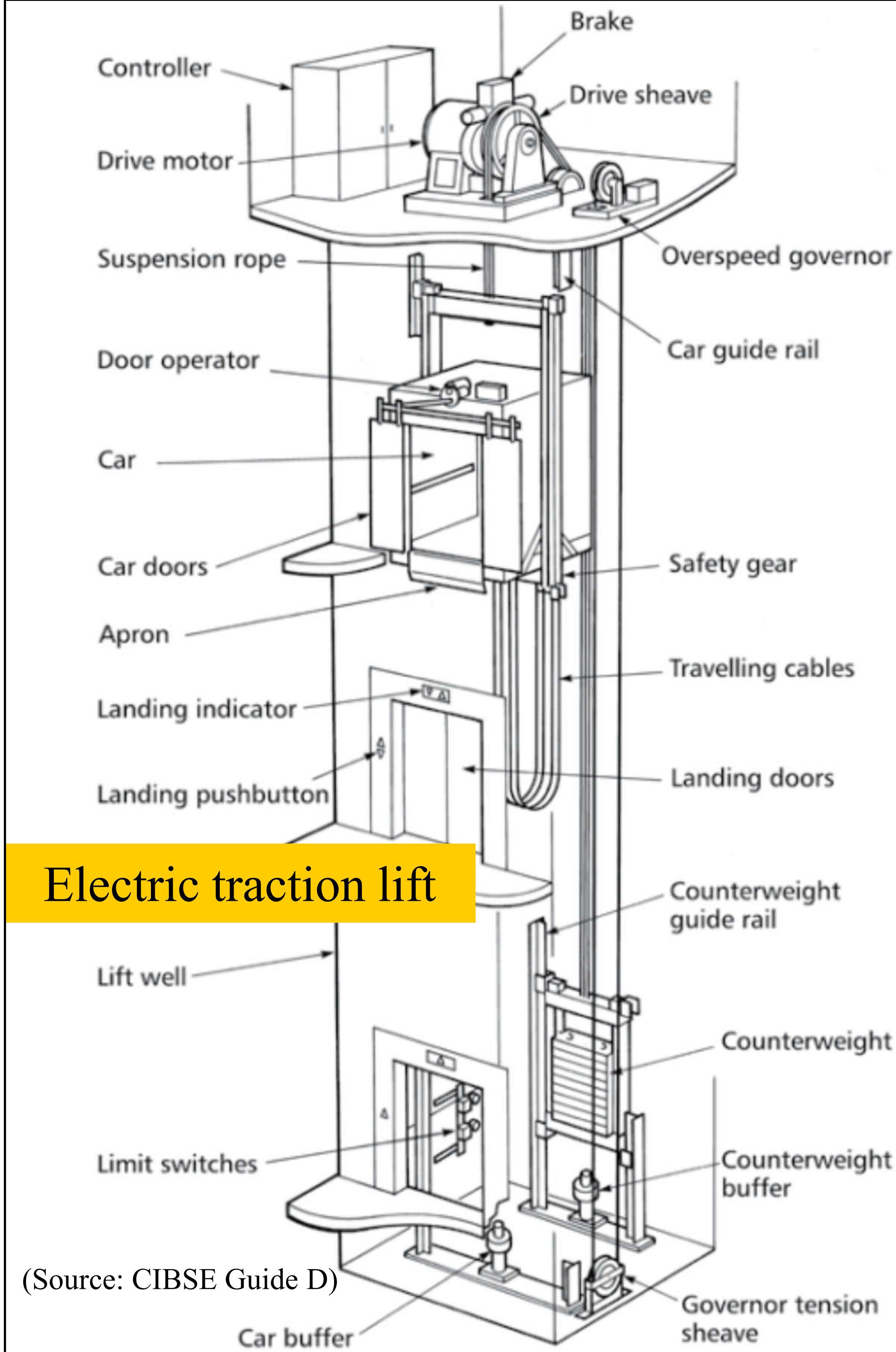
[Source: http://www.howstuffworks.com/]

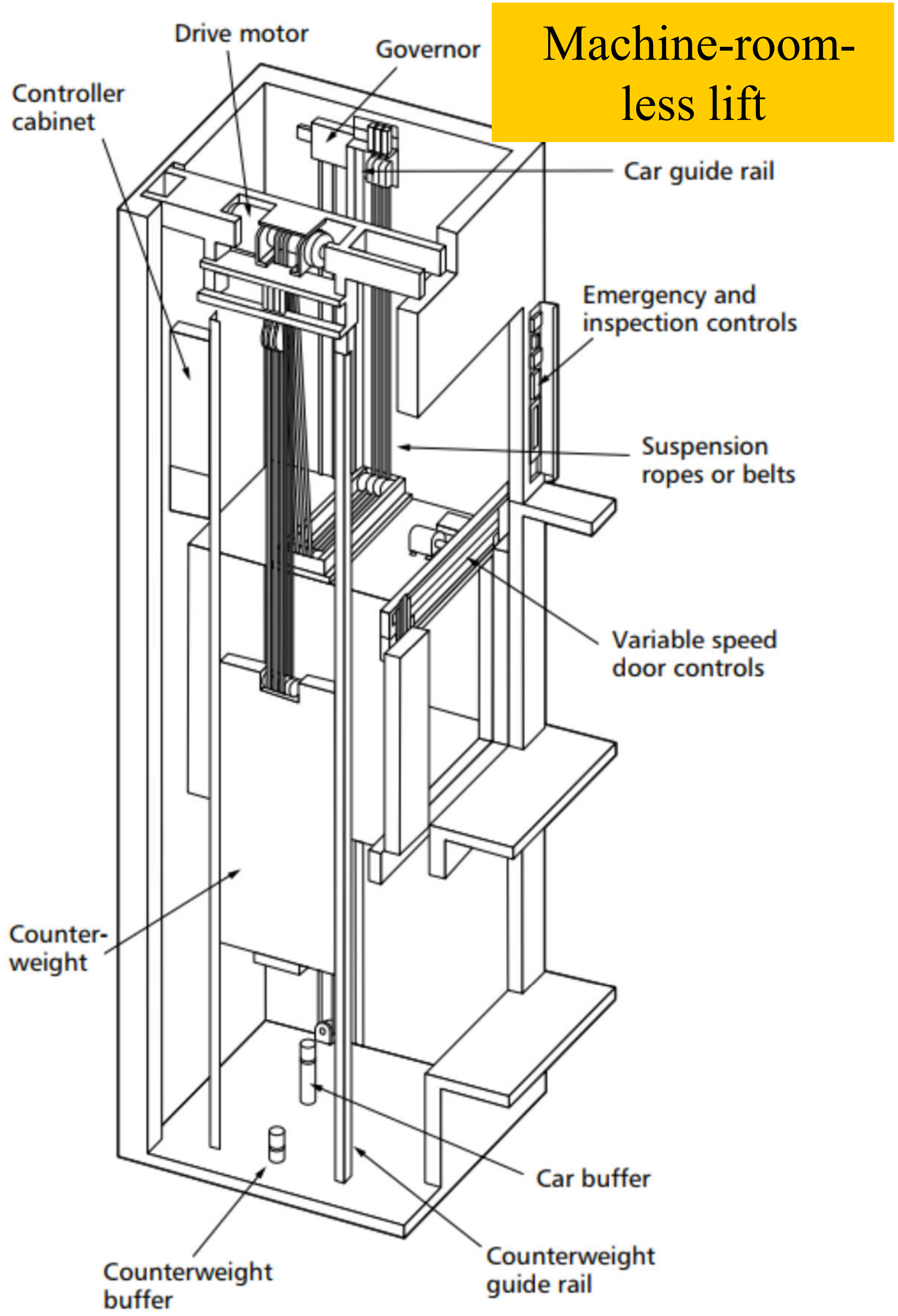
Simplified representation of electric traction lift & hydraulic lift





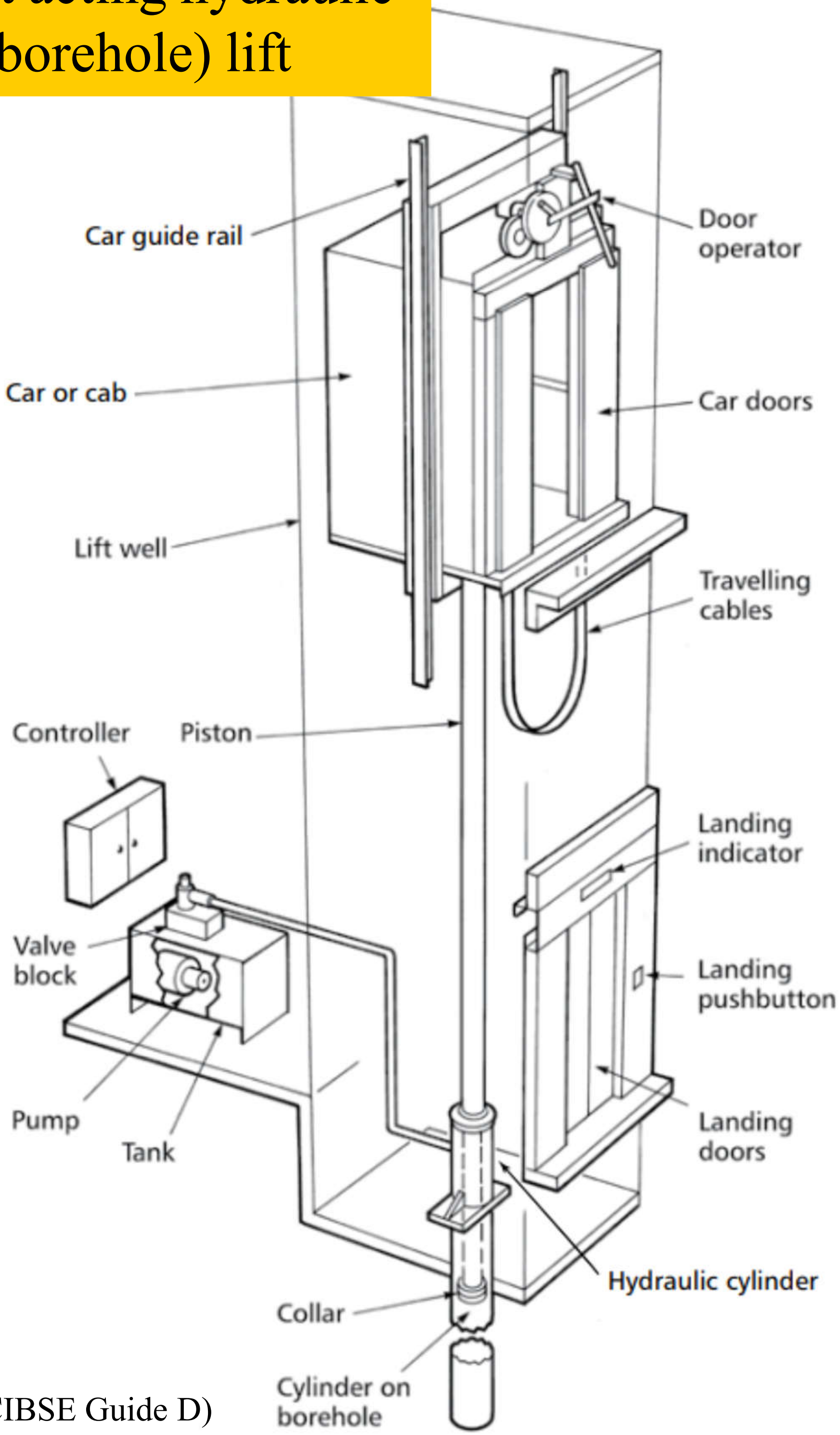
(Source: Fraunhofer ISI)



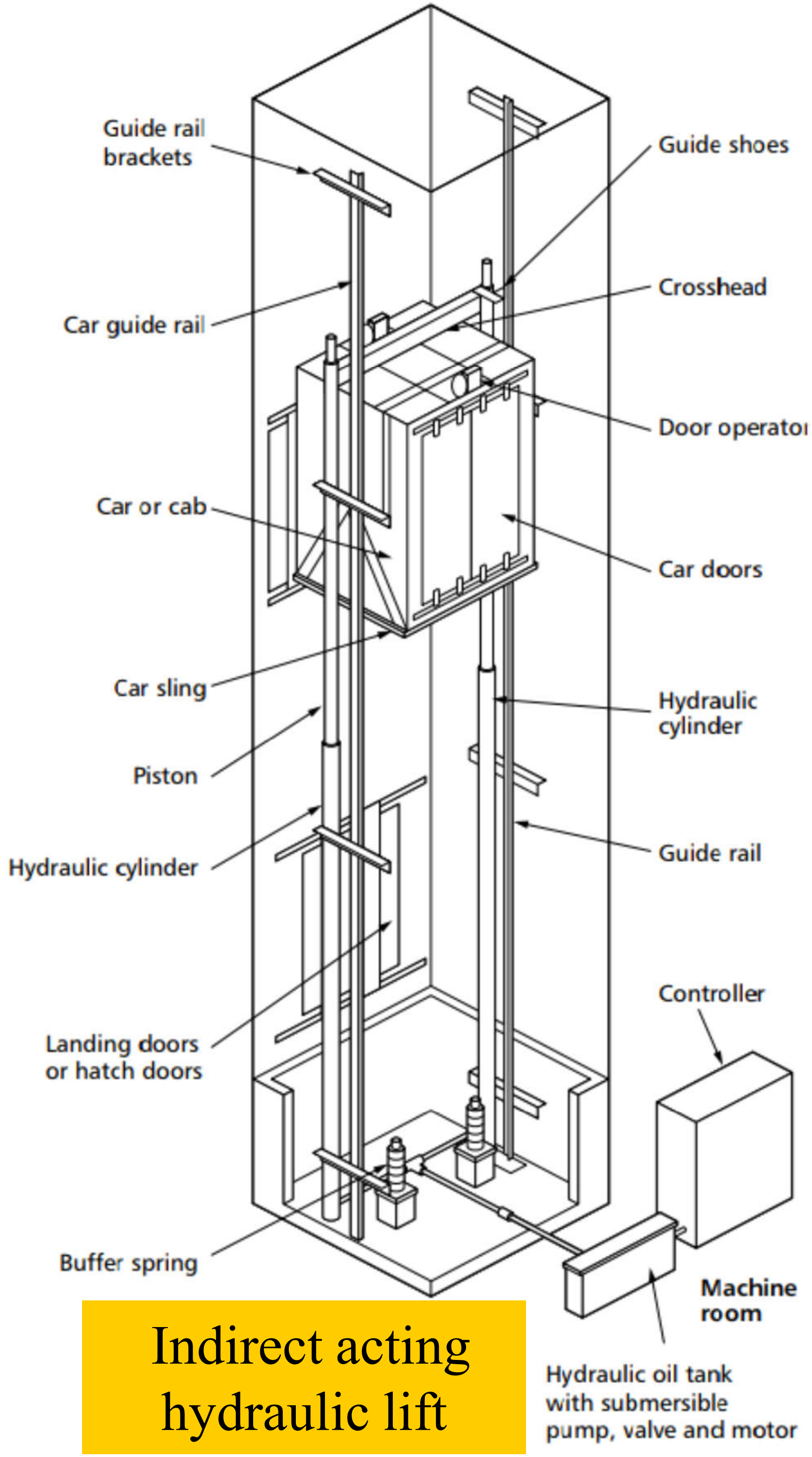


(Source: CIBSE Guide D)

Direct acting hydraulic (borehole) lift



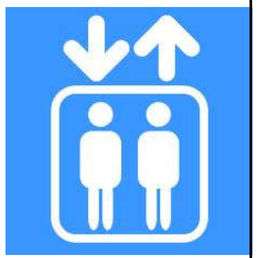
(Source: CIBSE Guide D)



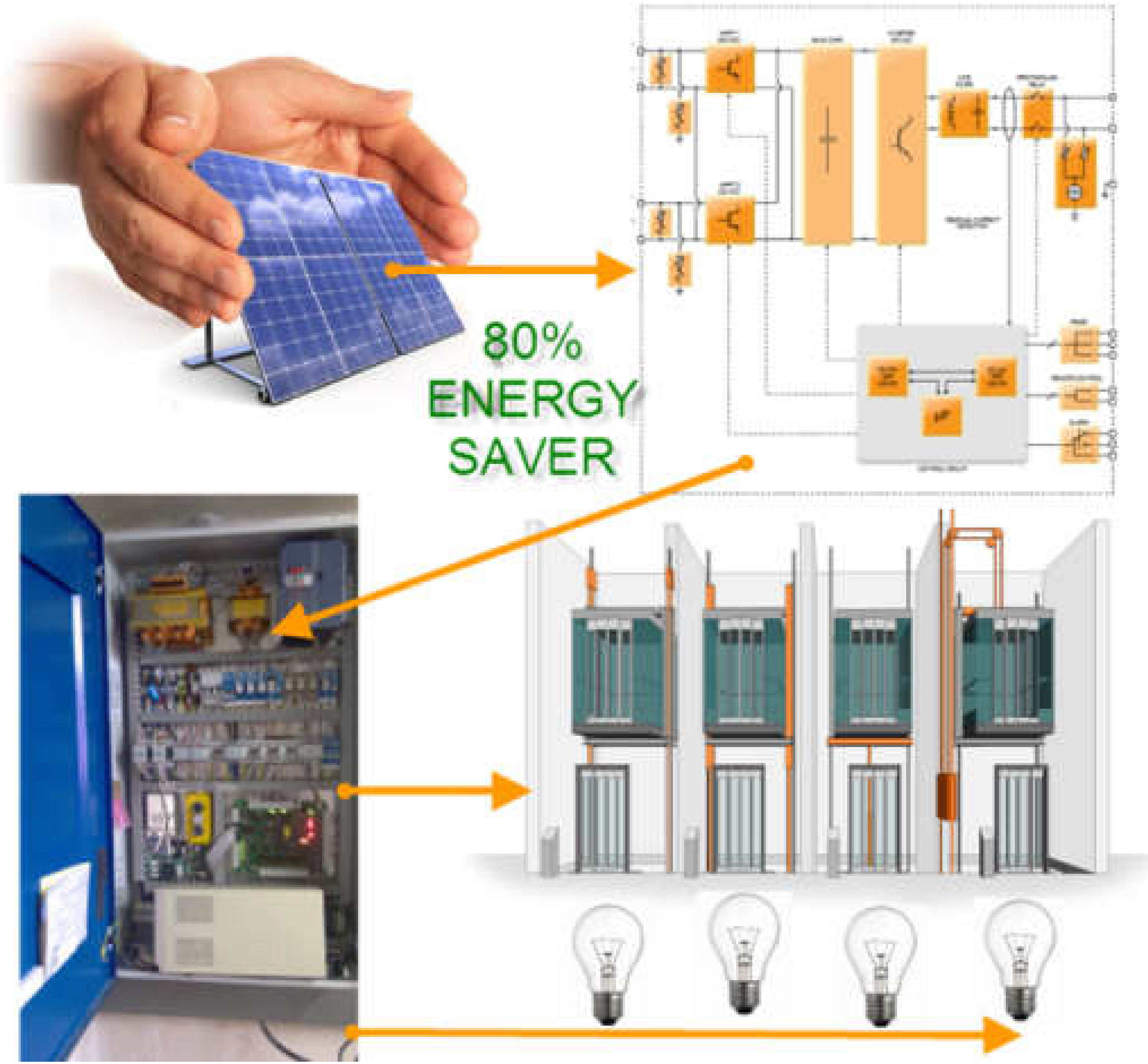
Indirect acting hydraulic lift

Introduction

- Recent technological advances to improve hardware, controls & other systems, and even generate electricity that a facility can use
- Energy is wasted in idle & standby situations
  - Standby power of lifts & escalators was often overlooked
  - If standby duration is long, the standby power consumption is significant
    - Standby consumption 25%-80% of total lift energy; could be up to 95% if low frequency of use



Energy efficient system connected to the network of lifts



(Source: https://ascensoriscalemobili.wordpress.com/energy-efficient-elevators-escalators-and-regeneration/)

Energy use for lift & escalator systems

- Electricity supply for lifts & escalators

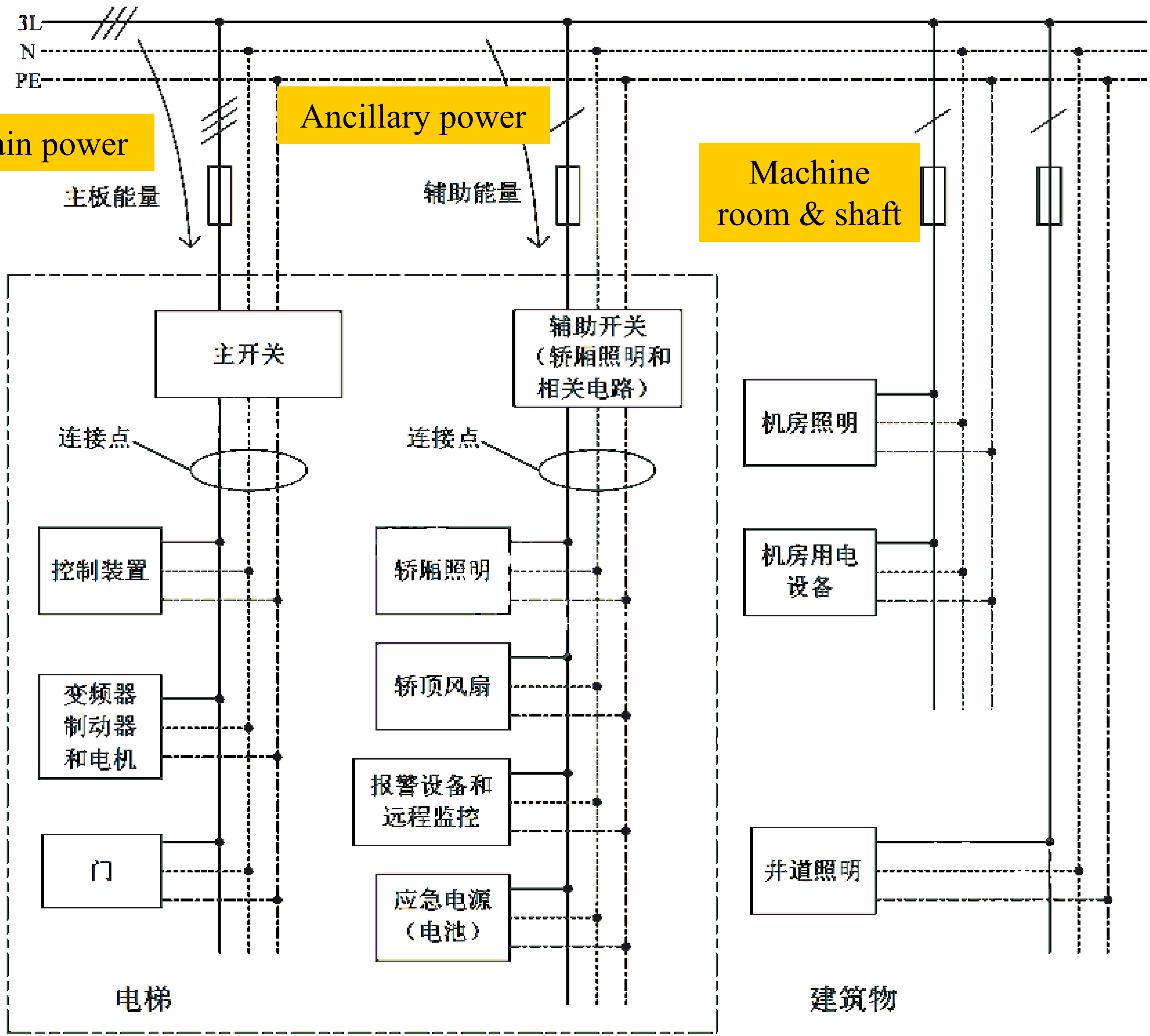
  - Separated into main power & ancillary power
  - Main power:
    - Motor drive, controller, converter & brake, door
  - Ancillary power:
    - Car lighting, ventilation (air-conditioning), alarm, telecom, CCTV, emergency power (battery)
  - Other equipment in machine room, shaft or hoist way (e.g. lighting & ventilation)
  - Standby power is affected by ancillary equipment

Main power, ancillary power & other equipment

For lifts:	
Main power	Controller, motor, converter and brake, doors
Ancillary power	Car light, ventilation fan on car, alarm device and tele-monitoring, emergency power supply (battery)
Other equipment	Hoistway light, machine room light and ventilation
For escalators or moving walks:	
Main power	Controller, motor, converter and brake, step gap lighting, comb plate lighting, direction indicator
Ancillary power	Lightings (balustrade, etc.), remote alarm and monitoring
Other equipment	External machine room light and ventilation

*** Information adapted from ISO (2012).**

Electric power flow for a lift system



(Source: DB42/T 1521—2019 电梯能效测试与评价规则, 湖北省地方标准, 湖北省市场监督管理局.)

Comparison of different types of lift & escalator systems

Type of system	Typical applications	Advantages	Disadvantages
Hydraulic	Low rise 2-6 floors	Low cost	Slow, high energy use, maintenance issues
Traction machine room-less	Low-Mid rise 2-10 floors	Easy installation, energy savings, faster then hydraulic option	Higher cost than hydraulic option
Traction geared	Mid rise 3-25 floors	Low cost for application	Speed, energy consumption
Traction gearless (direct drive)	High rise over 25 floors	High speed	High cost

Likely division of traffic between lifts & escalators

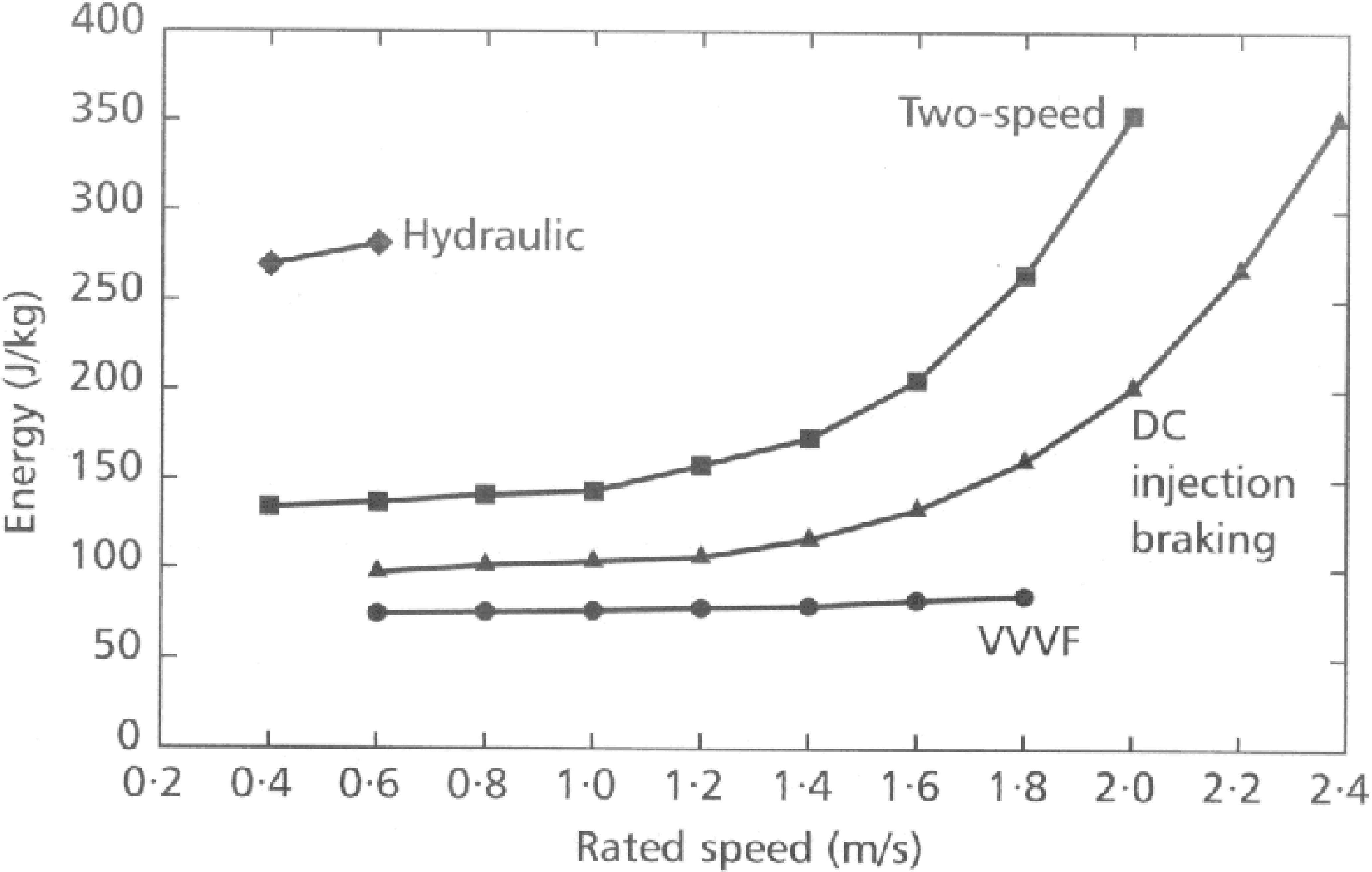
Floor travelled	Escalator	Lift
1	90%	10%
2	75%	25%
3	50%	50%
4	25%	75%
5	10%	90%

[Source: CIBSE Guide D]

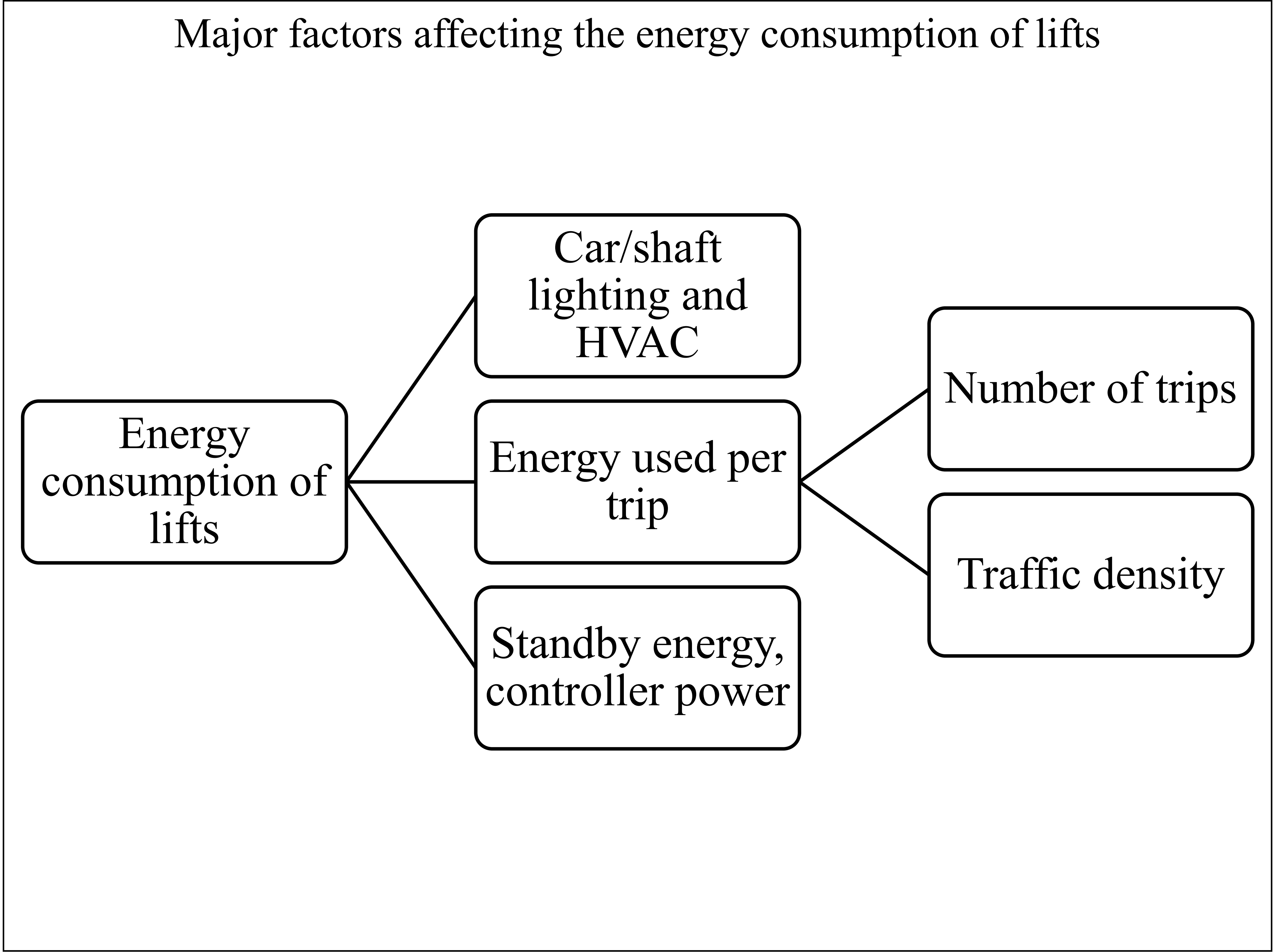
Energy use for lift & escalator systems

- Factors affecting energy consumption
  - Type of drive (hydraulic, two-speed, etc.)
  - Mechanical design (e.g. gearbox)
  - Efficiency of various components
  - Reduction of inertia (e.g. flywheel)
  - Type of gearing (if applicable)
  - Possibility of electricity regeneration
  - Running power factor
  - Loading (level of usage)

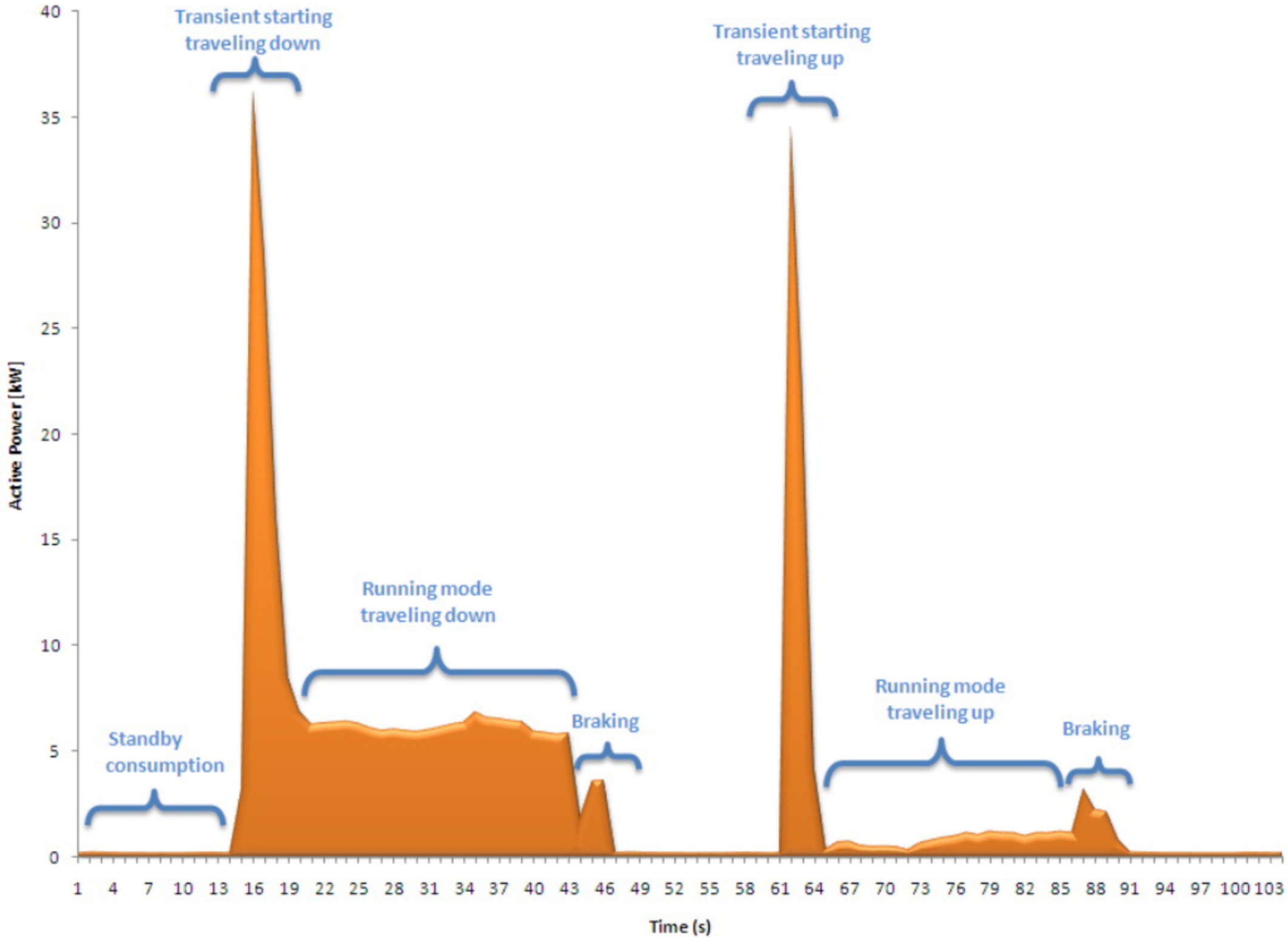
Energy consumption of various types of drives



[Source: CIBSE Guide D]

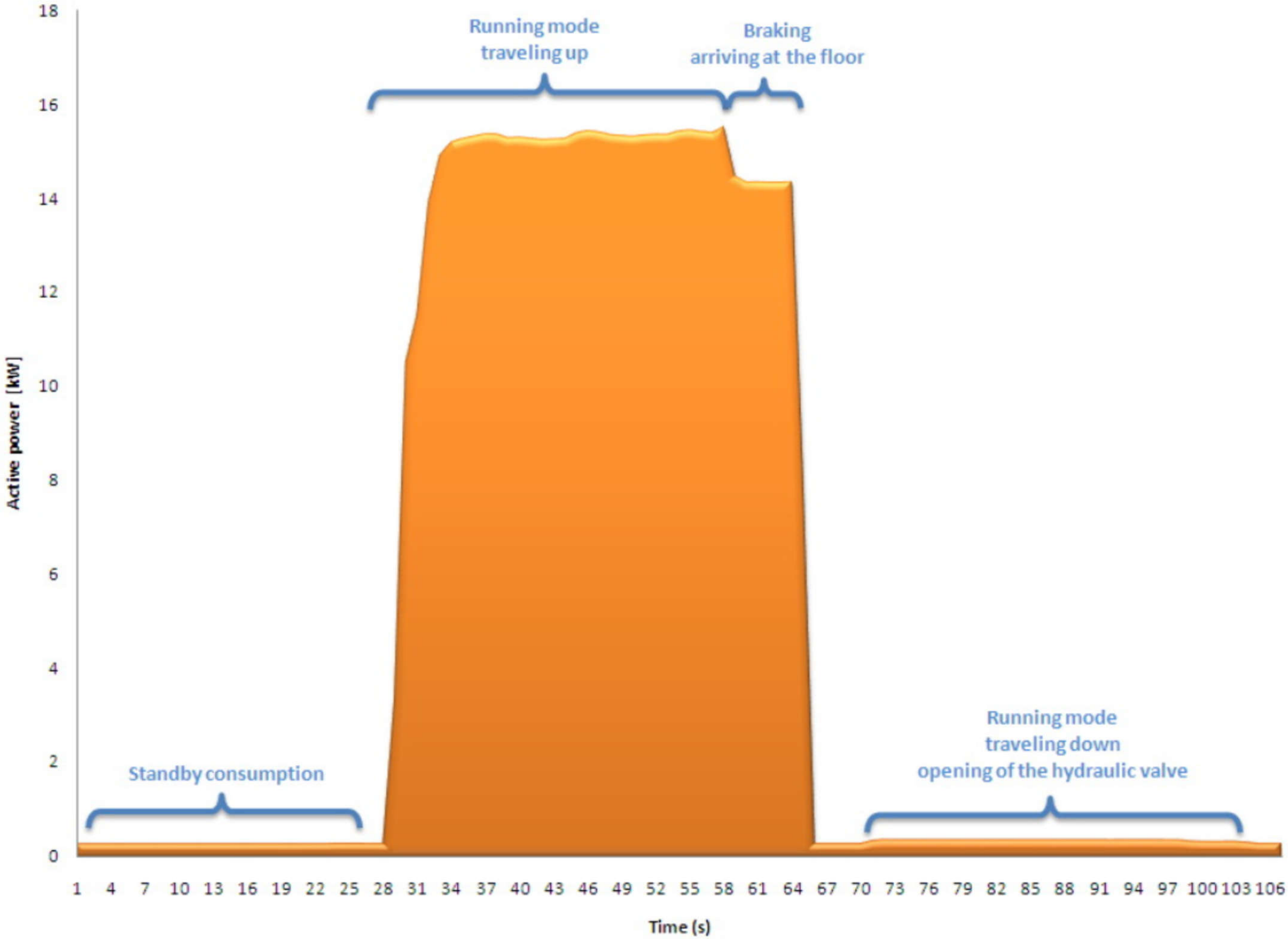

Major factors affecting the energy consumption of lifts
Energy consumption of lifts
Car/shaft lighting and HVAC
Energy used per trip
Standby energy, controller power
Number of trips
Traffic density

Typical cycle of a traction lift



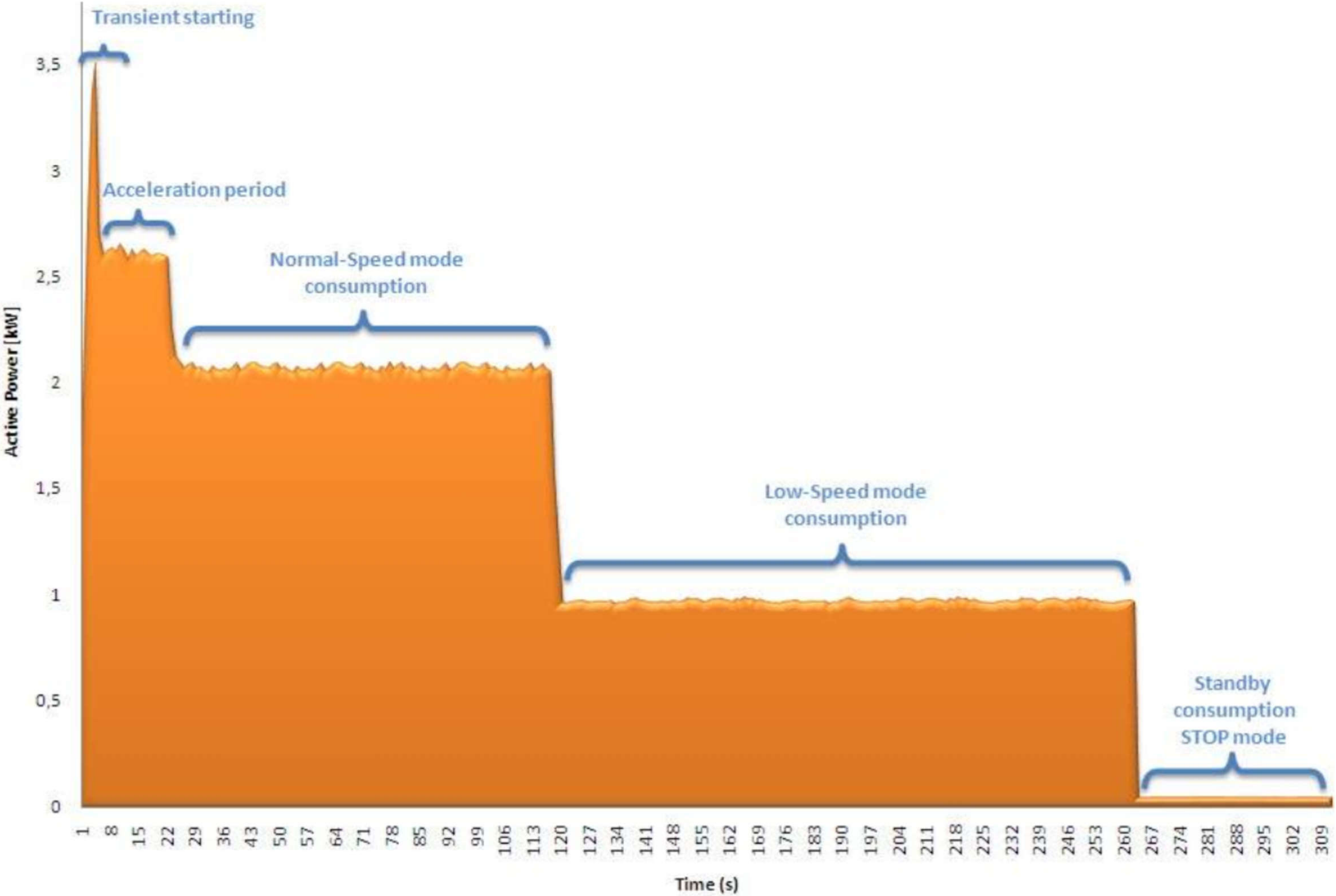
(Source: ISR-University of Coimbra, 2010. *E4 Energy-Efficient Elevators and Escalators*, technical report prepared for the Intelligent Energy of European Commission, University of Coimbra, Portugal.)

Typical cycle of a hydraulic lift



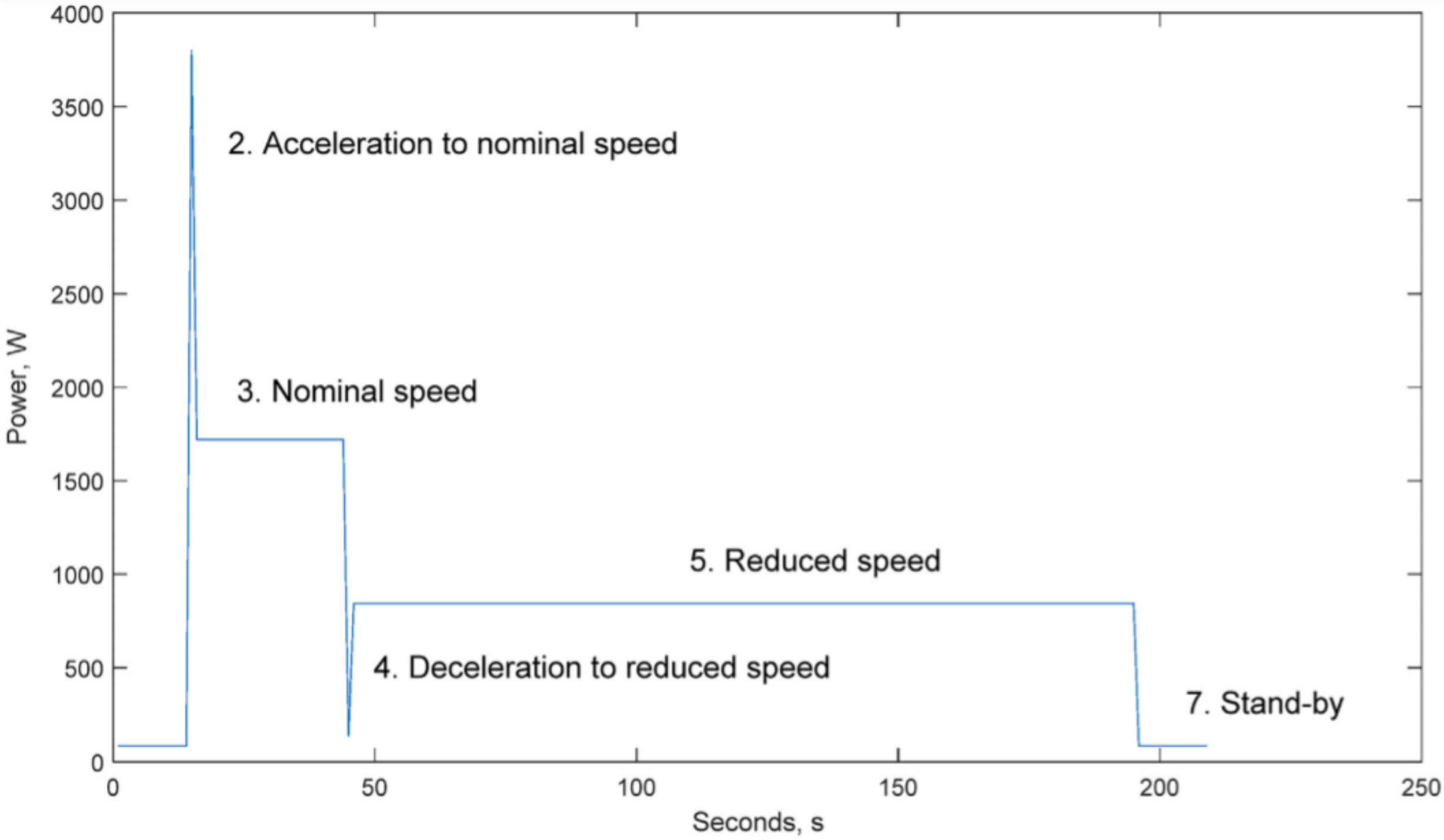
(Source: ISR-University of Coimbra, 2010. *E4 Energy-Efficient Elevators and Escalators*, technical report prepared for the Intelligent Energy of European Commission, University of Coimbra, Portugal.)

Active power of an escalator in different operation modes



(Source: ISR-University of Coimbra, 2010. *E4 Energy-Efficient Elevators and Escalators*, technical report prepared for the Intelligent Energy of European Commission, University of Coimbra, Portugal.)

Example of a power demand cycle for escalators



(Source: Uimonen S., Tukia T., Siikonen M.-L. & Lehtonen M., 2017. Impact of daily passenger traffic on energy consumption of intermittent-operating escalators, *Energy and Buildings*, 140: 348-358.)

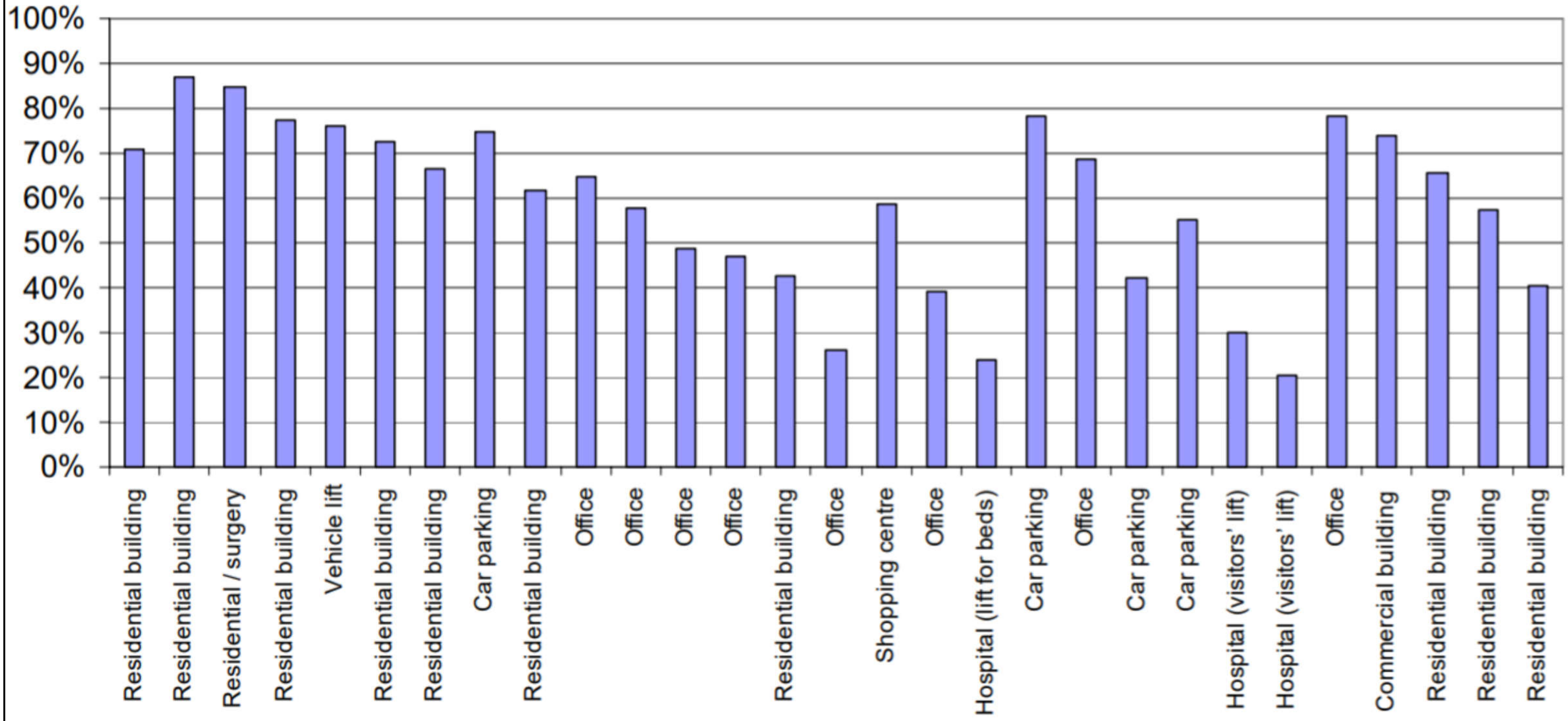
Energy use for lift & escalator systems

- Standby power consumption
  - Usually they are idle far more than running
  - Different conditions of operation:
    - For lifts: running, idle, standby (5 or 30 minutes)
    - For escalators: load, no load, standby
      - Standby modes: automatic low speed, automatic stop, manual stop
  - Major factors:
    - Lifts: cabin lights, door locking, air conditioner
    - Escalators: main power, passenger characteristics

Energy use for lift & escalator systems

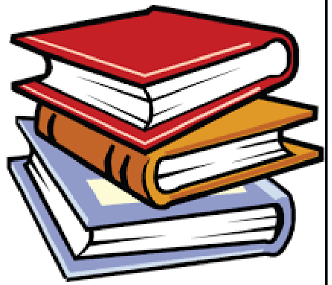
- Standby consumption for lift units
  - 10.4% to 98.5% of total lift electricity use
  - Affected by usage, vertical rise and rated speed
  - Idle power: varies from 208 W to 2577 W
  - Without air-conditioner, 200 W to 500 W only
- Annual S/R (stop/run) ratios for escalators
  - Are rather low (0.05 to 0.45)
  - Around 0.3 to 0.4 for escalators with “start-slow”
  - Upward consumes more energy than downward

Proportion of standby to overall energy consumption, by type of building



(Source: http://www.arena-energie.ch/d/_data/EEDAL-ID131_Lifts_Nipkow.pdf)

Latest research & technical standards



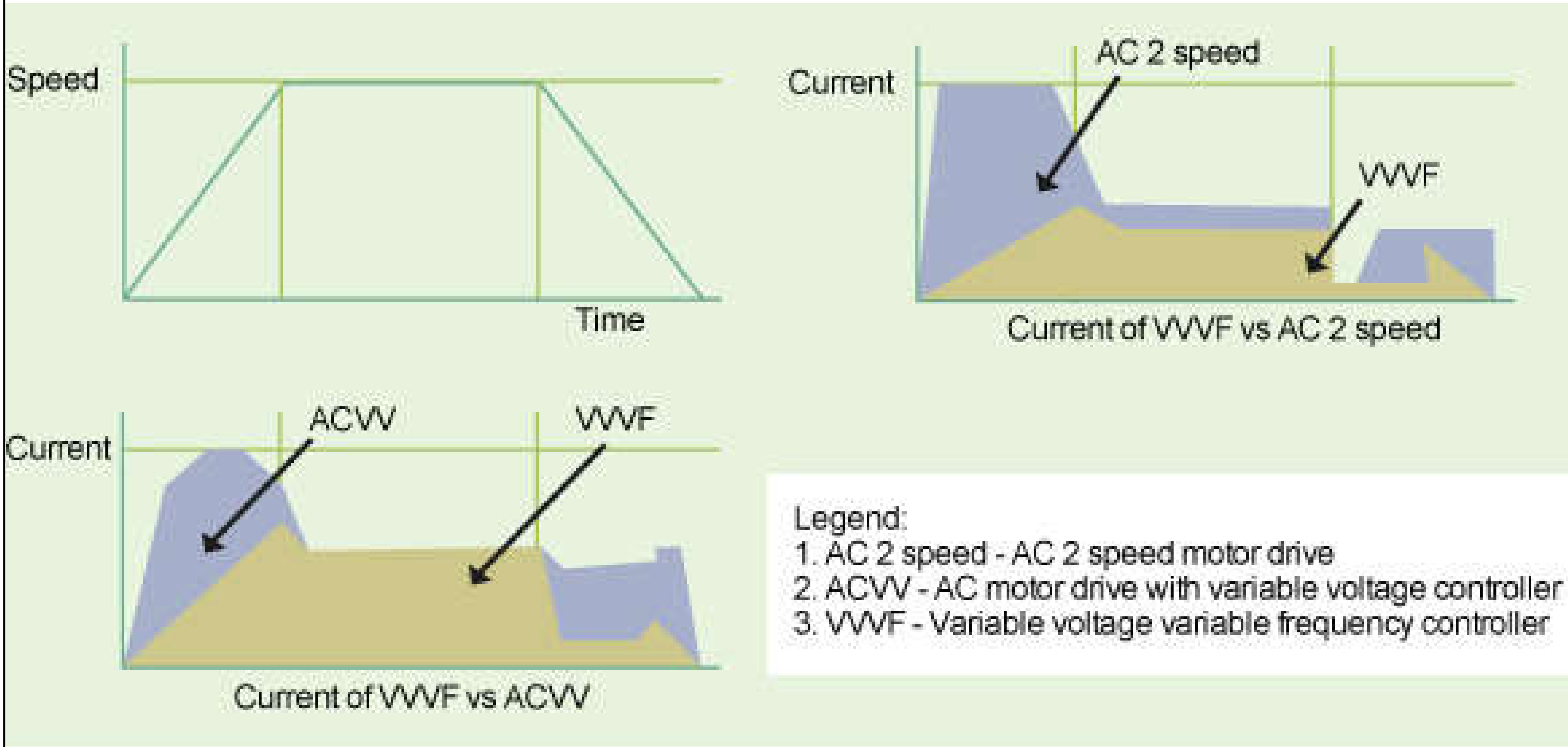
- The power consumption is affected by traffic demand, operation characteristics, control methods & drive technology
- Should turn off non-critical components & apply smart controls to save energy & reduce wastage with new technologies
- Need to overcome market barriers, raise awareness & set up suitable policies to promote energy efficiency

Current and emerging lift & escalator technologies

- High efficiency induction motors
- Linear motors
- Advanced drives & regeneration
- Variable voltage variable frequency (VVVF) lift power systems
- Regenerative function which recovers braking energy from lift operation
- Machine-room-less lift systems
- Permanent magnet motors
- Traffic handling/management
- Transmission and roping
- Other lift loads (stand-by loads, doors, lights, fans for ventilation, safety devices, automatic controls, sensors, etc.)
- Efficient hydraulic lifts
- Efficient escalators & moving walks
- Low friction bearings
- Integration with renewable energy systems (e.g. photovoltaic)

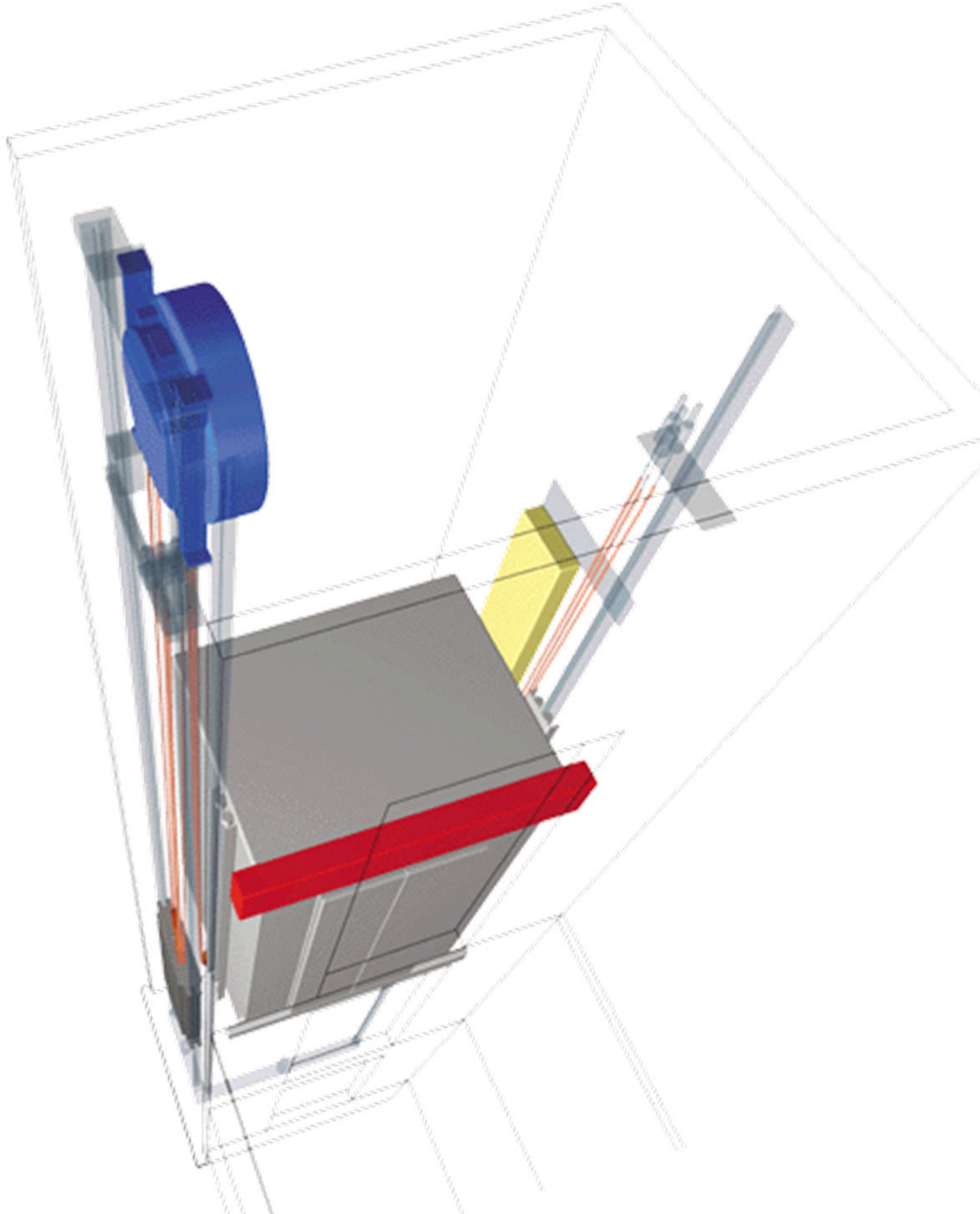
(Source: ISR-University of Coimbra, 2010. *E4 Energy-Efficient Elevators and Escalators*, technical report prepared for the Intelligent Energy of European Commission, University of Coimbra, Portugal.)

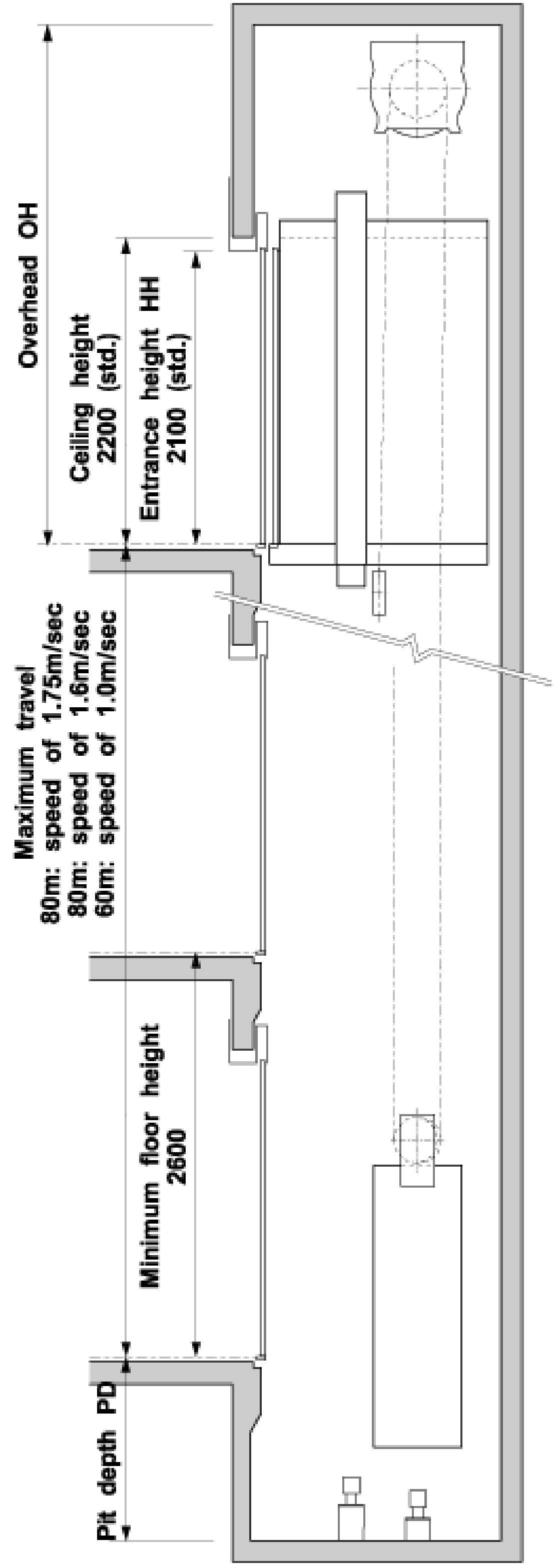
Operating characteristics of different motor drives for lifts



(Source: https://www.emsd.gov.hk/energyland/en/appAndEquip/equipment/lifts/vvvf.html)

Machine-room-less lift system





What are the advantages?

Traction elevator technologies

Component	Basic efficiency	Intermediate efficiency	Advanced efficiency
Hoist drive	Motor-generator or direct-current with silicon-controlled rectifiers	Gearless	Permanent magnet, gearless
Car lift	Wire rope	Wire rope	Polyurethane-coated belts, multiple rope
Controls	Electromechanical relays, group controller	Microprocessor	Software-defined (e.g., destination dispatch)
Lighting, ventilation	Incandescent, halogen	CFLs, efficient fans	LEDs, efficient fans, occupancy sensors
Energy sources	Grid	Grid plus regeneration	Regeneration plus solar
Considerations	Single operating mode, needs machine room	Standby mode, better power factor	Standby mode, variable door motors, power factor near 1, MRL, quick installation

Note: MRL = machine room–less.

Source: American Council for an Energy-Efficient Economy

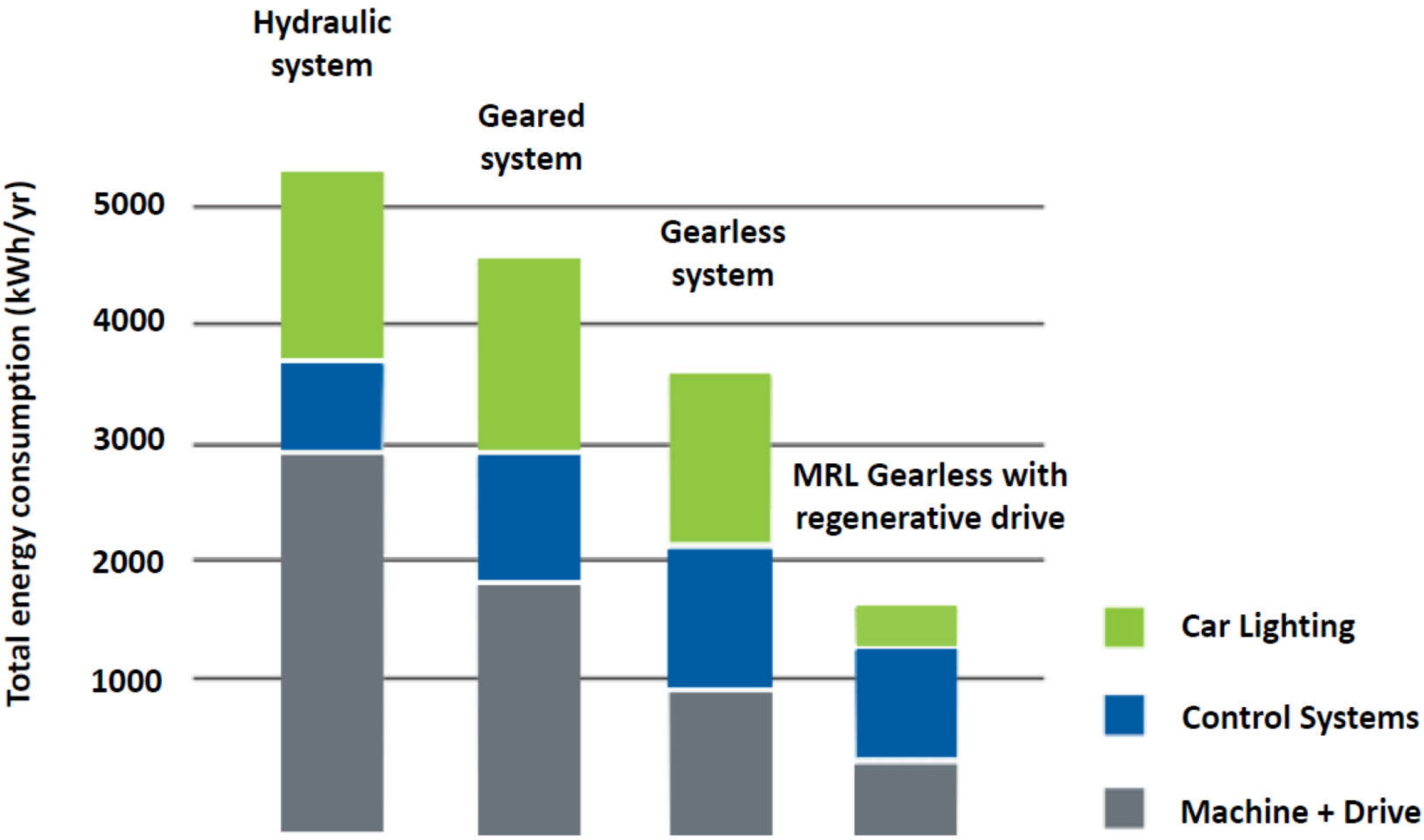
Characteristics of premium-efficiency elevators

Building type	Conventional elevators	Conventional drive type	Premium-efficiency elevators	Premium-drive type	Energy savings possible (%)
Low-rise (6 or fewer floors)	Hydraulic	Any	Geared regenerative, gearless nonregenerative, gearless regenerative	AC VVVF	21–24
Mid-rise (7–24 floors)	Geared nonregenerative	AC VVVF	Geared regenerative, gearless nonregenerative, gearless regenerative	AC VVVF, DC SCR, DC PWM	31–45
High-rise (25 or more floors)	Geared nonregenerative	AC VVVF	Geared regenerative, gearless nonregenerative, gearless regenerative	AC VVVF, DC SCR, DC PWM	30–43

Notes: AC = alternating current; DC = direct current; PWM = pulse-width modulating;
SCR = silicon-controlled rectifier; VVVF = variable voltage, variable frequency.

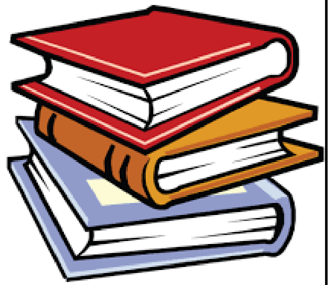
(Source: Elevators (Business Energy Advisor) https://ouc.bizenergyadvisor.com/article/elevators)

A comparison of energy consumptions among different lift systems



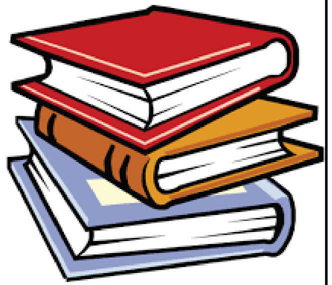
(Source: http://www.otisworldwide.com)

Latest research & technical standards



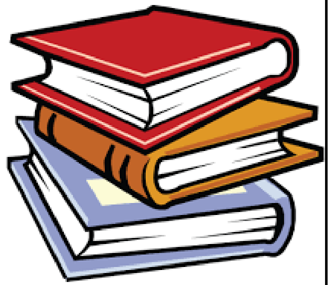
- Key points for efficient hydraulic lifts
  - Losses in the pump & the valve unit
  - The potential energy is dissipated as heat when travelling down
  - Absence of counterweight to balance the potential energy needed to lift the car
  - The pump works at constant flow, wasting energy during acceleration and deceleration
  - Oil cooling or heating to maintain suitable viscosity

Latest research & technical standards



- Technical standards for analysis
  - ISO 25745 and VDI 4707 (from Verein Deutscher Ingenieure (VDI), Association of German Engineers, Düsseldorf, Germany)
  - Evaluate the energy efficiency of lifts, escalators & moving walks
  - Define standby mode, travel & standby demand
  - Procedures for making measurements & calculations

Latest research & technical standards



- ISO 25745 - Energy performance of lifts, escalators and moving walks
  - Part 1: Energy measurement and verification
  - Part 2: Energy calculation and classification for lifts
  - Part 3: Energy calculation and classification of escalators and moving walks
- VDI 4707 - Energy efficient label for elevators
  - Part 1: Energy efficiency
  - Part 2: Energy efficiency of components
  - Part 3: Energy efficiency of lifts under the machinery directives

Definitions of idle, standby & load conditions

For lifts:	
Idle condition	condition when a lift is stationary at a floor following a run before the standby mode is entered
Standby condition	condition when a lift is stationary at a floor and may have reduced the power consumption to a lower level set for that particular lift
For escalators or moving walks:	
Load condition	condition in which an escalator or moving walk is running with one or more passengers
No load condition	condition when an escalator or moving walk is running at nominal speed without passengers
Standby condition	condition when an escalator or moving walk is stationary and powered on and can be started by authorized personnel

*** Information extracted from ISO (2015a & 2015b).**

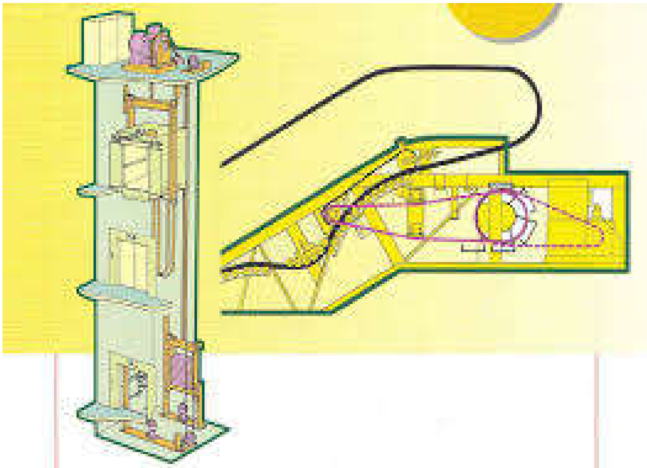
Guidelines for reducing energy consumption of escalators

Measure	Description	Remark
Auto start	Stopping the unit in case of absence of passengers	Reduction by switching from $E_{no\ load}$ to $E_{stand\ by}$
Slow speed	Slow down the unit to slow speed in case of absence of passengers	Reduction by switching from $E_{no\ load}$ to $E_{slow\ speed}$
Power OFF	Switch off the main supply, e.g during night	Reduction by switching $E_{standby}$ off
Power OFF ancillary equipment	Switch off the ancillary equipment supply	Reduction by switching $E_{ancillary}$ off
Motor voltage control	Load depending voltage reduction, e.g. star delta switching, frequency converter, voltage control	Improvement of η of motor resulting in reduction of $E_{no\ load,}$ $E_{slow\ speed}$ and partial load condition
Gear efficiency improvement	Usage of gear technologies with improved efficiency, e.g. helical gear	Improvement of η of gear resulting in reduction of $E_{no\ load}$, $E_{slow\ speed}$ and any load condition
Motor efficiency improvement	Usage of motor technologies with improved efficiency	Improvement of η of motor resulting in reduction of $E_{no\ load,}$ $E_{slow\ speed}$ and any load condition
Handrail system efficiency improvement	Usage of low friction handrail components	Reduction of $E_{no\ load}$, $E_{friction}$, $E_{slow\ speed}$ and any load condition
Step/pallet chain system efficiency improvement	Usage of automatic lubrication system	Reduction of $E_{no\ load}$, $E_{friction}$, $E_{slow\ speed}$ and any load condition

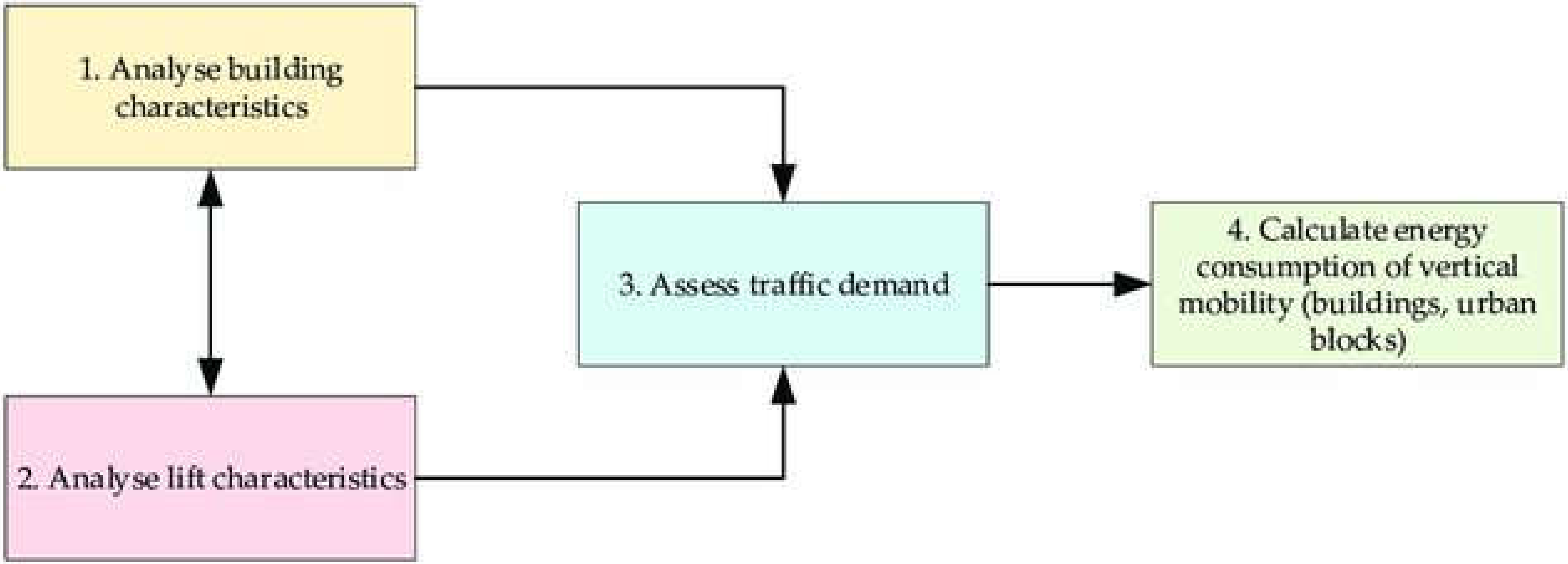
[Source: ISO 25745-3 Energy performance of lifts, escalators and moving walks, Part 3]

Latest research & technical standards

- EMSD building energy code in HK: https://www.emsd.gov.hk/beeo/
  - Requirements on lifts & escalators
    - Maximum allowable electrical power
    - Energy management of lift cars or escalators
    - Total harmonic distortion (motor drive)
    - Total power factor (motor drive)
  - Recommendations on lifts
    - Handling capacity
    - Lift traffic design

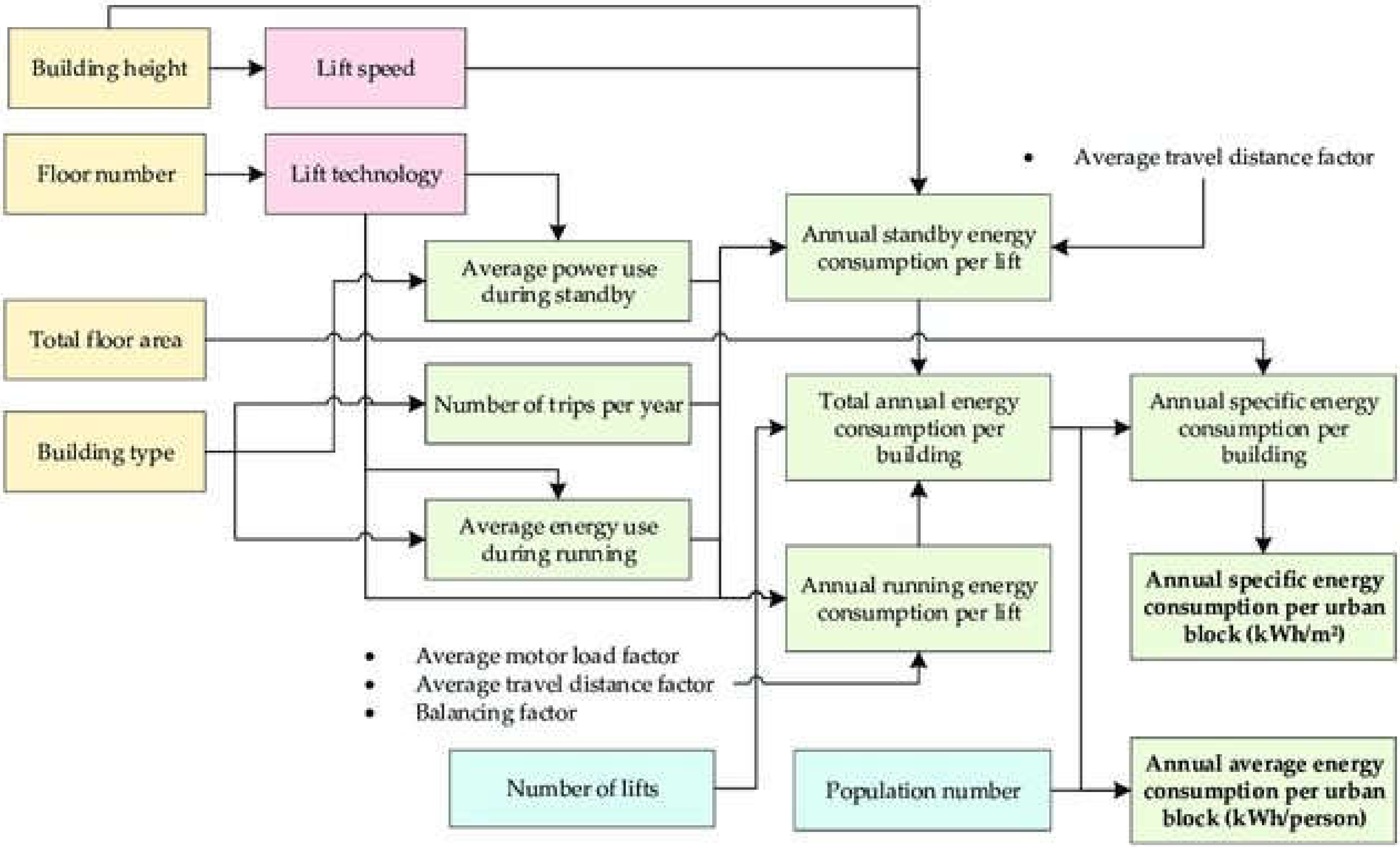


Method to calculate energy consumption of vertical mobility



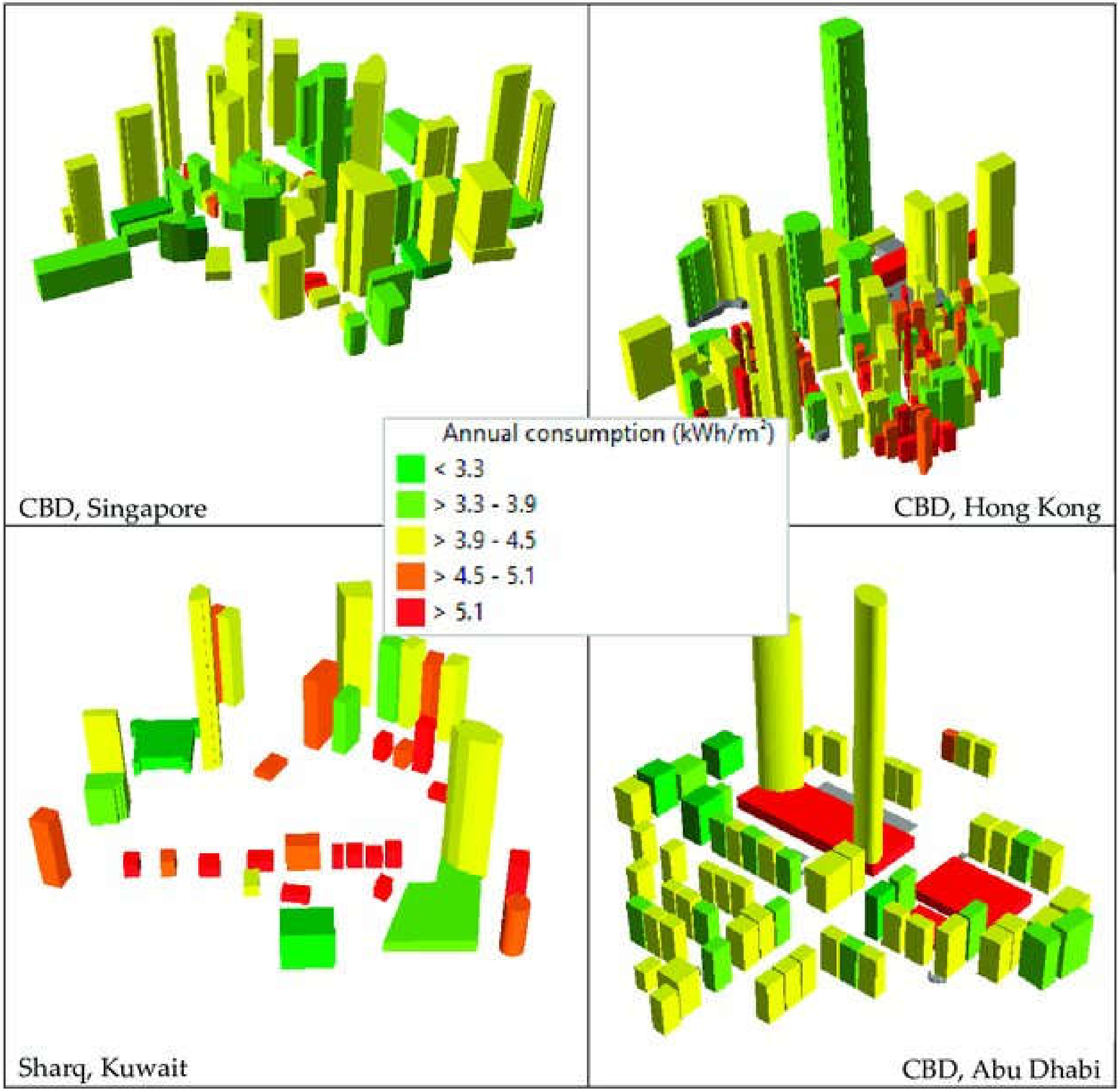
(Source: Murshed S. M., Duval A., Koch A. & Rode P., 2018. Impact of urban morphology on energy consumption of vertical mobility in Asian cities -- a comparative analysis with 3D city models, *Urban Science*, 3: 4.)

Methods to calculate energy consumption of lifts



(Source: Murshed S. M., Duval A., Koch A. & Rode P., 2018. Impact of urban morphology on energy consumption of vertical mobility in Asian cities -- a comparative analysis with 3D city models, *Urban Science*, 3: 4.)

Comparison of energy consumption of lifts in office buildings



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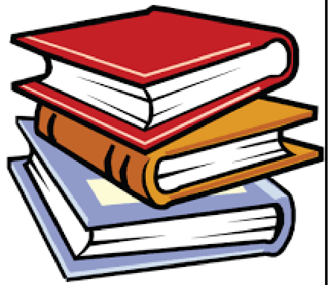
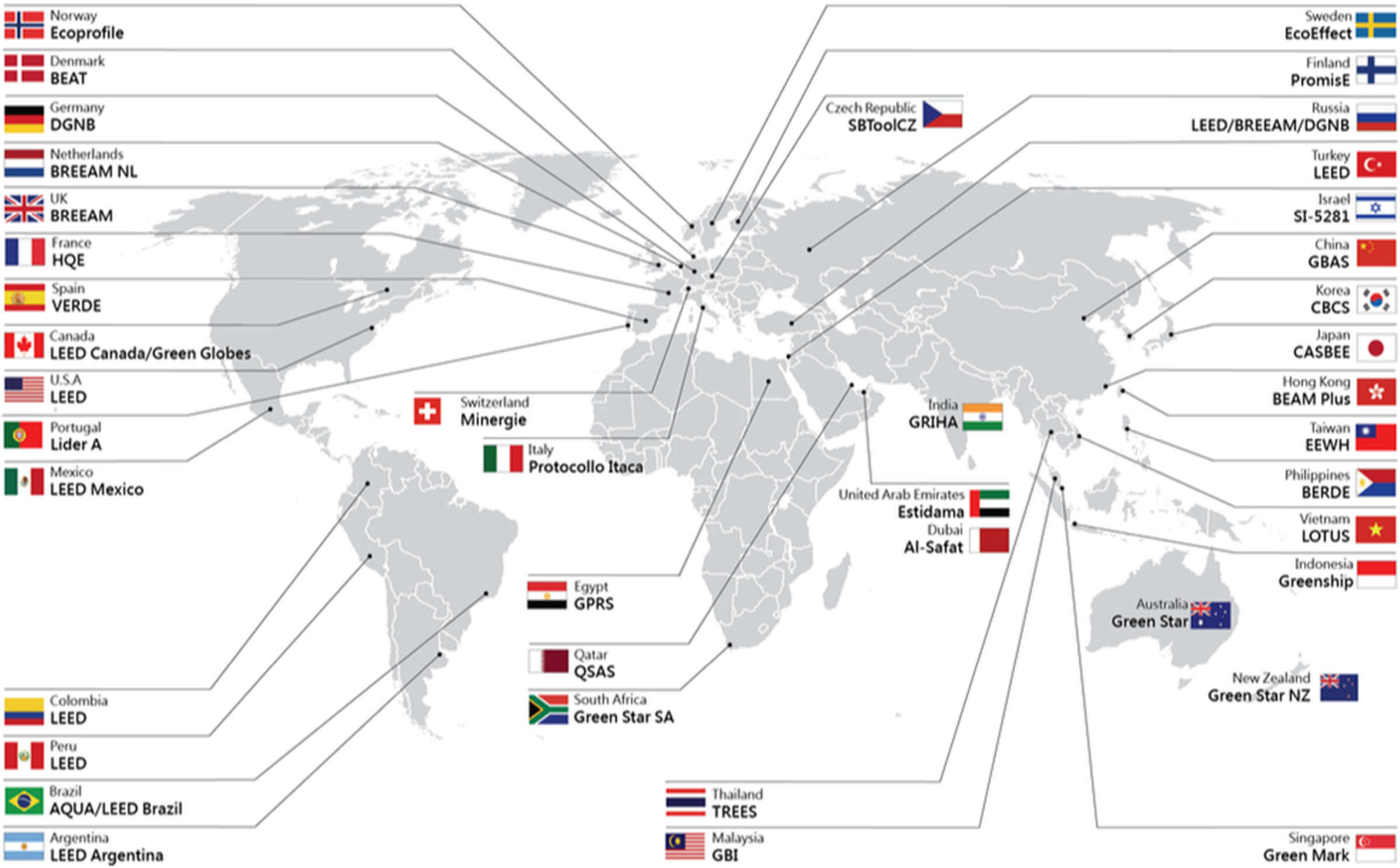
Latest research & technical standards



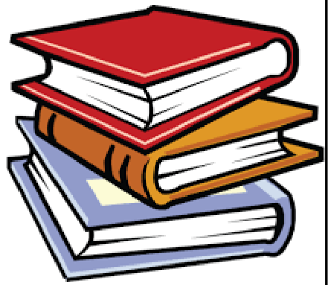
- How to make lifts & escalators GREEN?
  - Energy consumption is the key
  - The materials, processes & technologies also count
  - So too do the choices of interior paints, flooring, control panels, lighting & HVAC systems
  - Environment friendly retrofitting
- Green building assessment has included credit points for lifts & escalators
- Lift cycle analysis (LCA) of the systems

Global green building assessment systems



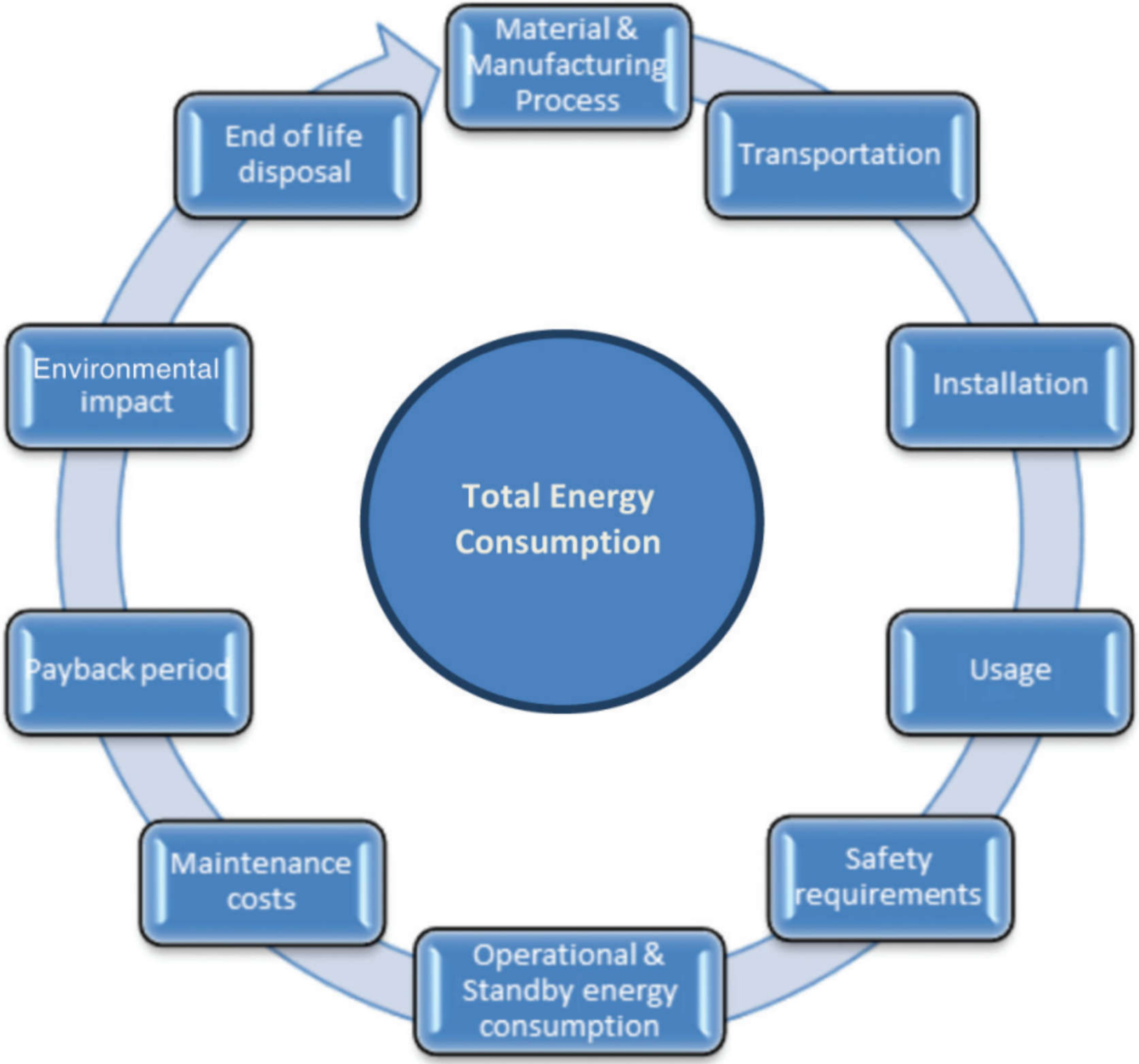
(Source: https://gbtw.weebly.com/background.html)

Latest research & technical standards



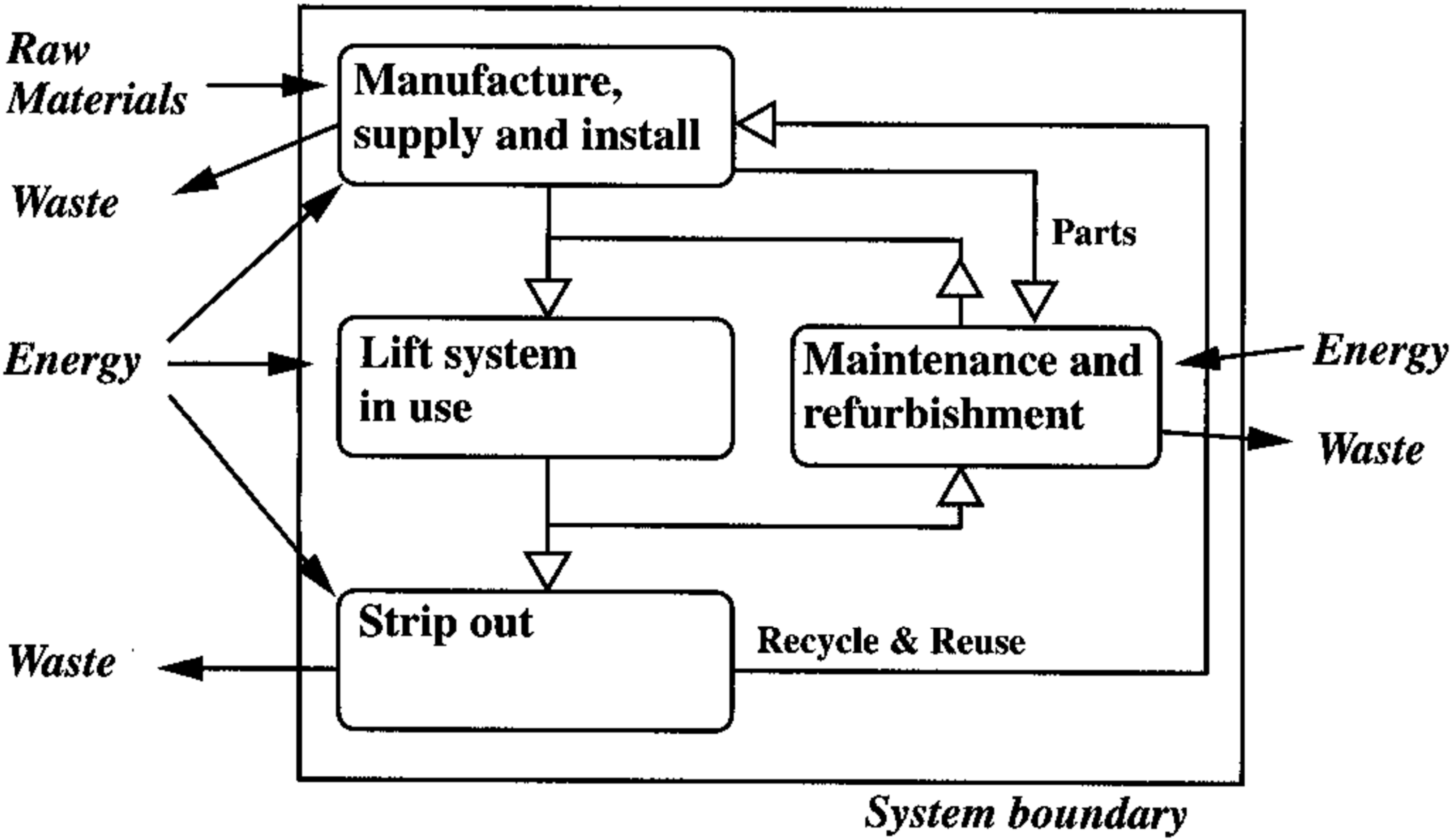
- Green building assessment methods:
  - BREEAM (UK)
    - e.g. BREEAM - Ene 06 Energy efficient transportation systems https://www.breeam.com/ndrefurb2014manual/content/06_energy/ene06.htm
  - LEED (USA)
  - Japan Green Building Guide & CASBEE
  - GB/T 50378-2019 and GOBAS (Mainland China)
  - HK-BEAM/BEAM Plus and CEPAS (HK)
  - Green Mark Scheme (Singapore)

Life cycle analysis of lift total energy consumption



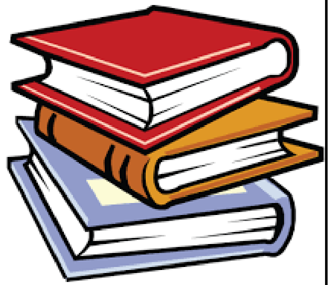
(Source: Mehta P., 2013. Energy-efficient VVVF hydraulic lift drive, *Elevator World*, June 2013, p. 87-92.)

Lift cycle analysis of a typical lift system



(Source: https://peters-research.com/index.php/papers/mathematical-modelling-of-lift-drive-motion-and-energy-consumption/)

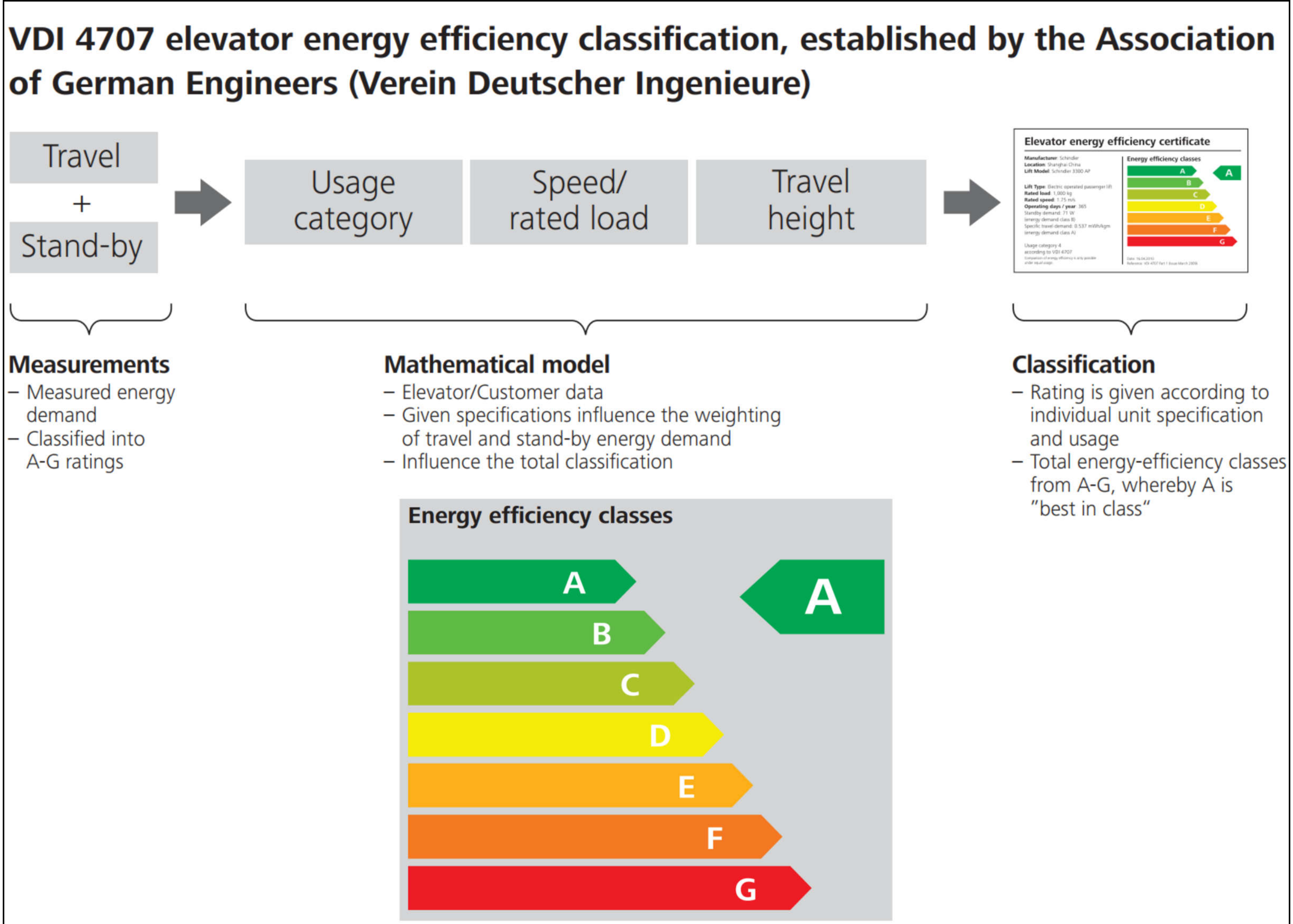
Latest research & technical standards



- Strategies to promote energy efficiency:
  - New installations (increase awareness & energy labels)
  - Retrofit projects (enhance knowledge & modernization)
- Energy efficiency specification, design, installation & operation

Energy classification methods

- Energy efficiency rating & labels
  - Based on VDI 4707 or ISO 25745
  - Classified into A to G ratings (A is the best)
  - Measurements for travel & standby
  - Mathematical models & equations to calculate the energy consumption
  - Rating is given according to individual unit specification & usage
- Similar to appliance energy efficiency labels



(Source: https://www.schindler.com/)

Lift energy efficiency certificate according to VDI 4707

Manufacturer: *Company*

Location: *Street*
City

Lift model: *Series/Version*

Lift type: electric operated passenger lift

Nominal load: 630 kg

Nominal speed: 1 m/s

Operating days per year: 365

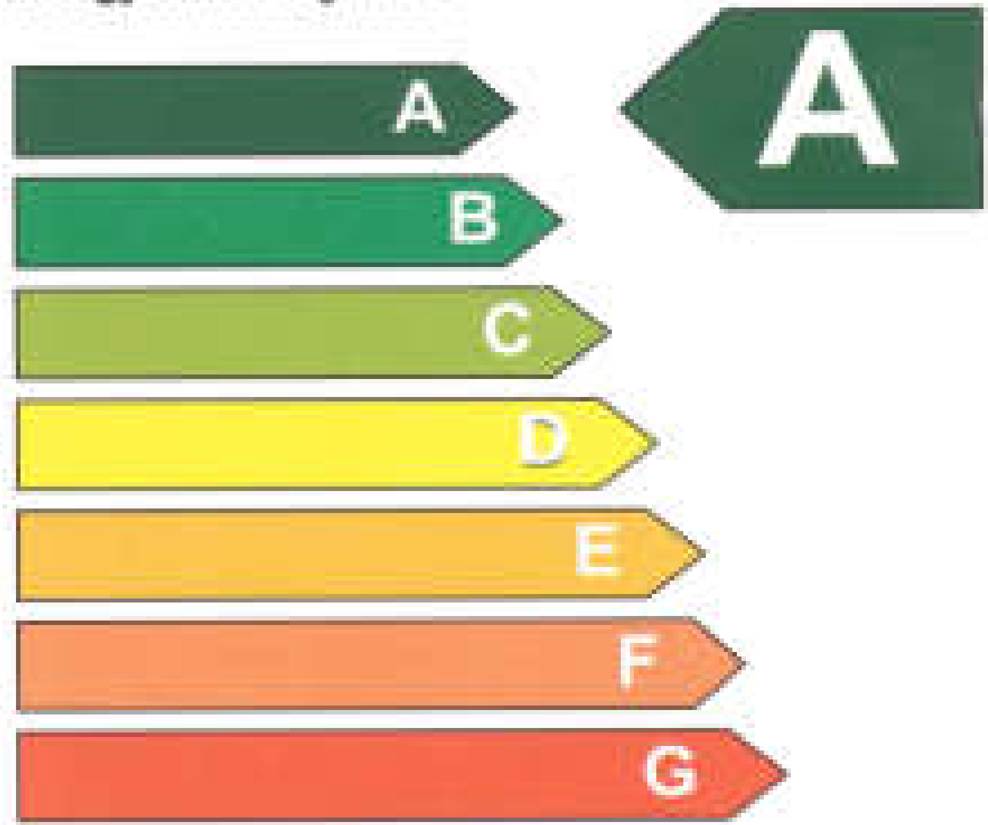
Standby demand:	**Specific travel demand:**
40 W (energy demand class A)	0,50 mWh/(kg·m) (energy demand class A)

Usage category 2 according to VDI 4707

Comparision of energy efficiency classes is only possible under equal usage.

Date: 01.03.2009
Reference: VDI 4707 Part 1 (issue 03-2009)

Energy efficiency class



Nominal demand per year for nominal values as shown:
550 kWh

Lift energy efficiency certificate per VDI 4707

電梯能源效率標章

製造商：	永大機電工業股份有限公司	**能源效率等級 A**
安裝位置：	桃園市桃園區春日路 1352 號	
電梯型號：	YHVF	
電梯型式：	乘客用電梯	
序號：	ET94D12	
額定載重：	2000 kg	
額定速度：	4.0 m/sec	
每年運轉天數：	365	
待機需求： 218 W (待機能量需求等級 D)	特定運行需求： 0.333 mWh/(kg・m) (運行能量需求等級 A)	
依據 VDI 4707 使用類別 5 僅限相同使用類別時方能比較能源效率等級 日期: 2020 年 7 月 1 日 參考依據: VDI 4707 Part 1 (2009 年 3 月頒布)		每年額定能量需求： **22,443 kWh**

標章編號: I0220042

有效期限：2023 年 6 月 30 日

(Source: https://www.yungtay.com.tw/)

Classification of energy efficiency of lifts

Energy efficiency class	Energy consumption per day (Wh)
A	$E_d \leq 0.72 * Q * n_d * s_{av} / 1000 + 50 * t_{nr}$
B	$E_d \leq 1.08 * Q * n_d * s_{av} / 1000 + 100 * t_{nr}$
C	$E_d \leq 1.62 * Q * n_d * s_{av} / 1000 + 200 * t_{nr}$
D	$E_d \leq 2.43 * Q * n_d * s_{av} / 1000 + 400 * t_{nr}$
E	$E_d \leq 3.65 * Q * n_d * s_{av} / 1000 + 800 * t_{nr}$
F	$E_d \leq 5.47 * Q * n_d * s_{av} / 1000 + 1600 * t_{nr}$
G	$E_d > 5.47 * Q * n_d * s_{av} / 1000 + 1600 * t_{nr}$

E_d = Total daily energy consumption (Wh)
Q = Rated load (kg)
n_d = Number of trips per day
s_{av} = Average travel distance for target installation (m)
t_{nr} = Non running (idle and standby) time(s) per day (h)

[Source: ISO 25745-2 Energy performance of lifts, escalators and moving walks, Part 2]

Energy efficiency classes for elevator per VDI 4707

Table 4: Energy efficiency classes for the elevator

Energy efficiency class	Specific energy demand E_{spec} in mWh/(m·kg)			
	Utilization category			
	1	2	3	4
A	≤ 1.45	≤ 1.01	≤ 0.90	≤ 0.84
B	≤ 2.51	≤ 1.62	≤ 1.39	≤ 1.28
C	≤ 4.41	≤ 2.63	≤ 2.19	≤ 1.97
D	≤ 7.92	≤ 4.37	≤ 3.48	≤ 3.04
E	≤ 14.41	≤ 7.33	≤ 5.56	≤ 4.67
F	≤ 26.88	≤ 12.67	≤ 9.11	≤ 7.33
G	> 26.88	> 12.67	> 9.11	> 7.33

Note: The values in the table are derived for an elevator with 1000 kg rated load and nominal velocity of 1 m/s, from the combination of the consumption values for stand-by and during travel, with the same class in each case (e.g. Class A for travel plus Class A for stand-by = overall efficiency Class A; Class D for travel plus Class D for stand-by = overall efficiency Class D).

(Source: Table 4, VDI 4707 E)

Table 1: Utilization categories for elevators as per VDI 4707 E

Utilization category	1	2	3	4
Use intensity/ frequency	Low Seldom	Medium Occasionally	High Frequently	Very high Very frequently
Average travel time in hours per day *)	0.5 (≤ 1)	1.5 (> 1–2)	3 (> 2–4.5)	6 (> 4.5)
Average stand-by time in hours per day	23.5	22.5	21	18
Typical types of buildings and building use	• Residential building with up to 20 units • Small office or administration building with 2 to 5 stories • Small hotels • Seldom used freight elevator	• Residential building with up to 50 units • Small office or administration building with up to 10 stories • Medium-sized hotels • Freight elevator with medium use frequency	• Residential building with more than 50 units • Tall (more than 10 stories) office or administration building • Large hotels • Small to medium-sized hospital • Freight elevator in a single-shift production process	• Office or administration building more than 100 m tal • Large hospital • Freight elevato in a multi-shift production process

*) Can be determined on the basis of the average number of trips and average trip duration.

(Source: VDI 4707

(Source: Mehta P., 2013. Energy-efficient VVVF hydraulic lift drive, *Elevator World*, June 2013, p. 87-92.)

Energy demand classes during travel and for stand-by

Table 3: Energy demand classes during travel

Specific energy demand E_{spec} in mWh/(m·kg)	≤ 0.8	≤ 1.2	≤ 1.8	≤ 2.7	≤ 4.0	≤ 6.0	> 6.0
Class	A	B	C	D	E	F	G

(Source: Table 3 of VDI 4707 E)

Table 2: Energy demand class for stand-by

Rating P_{St} in W	≤ 50	≤ 100	≤ 200	≤ 400	≤ 800	≤ 1600	> 1600
Class	A	B	C	D	E	F	G

(Source: Table 2 of VDI 4707 E)

(Source: Mehta P., 2013. Energy-efficient VVVF hydraulic lift drive, *Elevator World*, June 2013, p. 87-92.)

Improving energy efficiency

- General approach for lifts & escalators
  - Minimise friction losses & dynamic losses
  - Possible regeneration into the supply system
- General principles to energy efficiency
  - Specify energy efficiency equipment
  - Do not over design the system
  - Suitable zoning arrangement
  - Suitable control and energy management
  - Use light weight materials for lift car decoration
  - Good house keeping

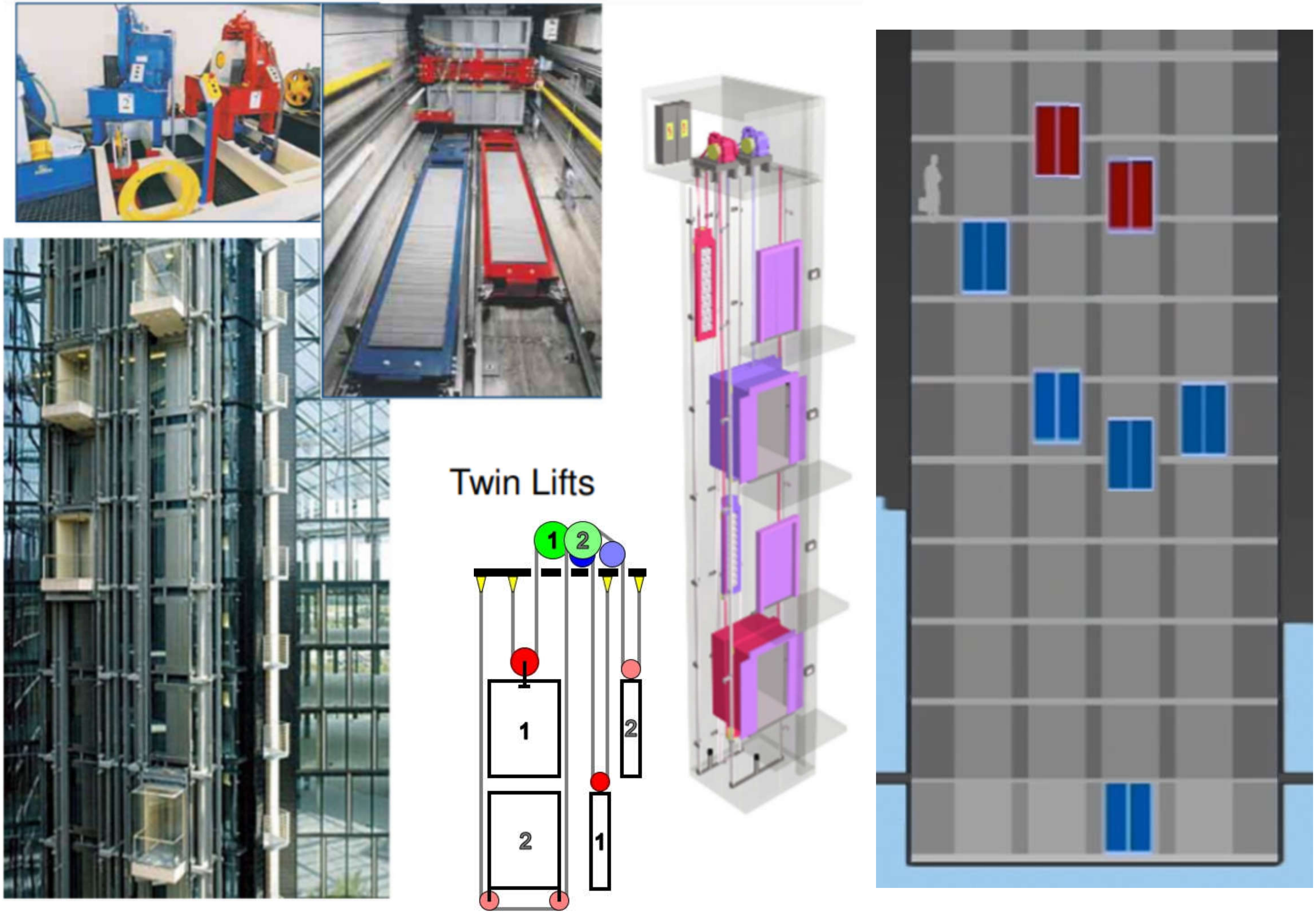
Improving energy efficiency

- System level improvements
  - Selection of the right number, capacity & speed based on traffic calculation
  - Design & use lifts in groups effectively
  - Use destination control systems or twin lifts that reduce the number of stops
  - Use double decker in tall buildings esp. with express elevators to the sky lobby
  - Efficient control software that can switch between performance & energy saving modes as needed

Typical double-deck lifts

[Source: http://www.elevator-world.com]

Twin lift (two independent cars running in one shaft)

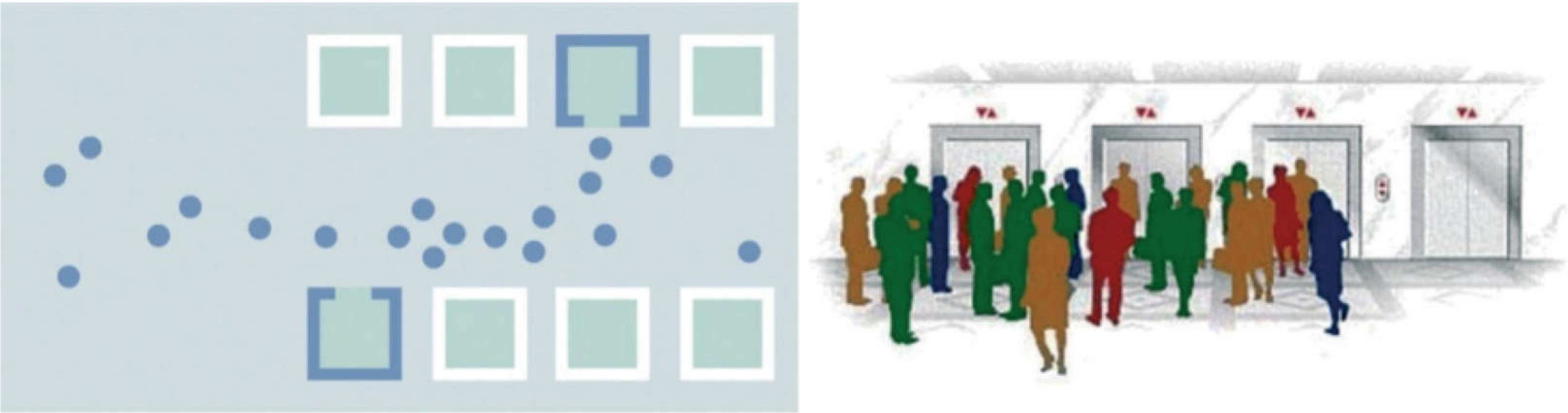


(Source: https://www.thyssenkruppelevator.com/elevator-products/twin)

Hall call allocation system

[Source: Schindler https://www.schindler.com/]

Conventional versus destination dispatching system



Conventional dispatching system

Destination dispatching system

(Source: http://www.ThyssenKrupp.com)

Practical guidelines on energy efficiency for lift systems (1 of 2)

Energy efficiency specification - Check necessity of lift or escalator installation - Check location & number of installations
Design of the drive system - Check dimensioning - Check necessity of additional non-lift comfort equipment - Check for appropriate drive technology - Check for adequate gearing & roping of the system - Check system architecture - Check usage of high efficiency & properly sized motor - Check benefits of using regenerative drives - Check usage of a frequency converter with automatic standby function - Check usage and optimisation of counter-balancing - Reduce the mass of the car
Design of ancillary lift equipment - Use energy-efficient lighting & appropriate surface material - Avoid stalled motor door operator - Use energy-efficient transformer & power supply - Use energy-efficient components for all other components & equipment

(Source: ISR-University of Coimbra, 2010. *E4 Energy-Efficient Elevators and Escalators*, technical report prepared for the Intelligent Energy of European Commission, University of Coimbra, Portugal.)

Practical guidelines on energy efficiency for lift systems (2 of 2)

Installation - Ensure installation quality - Interface lift and building: shaft ventilation, smoke clearance, shaft insulation
Operation - Switching off car lighting when not in use - Use automatic car fan control/switch-off fan - Switch off other lift components when not in use - Switch off comfort equipment when not required - Switch temperature control of machine room according to requirements - Operate oil heater & cooler only when required - Switch off car roof light/ shaft illumination after service - Check correct type & adequacy of lubrication - Optimise traffic handling & management - Check benefits of using condition monitoring

(Source: ISR-University of Coimbra, 2010. *E4 Energy-Efficient Elevators and Escalators*, technical report prepared for the Intelligent Energy of European Commission, University of Coimbra, Portugal.)

Practical guidelines on energy efficiency for escalators

Drive system - Use high efficiency & properly sized motor - Check for adequate gearing - Check benefits of using variable speed drives/low speed mode/stop mode - Check benefits of using regenerative drives - Use high-efficiency bearings
Other aspects - Check benefits of adjusting operation mode to load and passengers - Use energy-efficient lighting - Use sleep-mode on escalator equipment

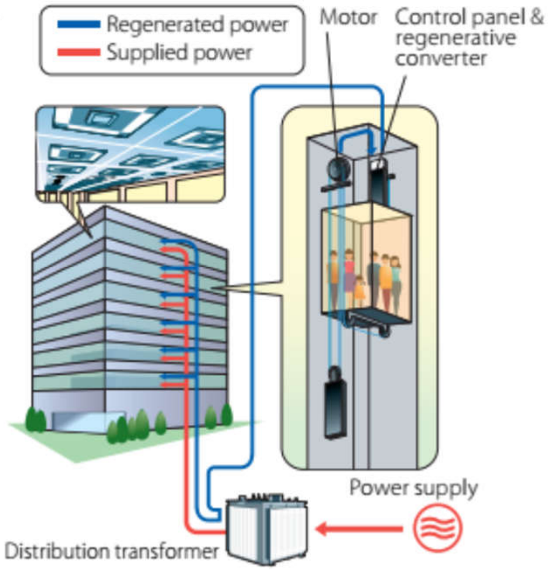
(Source: ISR-University of Coimbra, 2010. *E4 Energy-Efficient Elevators and Escalators*, technical report prepared for the Intelligent Energy of European Commission, University of Coimbra, Portugal.)

Energy saving measures for lift systems

Regenerative Converter

Energy savings 35%

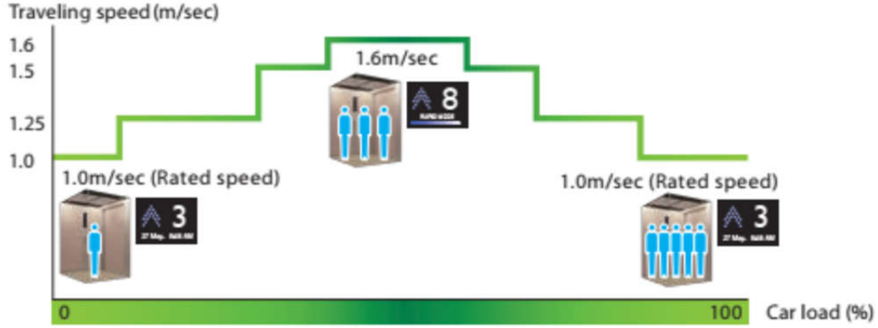
The Regenerative Converter transmits the power regenerated by the traction machine via distribution transformer to the electrical network in the building.



Traffic improvement without increasing power-supply capacity 15%

Variable traveling speed elevator system

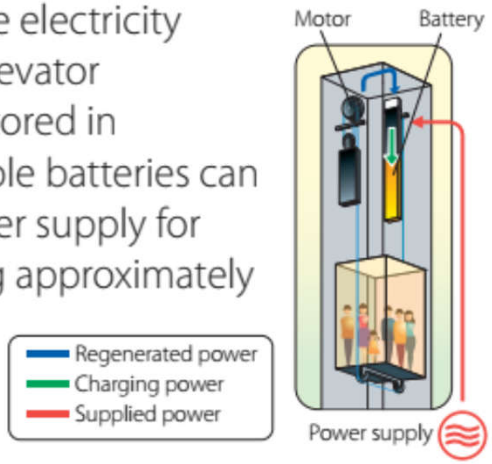
This system allows elevators to travel faster than their rated speed depending on the number of passengers in the car, thereby improving transport efficiency.



Electricity recycling system for elevators <ELESAVE>

Energy savings 20%

ELESAVE is designed to store electricity generated during regular elevator operations. The electricity stored in nickel-hydrogen rechargeable batteries can be used as an auxiliary power supply for running elevators, providing approximately 20% power savings.



PM motor with joint-lapped stator

Energy savings 20%

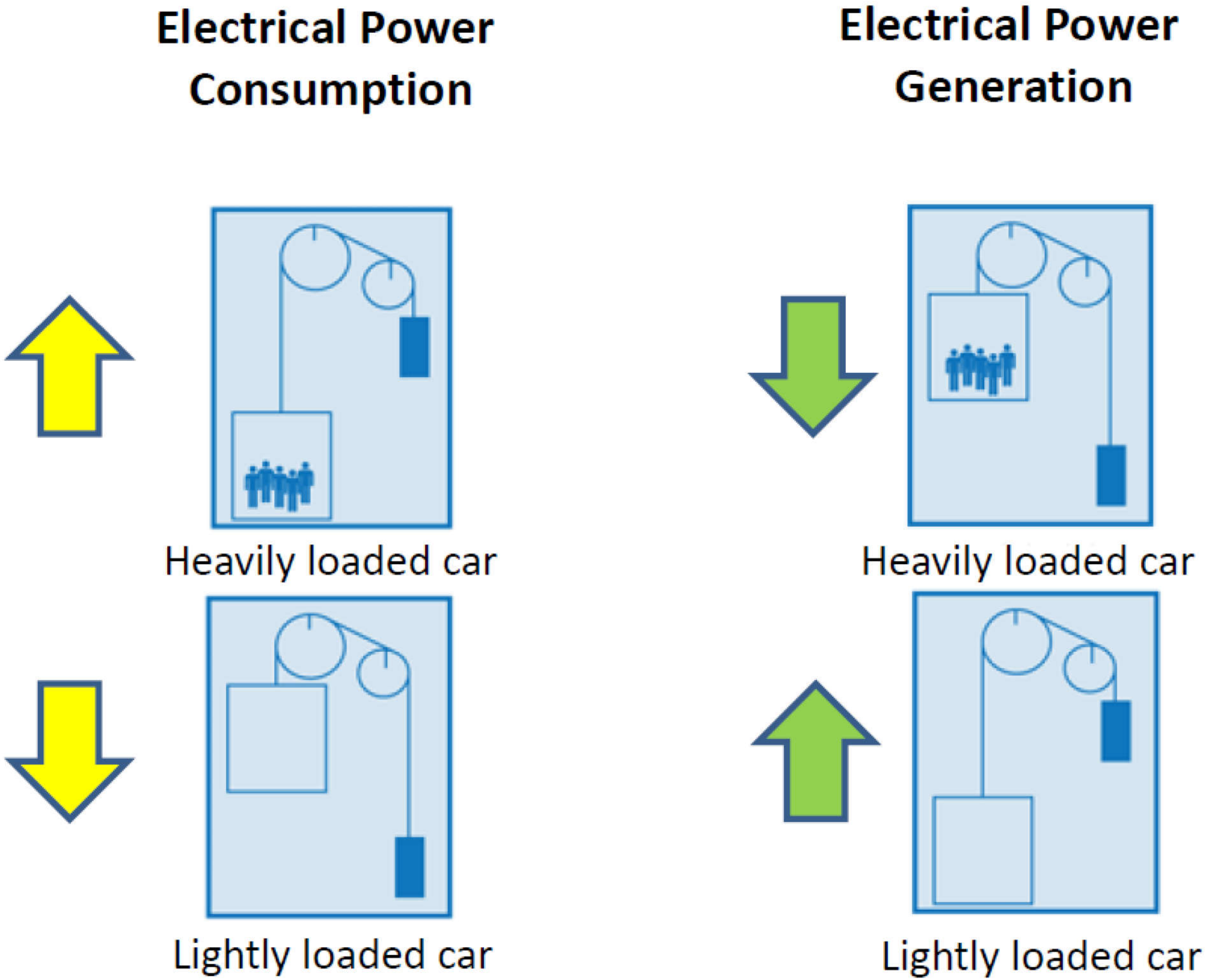
With the joint-lapped motor in traction machines, the iron core is split like a hinge, which allows coils to be wound around the core more densely, resulting in greater motor efficiency and compactness.

Permanent magnet (PM) door motor

The direct-drive PM door motor and the VVVF inverter realize efficient door opening and closing.

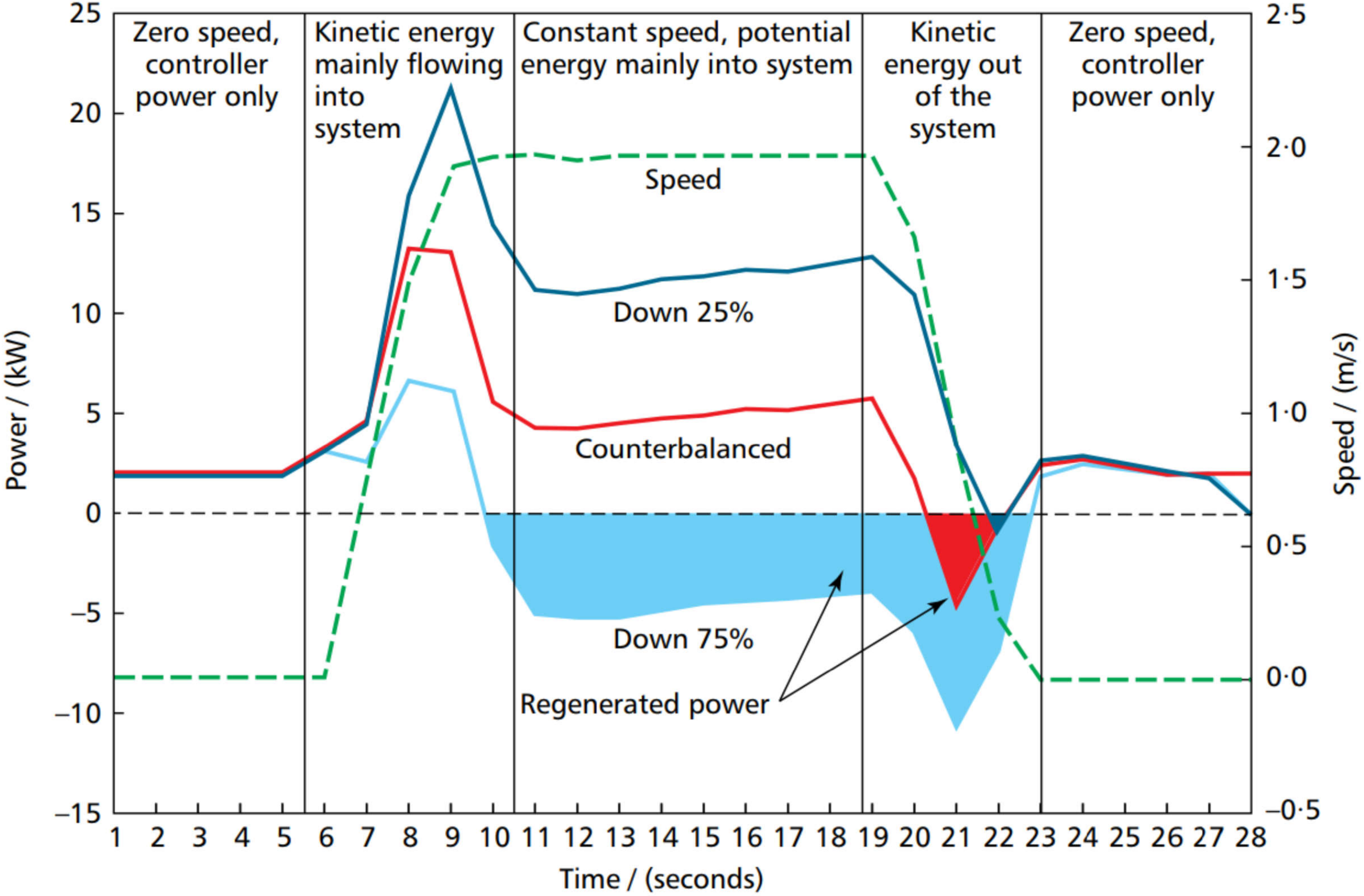
(Source: https://www.mitsubishielectric.com/)

Regenerative drive system



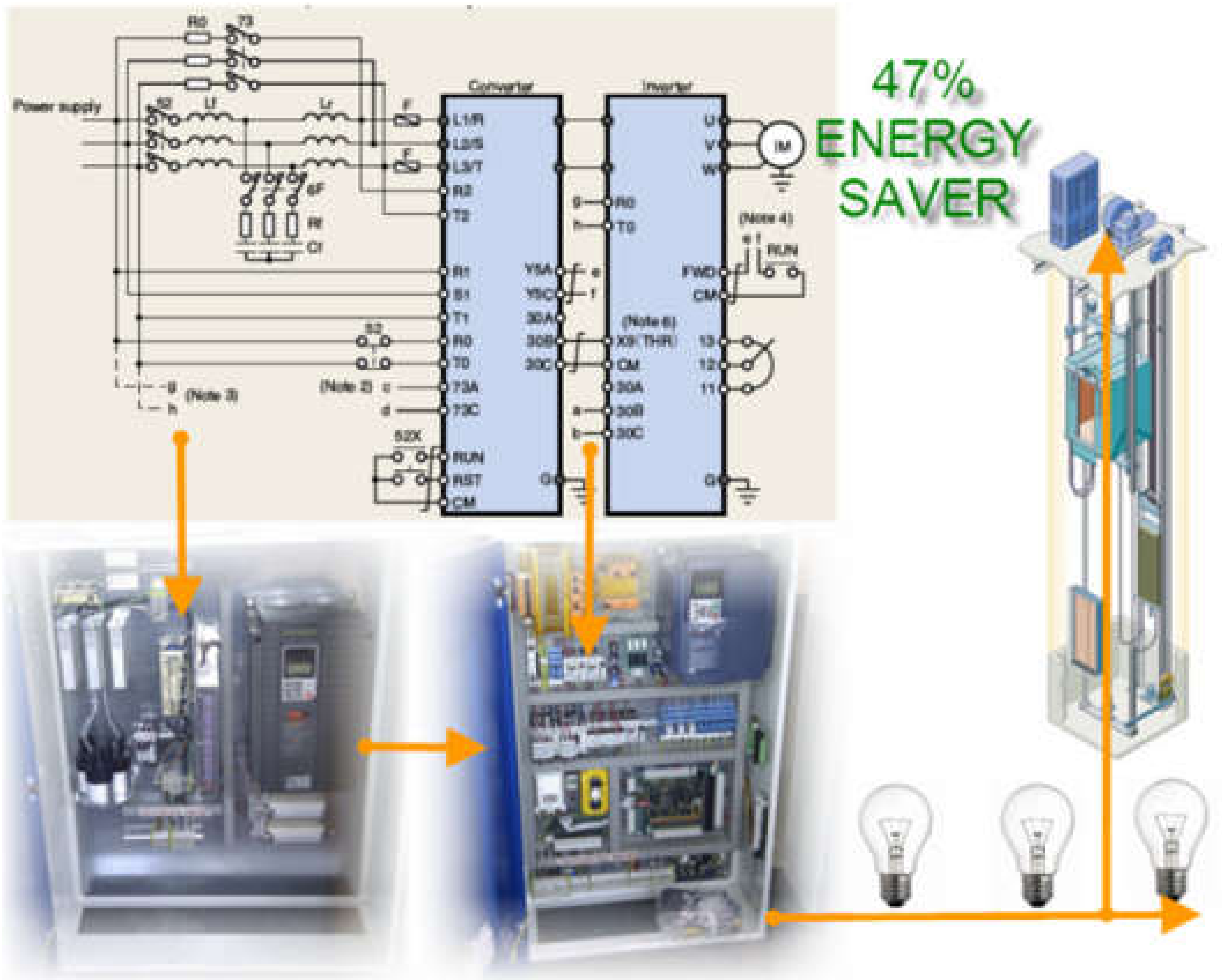
(Source: Al-Kodmany K., 2015. Tall buildings and elevators: a review of recent technological advances, *Buildings*, 5(3) 1070-1104. https://doi.org/10.3390/buildings5031070)

Speed and energy consumption of a lift carrying different loads



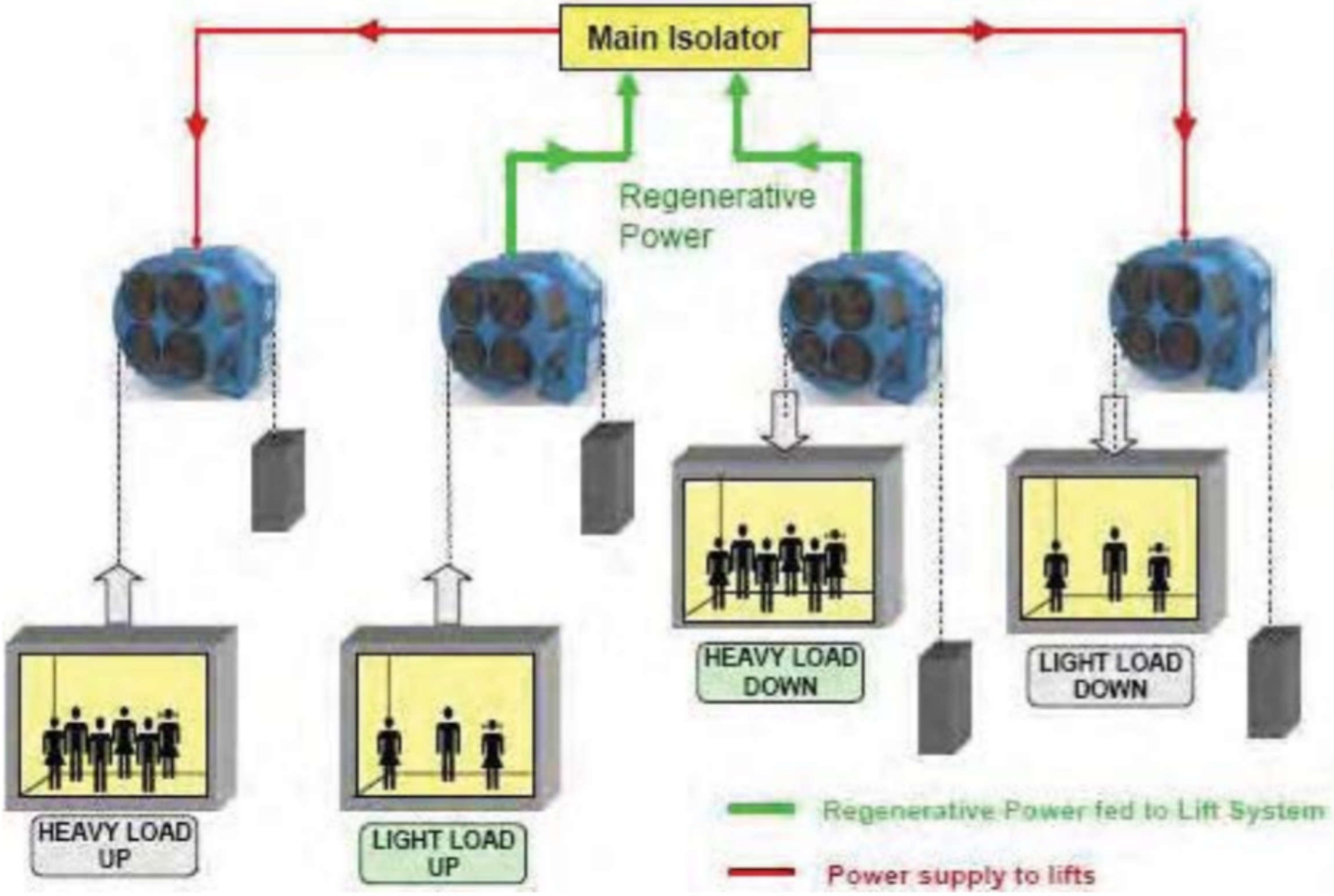
[Source: CIBSE Guide D]

A typical energy recovery system connected to a lift



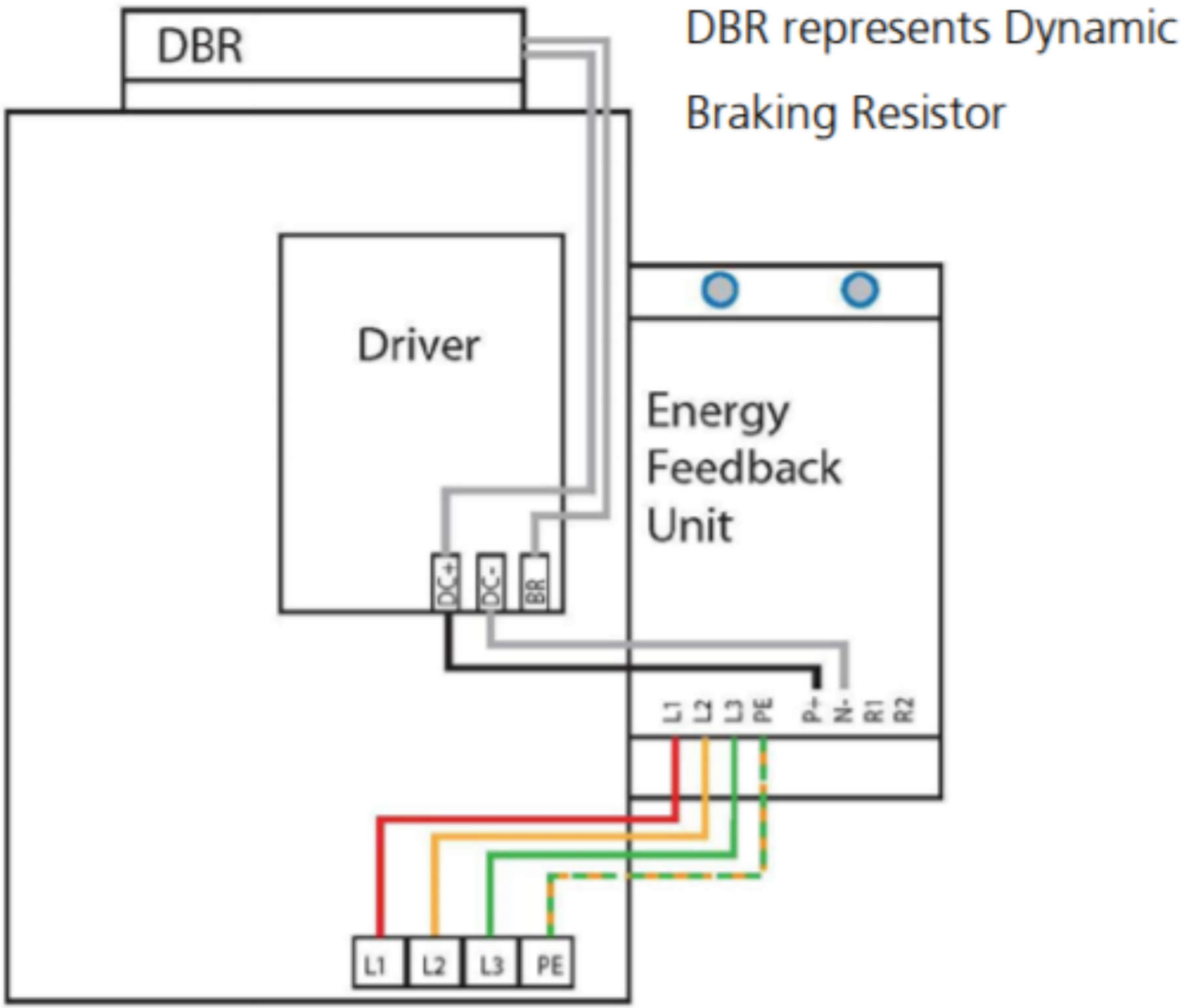
(Source: https://ascensoriscalemobili.wordpress.com/energy-efficient-elevators-escalators-and-regeneration/)

Regenerative power used by other lifts



(Source: https://www.emsd.gov.hk/filemanager/en/content_764/applctn_lift_rgnrt_pwr.pdf)

Lifts retrofitted with dynamic braking resistor for regenerative power



(Source: https://www.emsd.gov.hk/filemanager/en/content_764/applctn_lift_rgnrt_pwr.pdf)

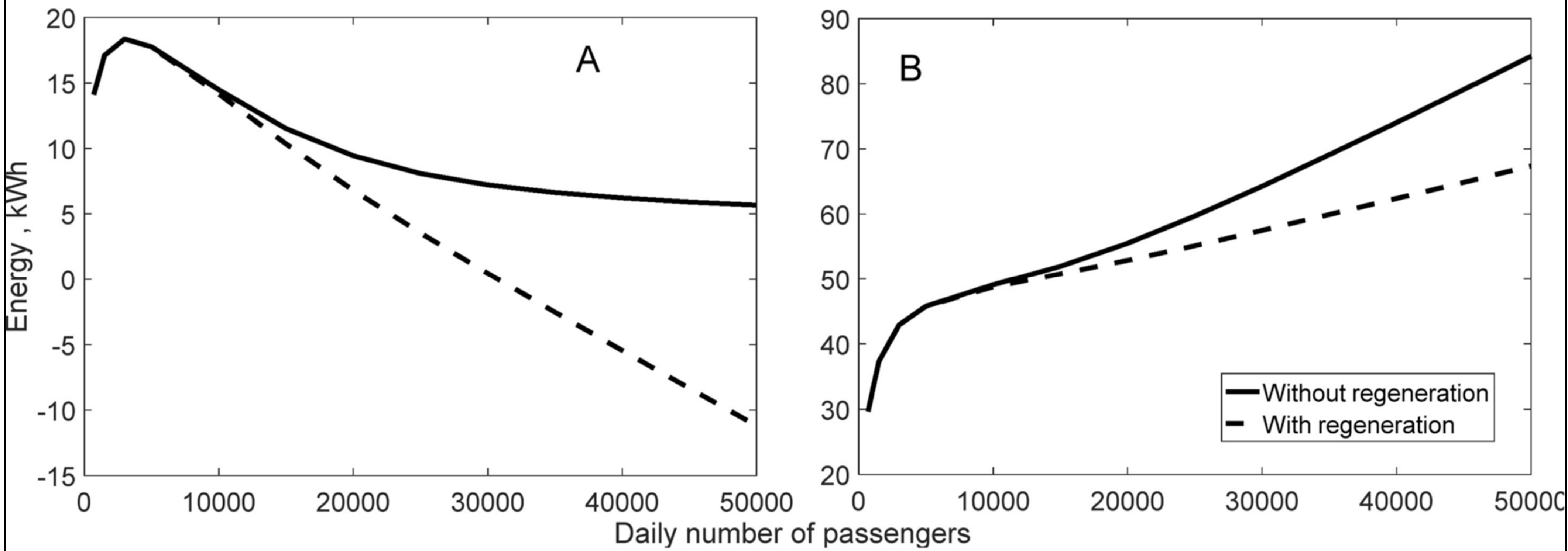
Energy saving of lift regenerative power in government offices

Lift No. (Speed)	Item	Energy from 16 Aug to 16 Dec 2013 (kWh)	% of Electricity Saving
East Wing High Zone (6 m/s)	Energy Consumed	45,913	25.7%
	Energy Regenerated	15,847	
East Wing Low Zone (5 m/s)	Energy Consumed	29,311	22.4%
	Energy Regenerated	8,459	
West Wing High Zone (5 m/s)	Energy Consumed	43,518	27.0%
	Energy Regenerated	16,072	
West Wing Low Zone (2.5 m/s)	Energy Consumed	24,640	18.9%
	Energy Regenerated	5,760	
East Wing Passenger (High + Low Zone) (3 m/s)	Energy Consumed	9,405	23.3%
	Energy Regenerated	2,852	
West Wing Passenger (High + Low Zone) (3.5 m/s)	Energy Consumed	16,181	26.4%
	Energy Regenerated	5,796	
East Wing Services (High + Low Zone) (2.5 m/s)	Energy Consumed	7,361	22.4%
	Energy Regenerated	2,120	
West Wing Services (1 to 3/F) (1.75 m/s)	Energy Consumed	2,505	17.1%
	Energy Regenerated	565	

(Source: https://www.emsd.gov.hk/filemanager/en/content_764/applctn_lift_rgnrt_pwr.pdf)

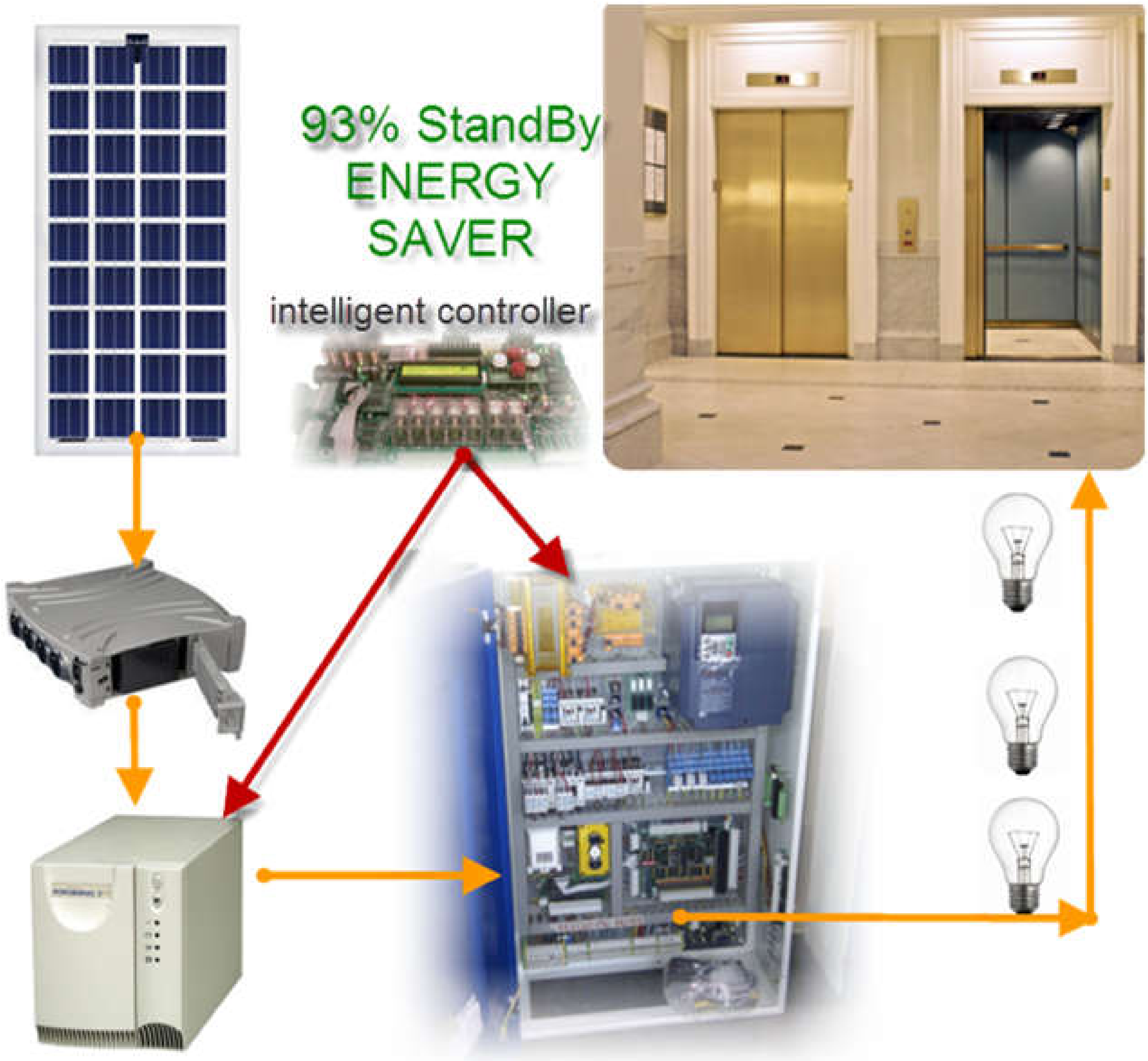
(A) Energy consumption of a downward escalator with and without regenerative capabilities as a function of traffic intensity

(B) Energy consumption of an escalator pair with and without regenerative capabilities as a function of traffic intensity



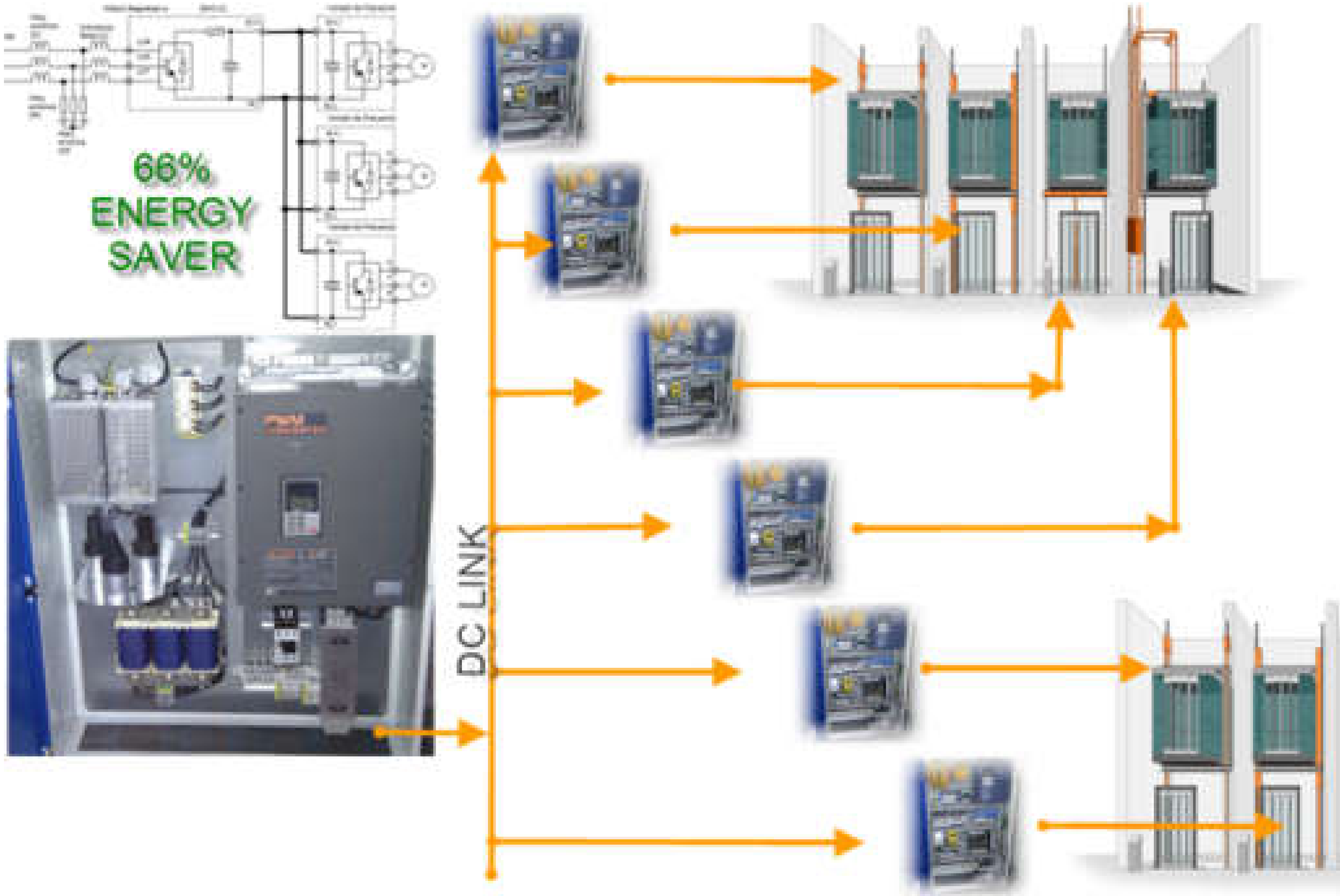
(Source: Uimonen S., Tukia T., Siikonen M.-L. & Lehtonen M., 2017. Impact of daily passenger traffic on energy consumption of intermittent-operating escalators, *Energy and Buildings*, 140: 348-358.)

A standby energy saver & photovoltaic (PV) system connected to a lift



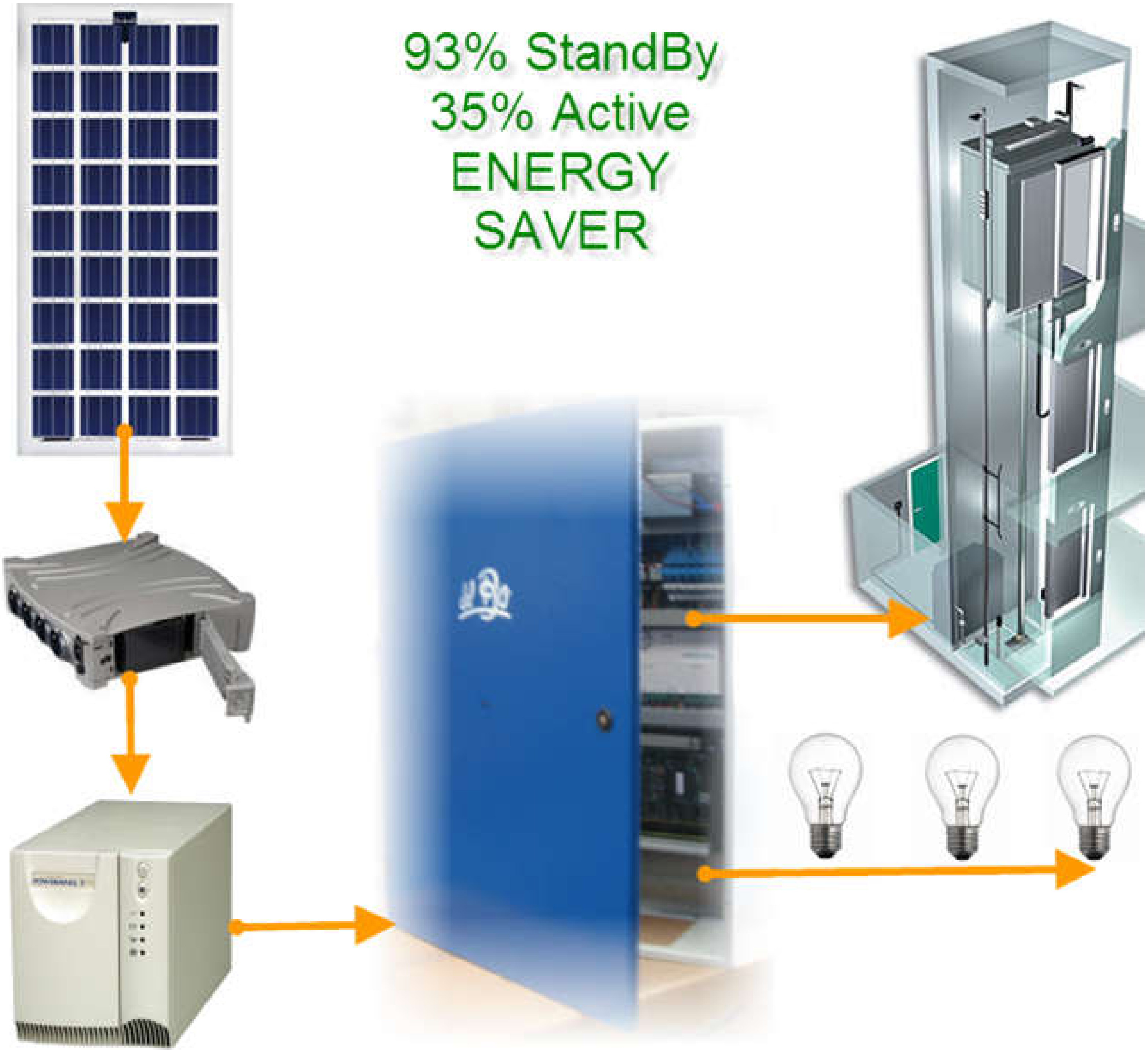
(Source: https://ascensoriscalemobili.wordpress.com/energy-efficient-elevators-escalators-and-regeneration/)

An energy recovery system multiplex parallel connections DC Link



(Source: https://ascensoriscalemobili.wordpress.com/energy-efficient-elevators-escalators-and-regeneration/)

A typical energy recovery system for hydraulic lifts

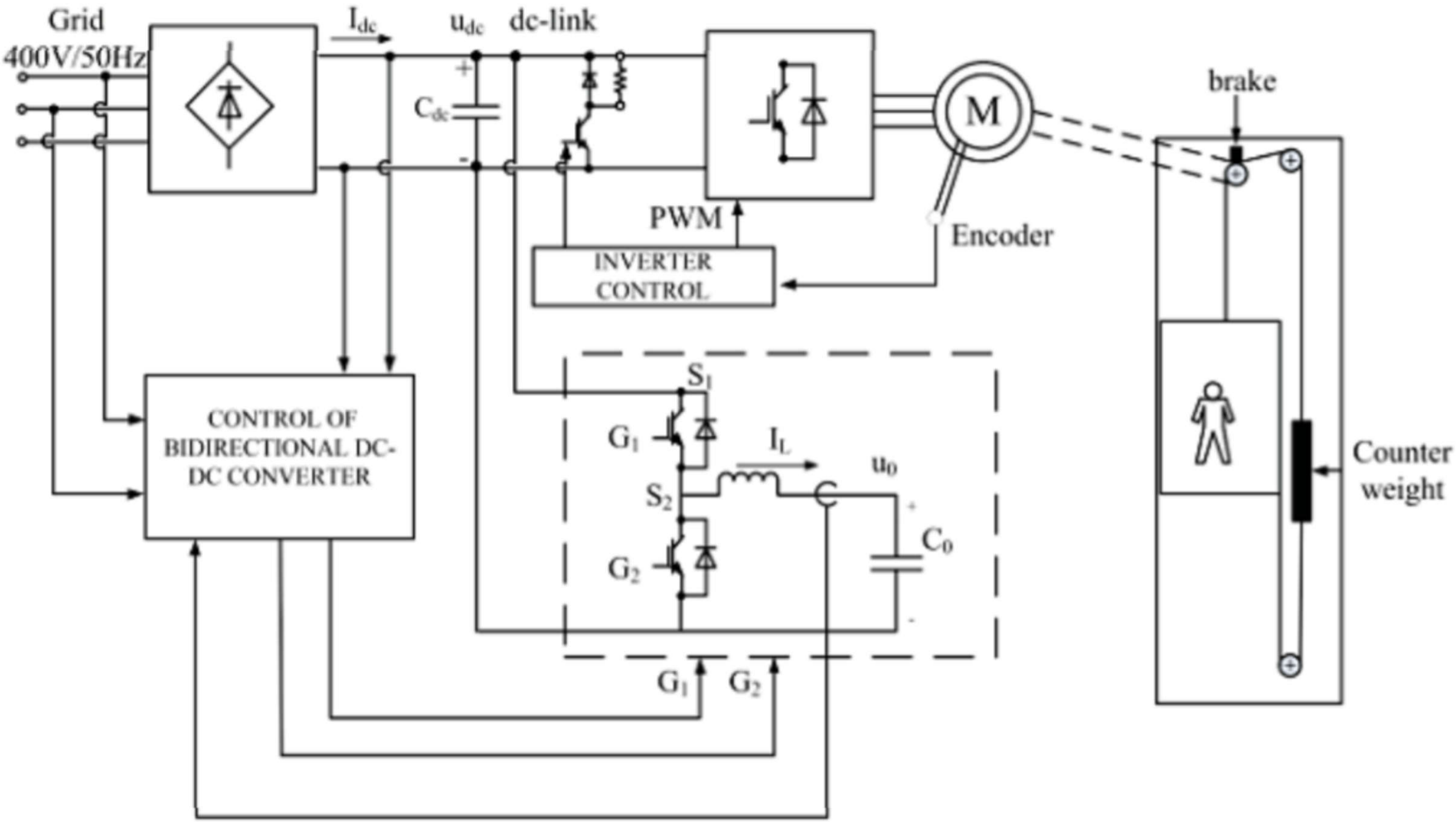


(Source: https://ascensoriscalemobili.wordpress.com/energy-efficient-elevators-escalators-and-regeneration/)

A typical energy recovery system for escalators

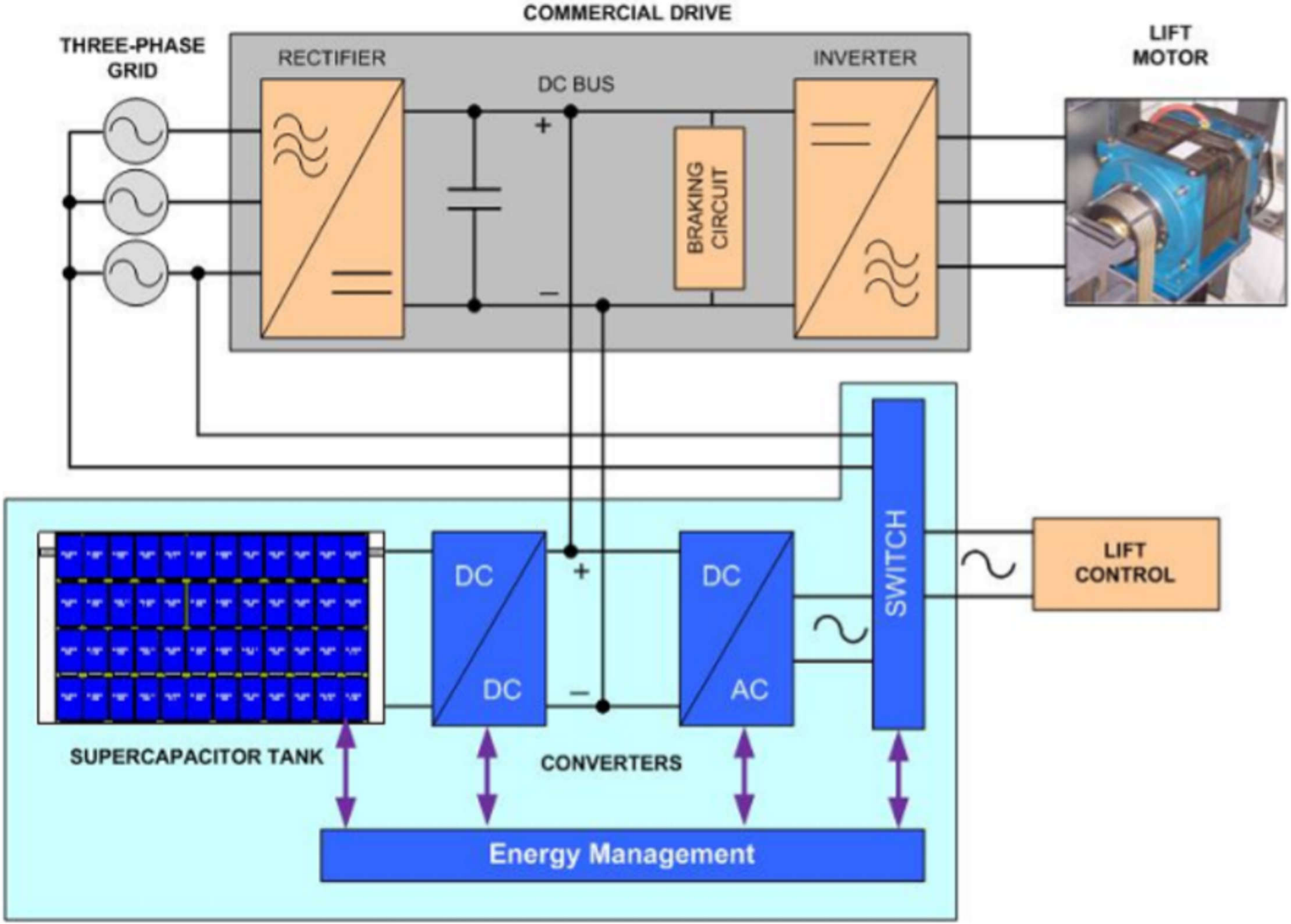
(Source: https://ascensoriscalemobili.wordpress.com/energy-efficient-elevators-escalators-and-regeneration/)

Energy storage system based on supercapacitor bank for lift system



(Source: Gao P., Niu W., Quanji Z., Yang Y. & Lv Y., 2016. Elevator regenerative energy feedback technology, *Advances in Computer Science Research*, 63: 168-175.)

Lift system with energy storage based on supercapacitor bank

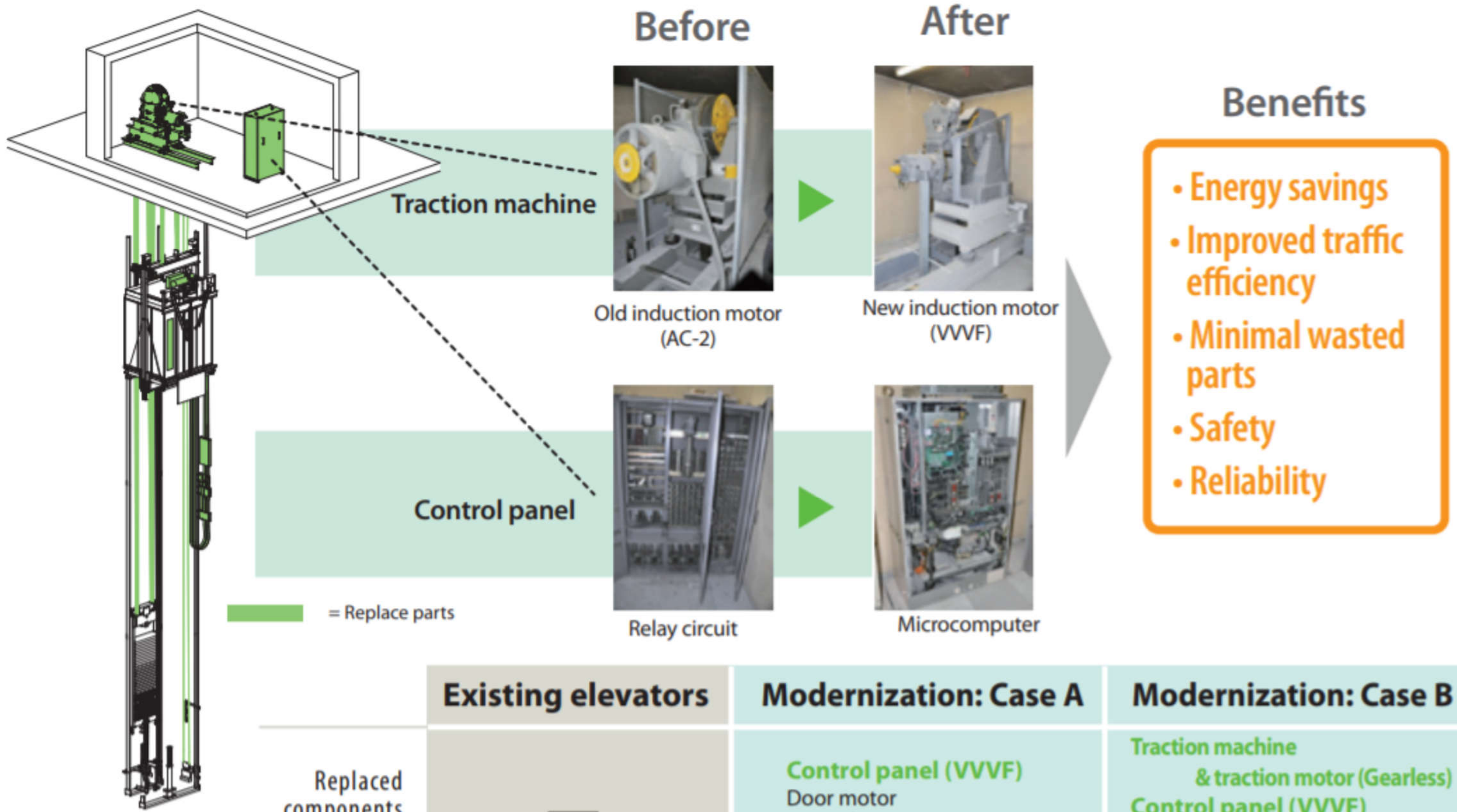


(Source: Gao P., Niu W., Quanji Z., Yang Y. & Lv Y., 2016. Elevator regenerative energy feedback technology, *Advances in Computer Science Research*, 63: 168-175.)

Improving energy efficiency

- Lift modernization can help reduce standby consumption of old lift systems
- Energy saving in standby mode by:
  - Energy efficient LED lighting, smart sensors, controls on air conditioner and ventilation
  - Proper operation (e.g. shut off during mid-night and holidays)
- Lifts & escalators are included in building energy efficiency standards like ASHRAE 90.1

Modernization allows a lift to be refurbished by replacing some of its components so that usable components can be retained



	Existing elevators	Modernization: Case A	Modernization: Case B
Replaced components	—	Control panel (VVVF) Door motor Signal fixture	Traction machine & traction motor (Gearless) Control panel (VVVF) Door motor Signal fixture
Energy-saving	100%	62% 38% cut	54% 46% cut
Reuse rate	100%	88%	71%

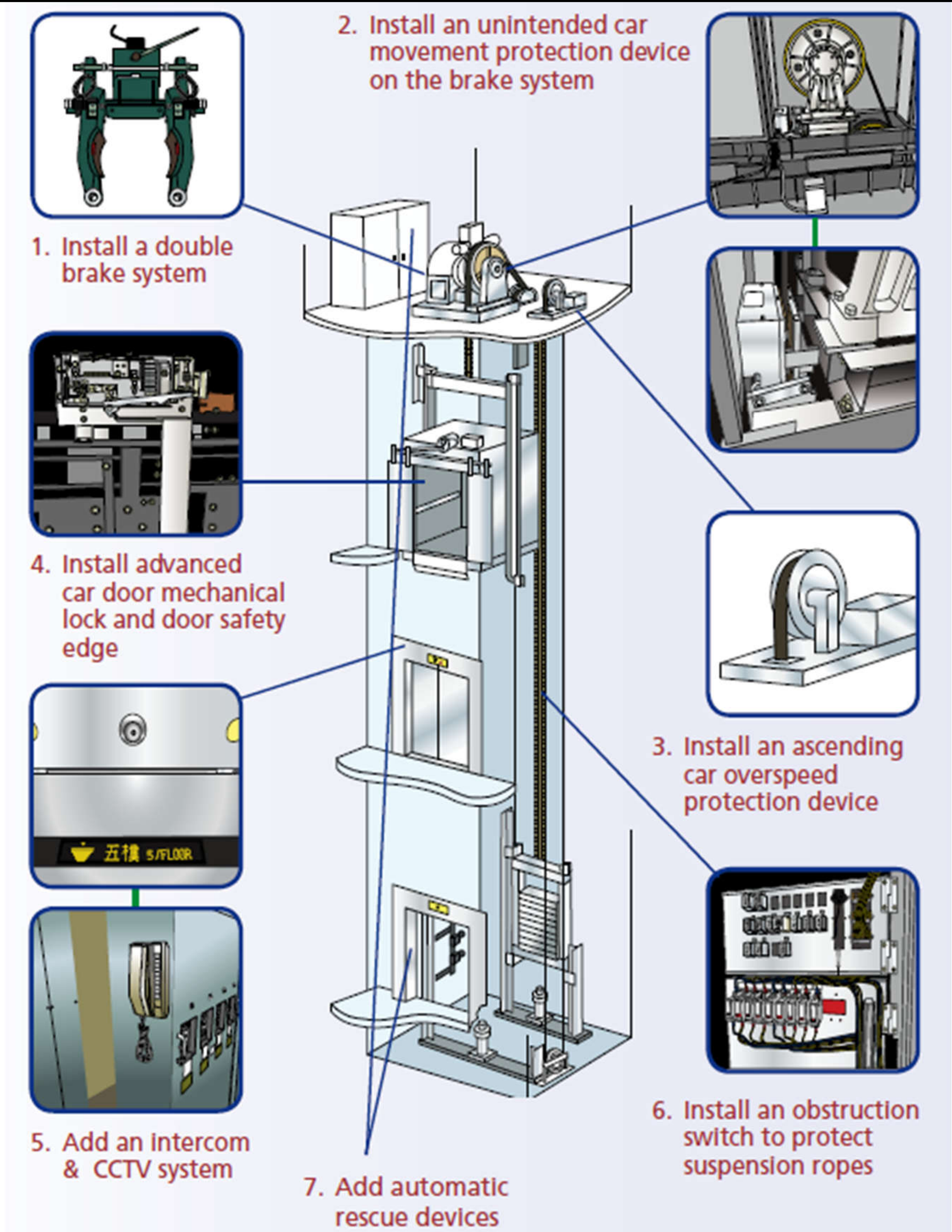
(Source: Mitsubishi Electric https://www.mitsubishielectric.com/)

Changes or modifications to existing lift during modernisation

- Rated speed
- Rated load
- Travel
- Mass
- Complete controller including door operations
- Drive control system
- From manual to power-operated doors
- Entrances

- Safety components
- Electric safety devices
- (Electric) drive components (lift machine, brake)
- (Hydraulic) jack & lift machine
- Car enclosure or interior finishes
- Door operator
- From gates to doors
- Guide rails

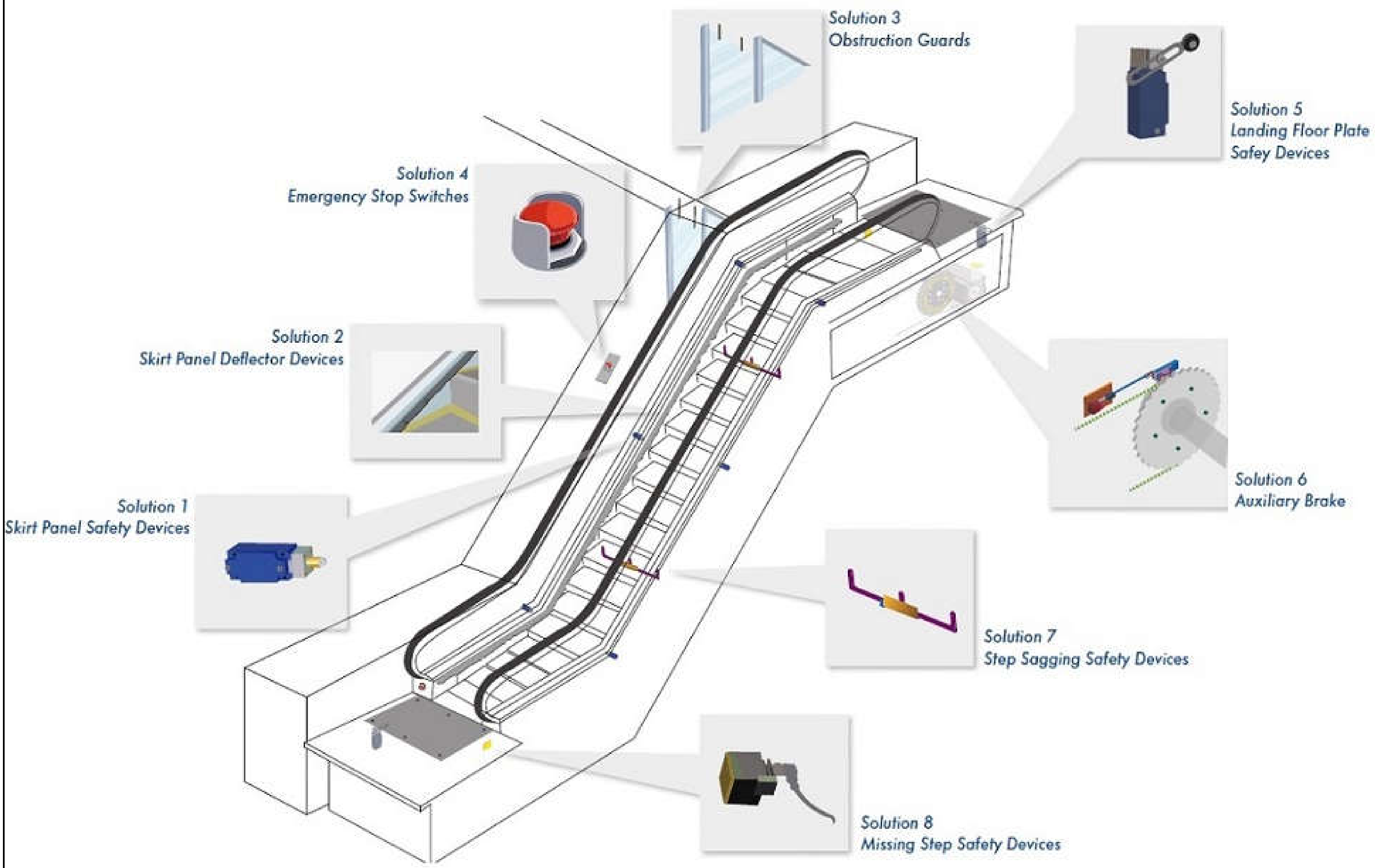
[Source: CIBSE Guide D]



Applicable solutions for enhancing requirements of existing lifts

(Source: https://www.brplatform.org.hk/en/defects-and-orders/common-building-defects/defective-lift)

Escalators modernisation

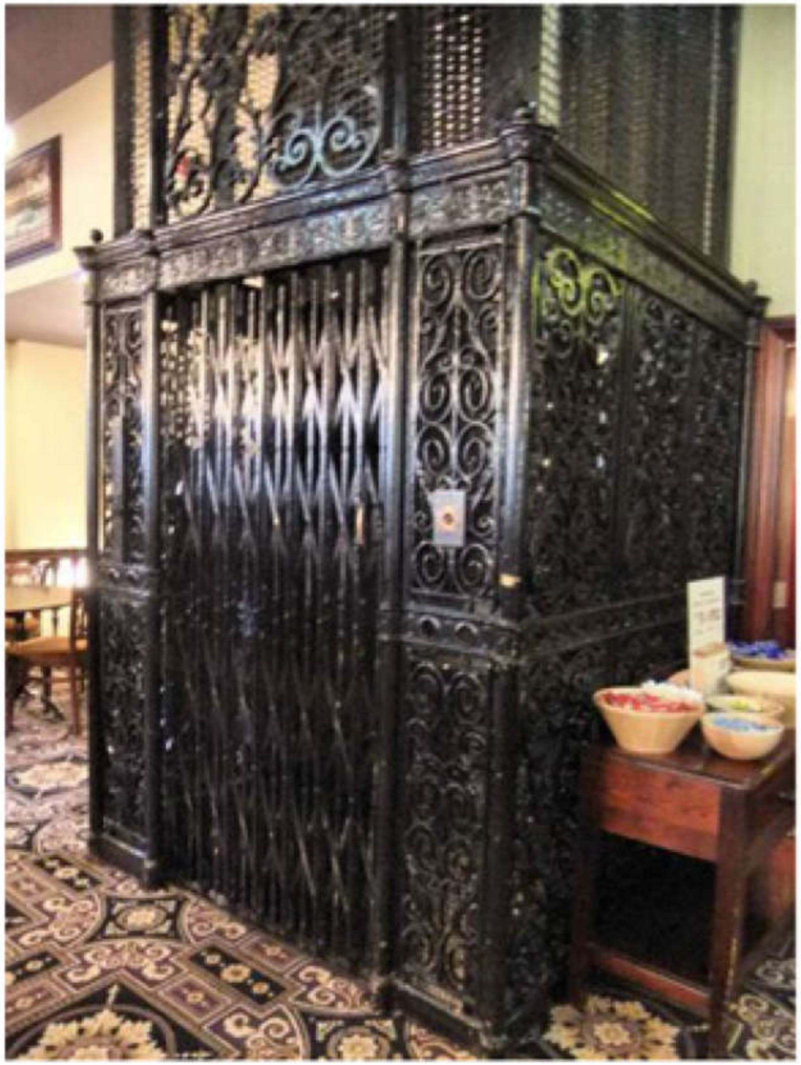


(Source: https://www.emsd.gov.hk/en/lifts_and_escalators_safety/responsible_persons_corner/lift_modernisation_resource_corner/)

Conclusions

- Energy efficiency of lift & escalator systems can be improved by technological advances
- Knowledge on the economic efficiency of the technological measures is needed
- Current limitations:
  - Lack of information about energy pattern & usage
  - Split incentives between contractors, owners of installations as well as those paying for the energy consumption of installations

Thank You



Q & A