Building Energy Use

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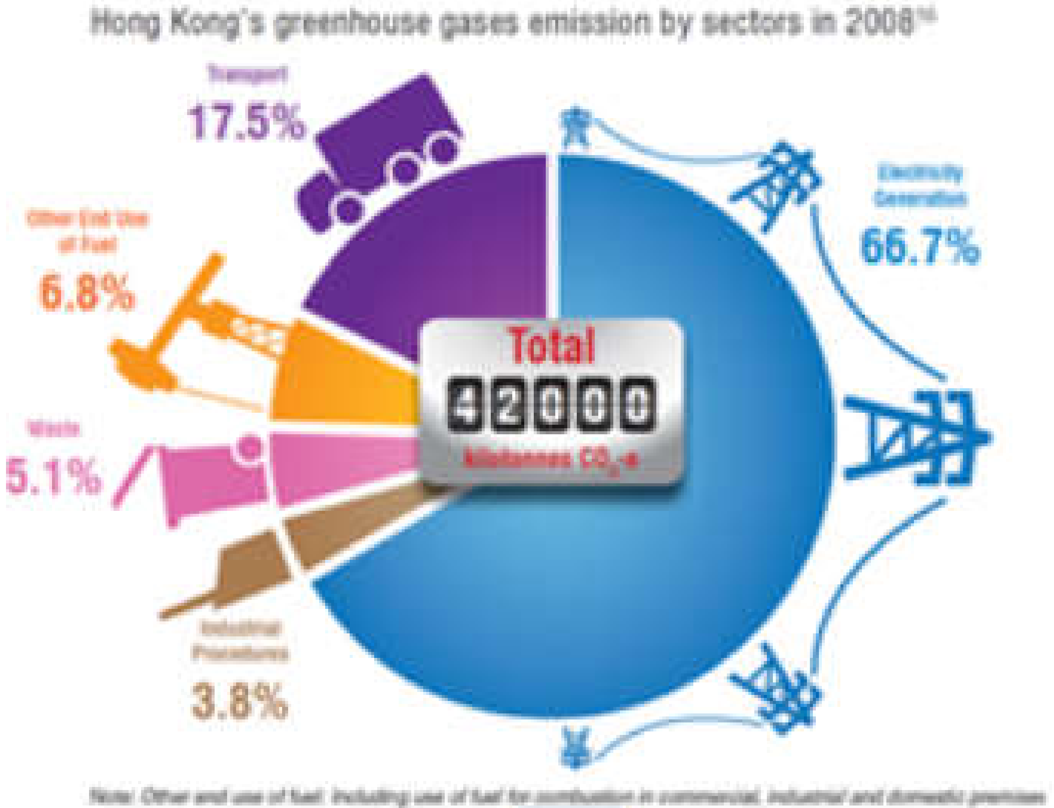
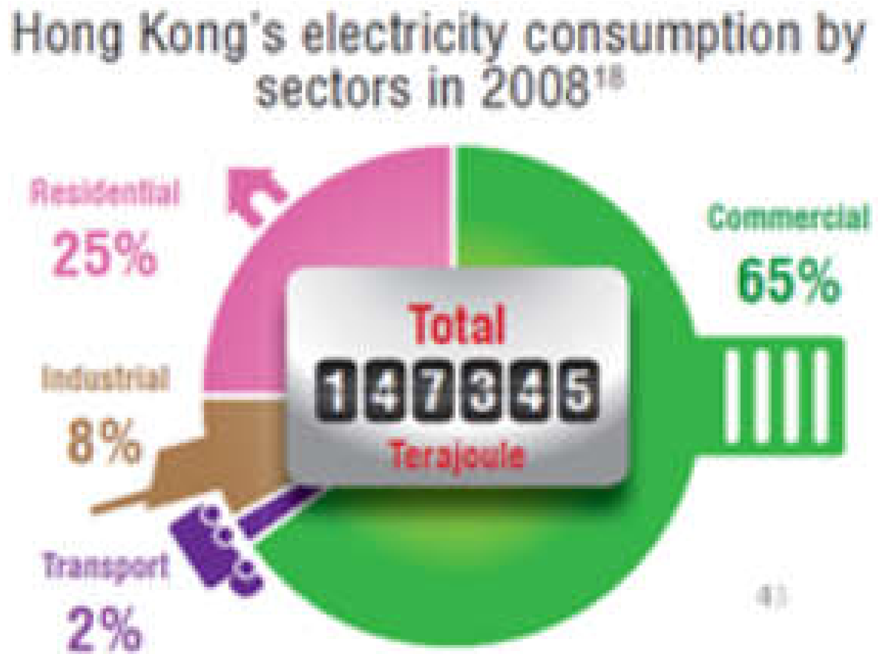
Energy use in buildings

- Buildings constitute 30% to 60% of total energy needs in a society
  - Residential + commercial + industrial buildings
  - The potential for energy saving is large
  - About 90% of total electricity consumption in Hong Kong is contributed by buildings*
- Electricity generation contributes 63% of total greenhouse gas (GHG) emission in Hong Kong in 2022

(* Source: Hong Kong Energy End-use Data, http://www.emsd.gov.hk/emsd/eng/pee/edata.shtml)

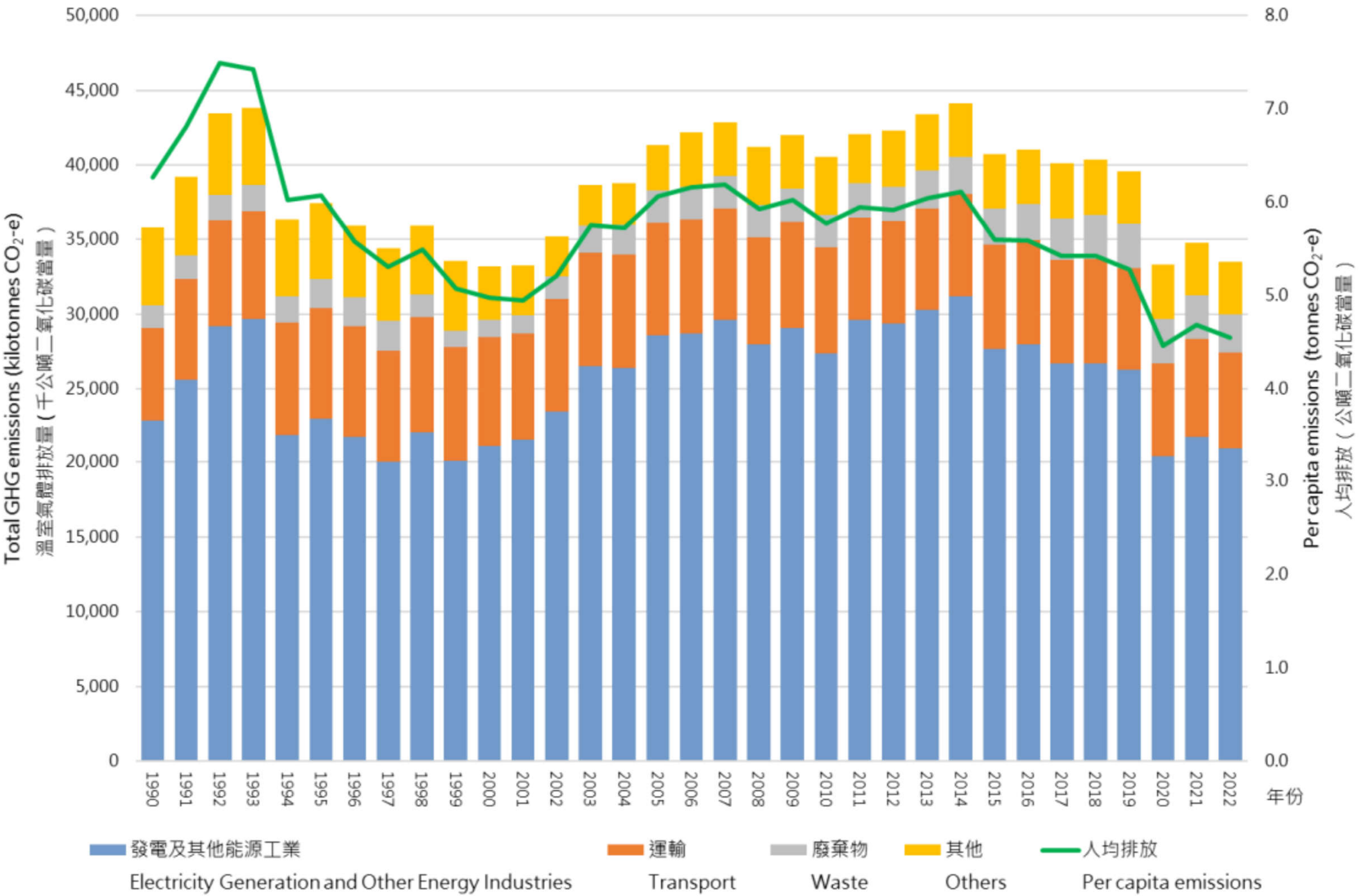
Greenhouse gas (GHG) emission of Hong Kong 2008





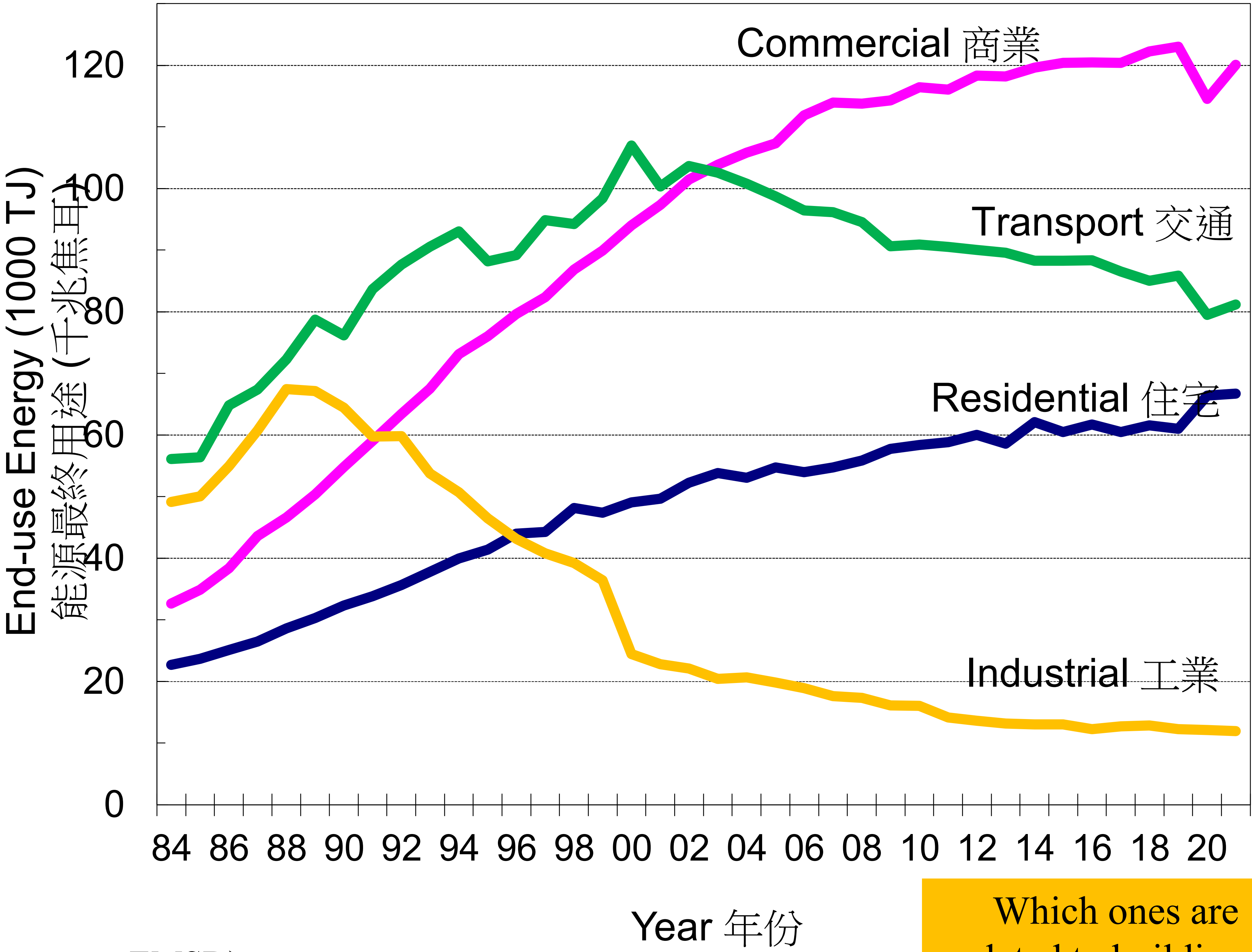
(Source: www.epd.gov.hk)

Greenhouse gas (GHG) emission trends of Hong Kong 1990-2022



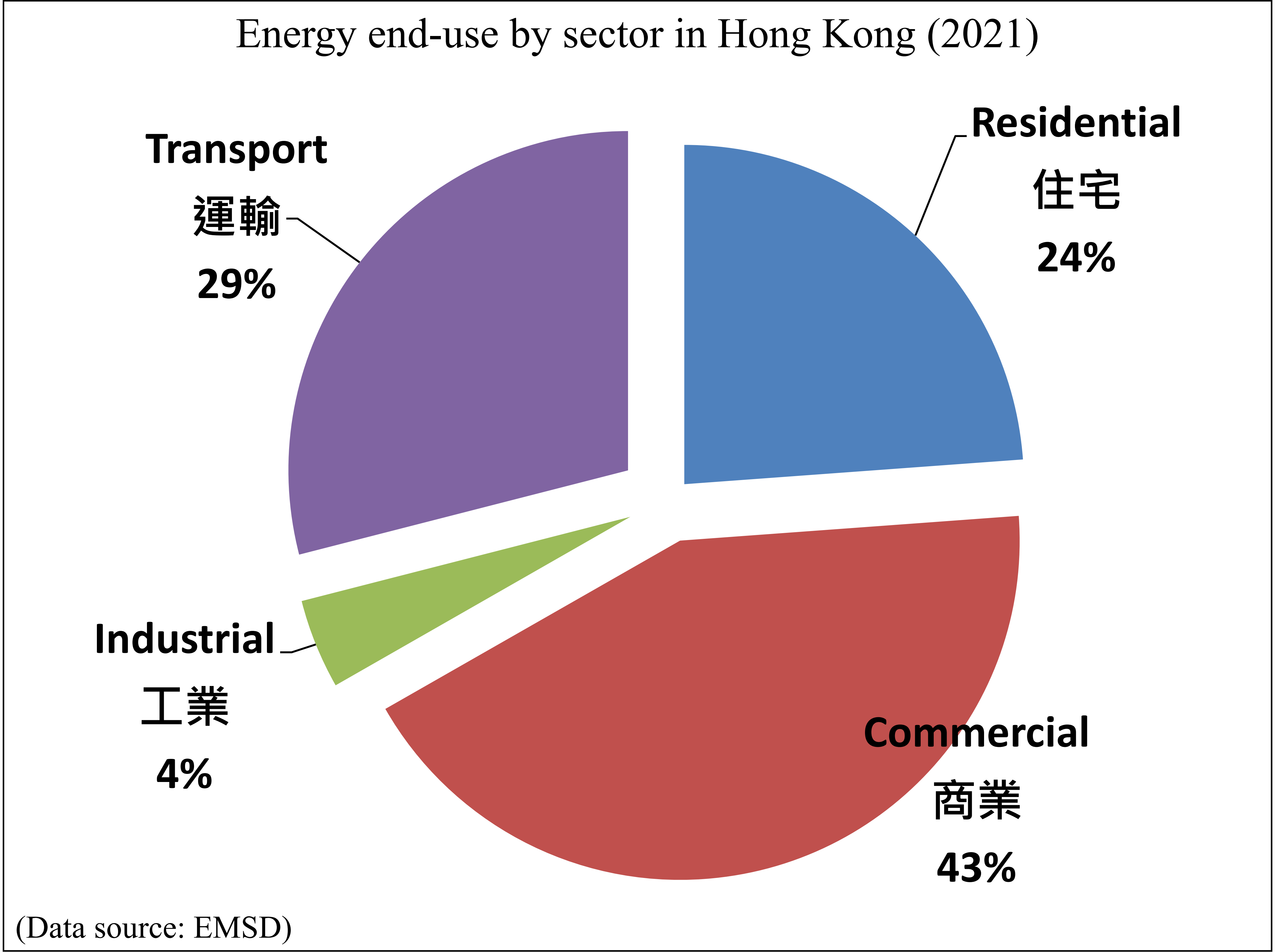
(Source: https://cnsd.gov.hk/en/climate-ready/ghg-emissions-and-trends/)

Energy end-use in Hong Kong by sectors, 1984-2021



Which ones are related to buildings?

(Data source: EMSD)



Energy end-use by sector in Hong Kong (2021)
Residential
住宅
24%
Transport
運輸
29%
Industrial
工業
4%
Commercial
商業
43%
(Data source: EMSD)

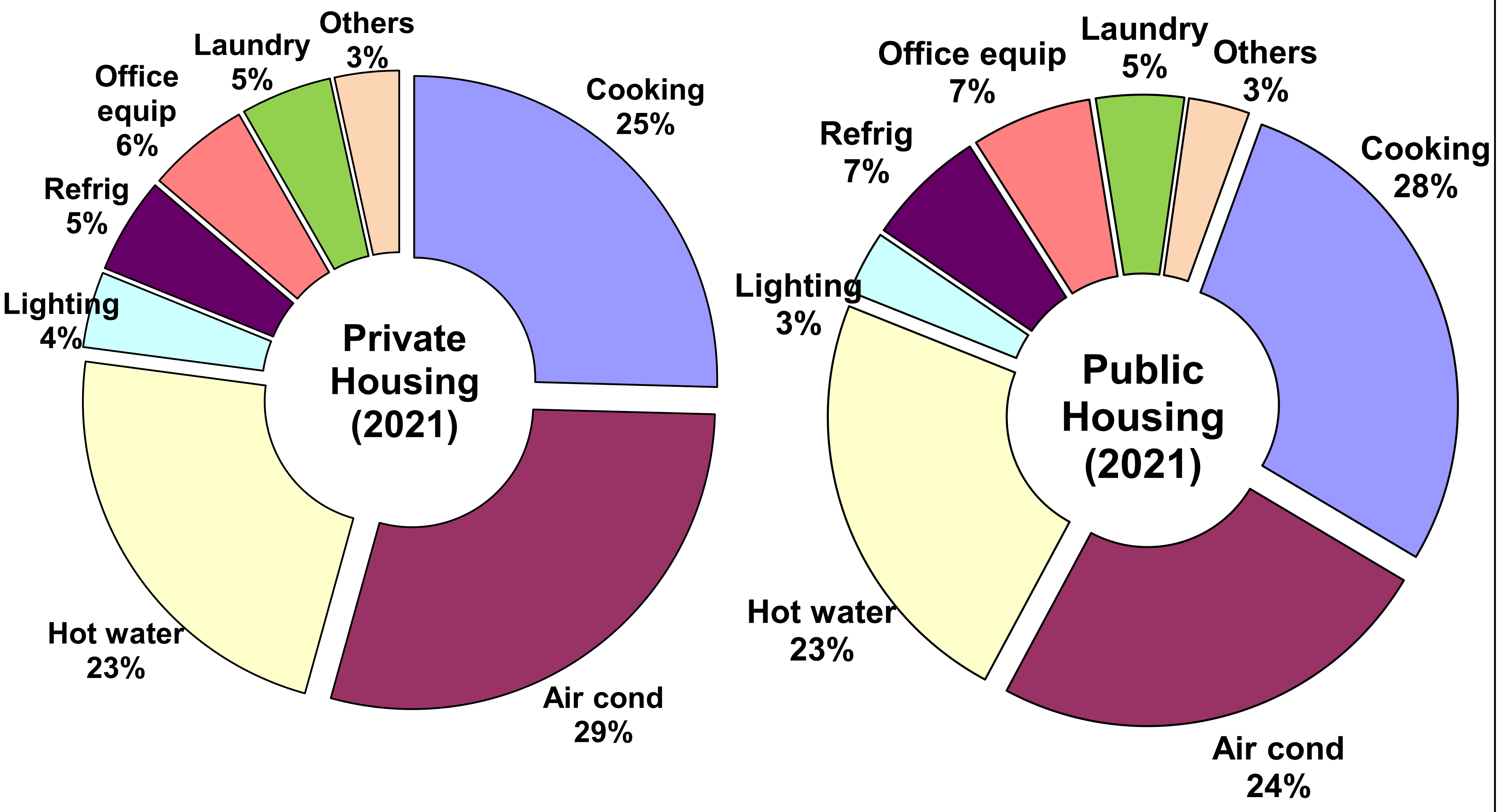
Electricity & towngas by sector in final energy requirements (FER) in Hong Kong (year 2012)

Unit: MJ	Commercial	Residential	Industrial	Total	(%)
Electricity	104350	45427	11087	160864	85%
	64.9%	28.2%	6.9%	100%	
Towngas	9709	15985	1704	27398	15%
	35.4%	58.3%	6.2%	100%	
Elec+ Towngas	114059	61412	12791	188262	100%
	60.6%	32.6%	6.8%	100%	
(% FER)	41.0%	22.1%	4.6%	67.7%	

Total FER for 2022 =		277949	TJ		

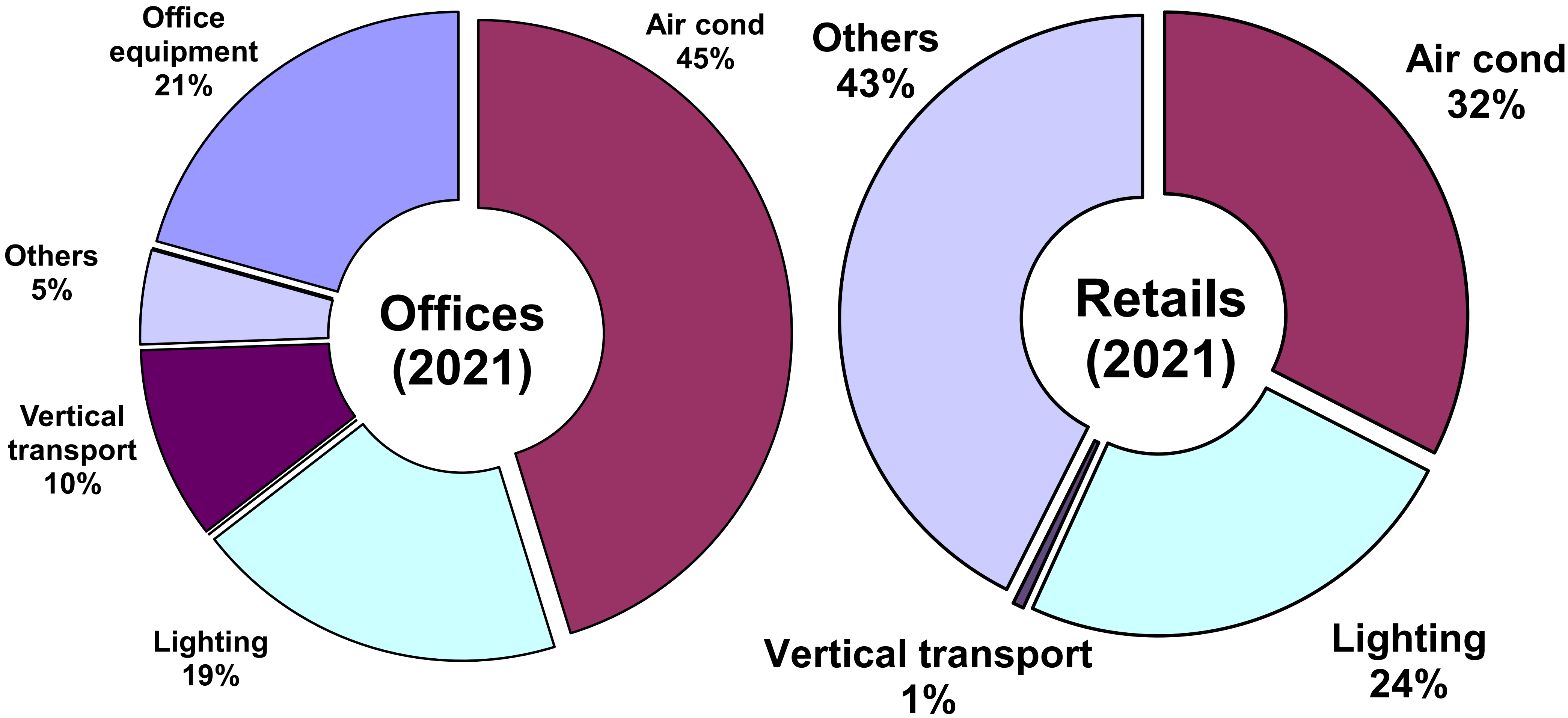
(Data source: *Hong Kong Energy Statistics 2022 Annual Report*)

Energy consumption patterns in residential buildings in Hong Kong (2021)



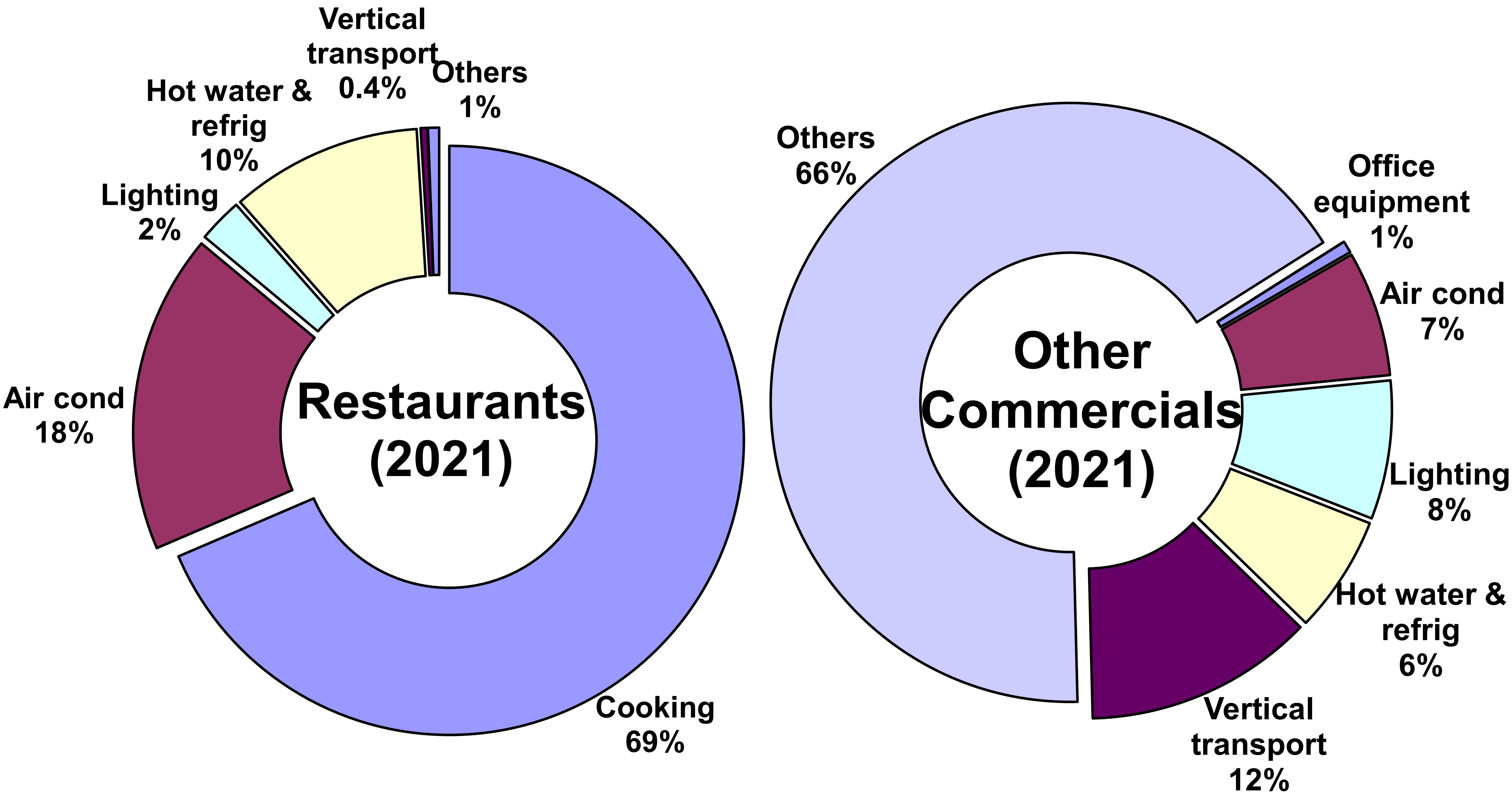
(Data source: Energy Efficiency Office, HK)

Energy consumption patterns in offices & retails in Hong Kong (2021)



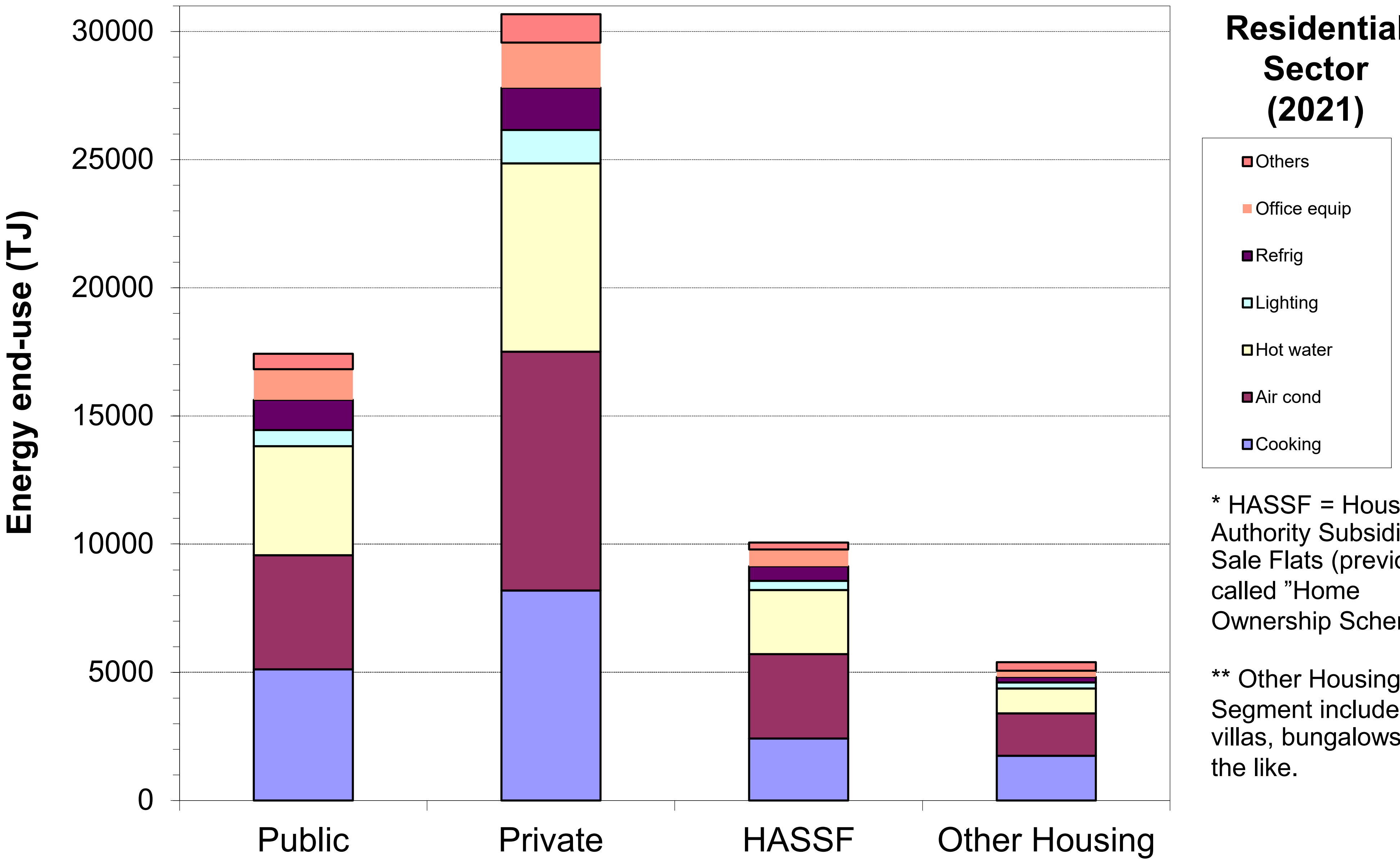
(Data source: Energy Efficiency Office, HK)

Energy consumption patterns in restaurants & other commercials in Hong Kong (2021)



(Data source: Energy Efficiency Office, HK)

Energy end-use in residential sector in Hong Kong (2021)

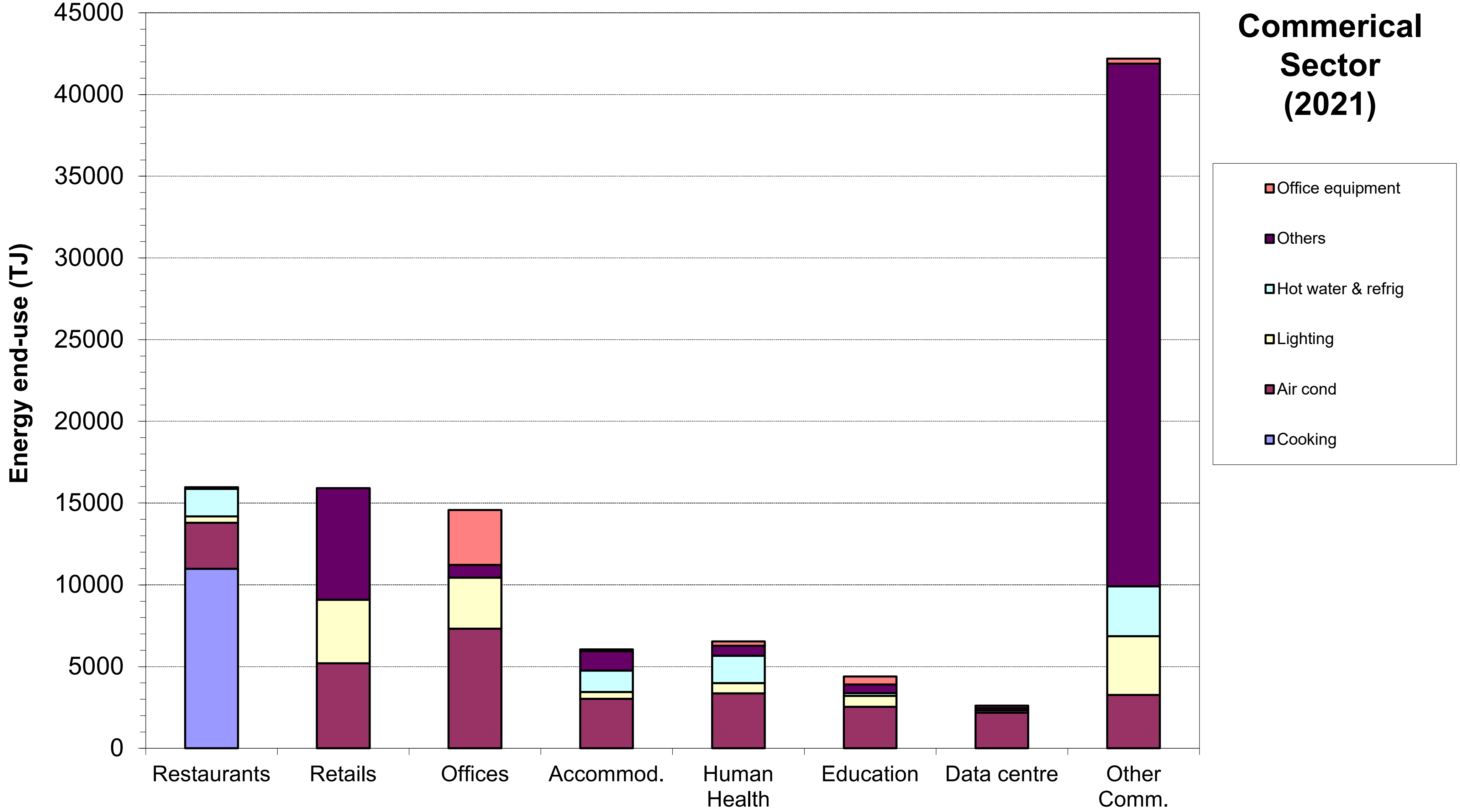


* HASSF = Housing Authority Subsidized Sale Flats (previously called "Home Ownership Scheme")

** Other Housing Segment includes villas, bungalows and the like.

(Data source: Energy Efficiency Office, HK)

Energy end-use in commercial sector in Hong Kong (2021)

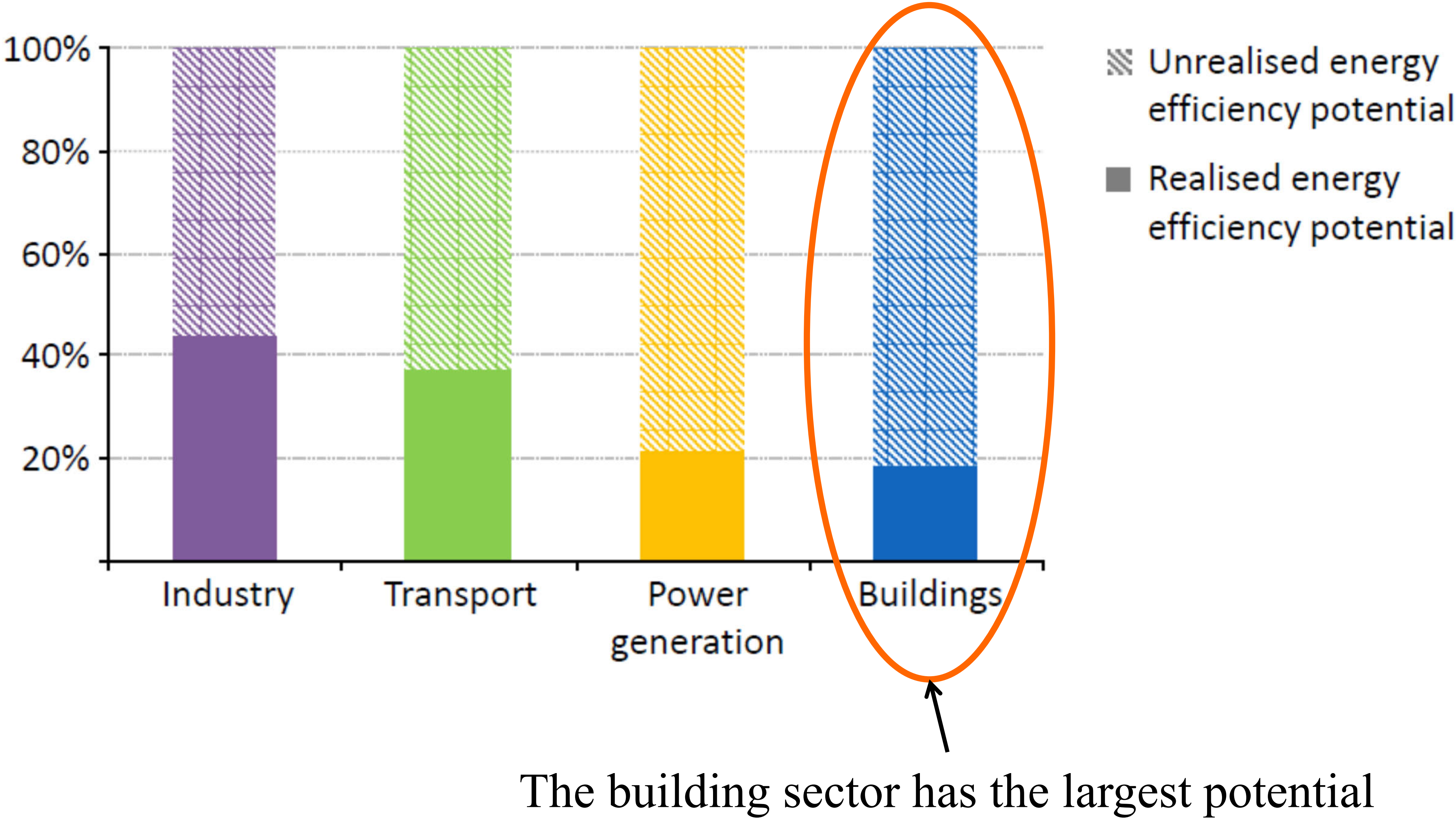


(Data source: Energy Efficiency Office, HK)

Building energy efficiency

- Possible benefits from energy efficiency:
  - 1. Improved building design & operation
  - 2. Better working environments
  - 3. Life-cycle cost savings
  - 4. Added market value of buildings
  - 5. Reduced CO_2 emissions & consumption of finite fossil fuels
  - 6. Reduced capital cost by better integration of building fabric & systems

Energy efficiency potential used by sector: a huge opportunity going unrealised



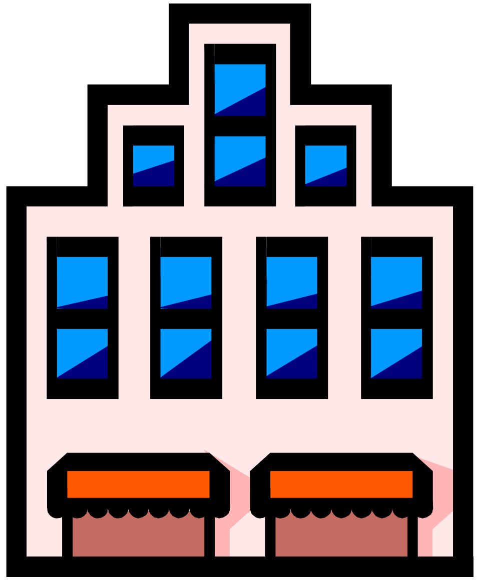
(Source: Fatih Birol, Chief Economist, International Energy Agency, www.iea.org)

Building energy efficiency

- Key persons in building energy efficiency
  - Building Developer or Owner (Client)
  - Architect & other building designers
  - Building Services Engineer
  - Building/Facility Manager
  - End-Users

Building energy efficiency

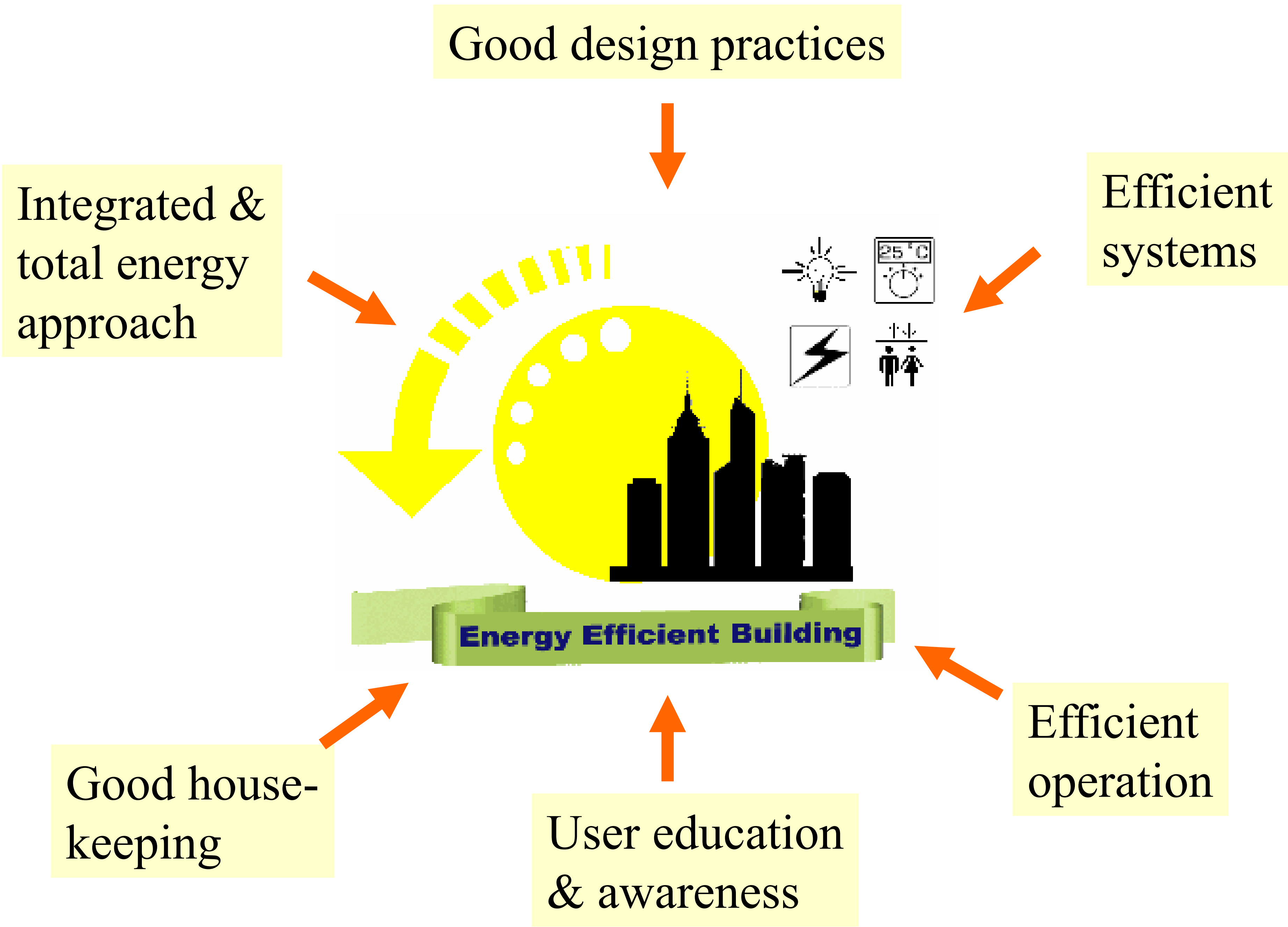
- For new buildings
  - Designing the building
    - Design strategy
    - Control strategies
    - Commissioning
- For existing buildings
  - Operating & upgrading the building
    - Building management
    - Refurbishment/renovation/retrofitting
    - Maintenance & monitoring



Building energy efficiency

- Energy efficiency is greatly affected by building management (BM), operation & maintenance (O&M)
  - Key to energy efficient management of existing buildings
    - A sound understanding of the building
    - A clear energy management & maintenance policy
    - Clear organisational structures & roles
    - Encourage & motivate the occupants
    - Set energy targets & continually monitor performance

Strategies for achieving energy efficient buildings



Building Energy Management Systems - How much energy can be saved

Energy conservation opportunities	**Estimated energy savings***
Turn up temperature to 25.5ºC in summer	5% of cooling cost for each ºC raised
Turn back temperature to 20ºC in winter	9% of heating cost for each ºC set back
Maintain air-conditioning units by annual check-ups & adjustments	15% of cooling cost
Maintain furnace at maximum efficiency by annual check-ups and adjustments	10% of heating cost
Set back domestic water heater from 60 to 43ºC	6-12% of hot water cost
Maximise use of daylight	50-60% of lighting cost
Improve lighting maintenance	10% of lighting cost
Turn off unnecessary lights	17% of lighting cost
Reduce lighting	15-28% of lighting in existing buildings 25-50% of lighting in new buildings
Use insulating glass	10-13% of cooling & heating costs
Insulate hot water pipes & storage tanks	15% of water heating costs
Provide adequate insulation for roof	20% of cooling & heating costs

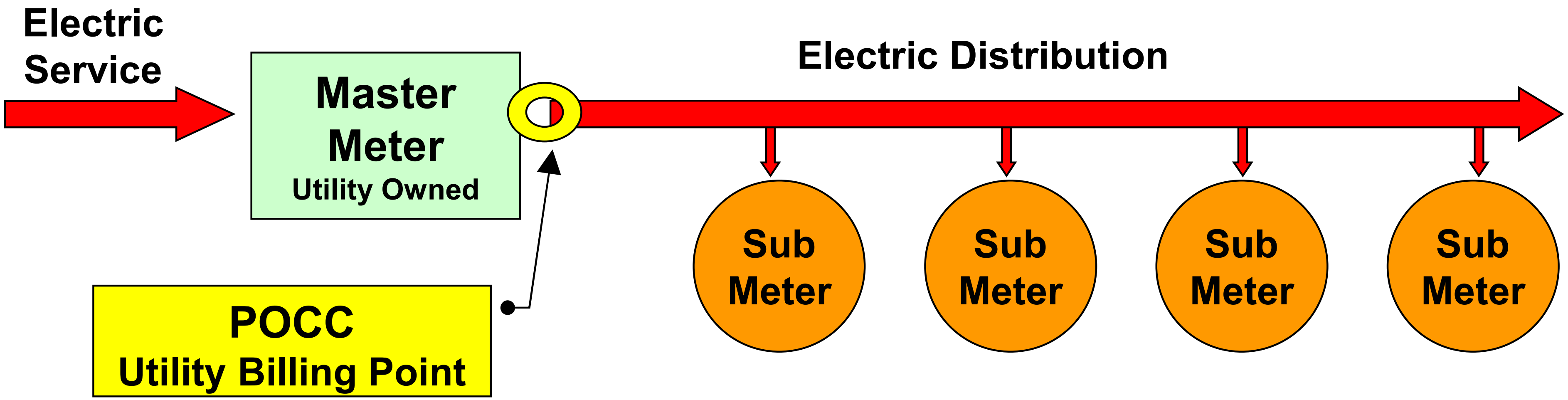
(* For typical examples only)

Submetering

- What is submetering?
  - Defined as a metering device installed after the main utility meter
    - Used for capturing facility energy data at a specific location, panel, circuit or user
  - Delivers granularity (breakdown) of facility energy performance data

Submeters –The critical component for accessing facility energy related data

What is Submetering?



POCC – Point of Common Coupling, the point where control passes from the Electric Utility to the building Owner

Electricity meter

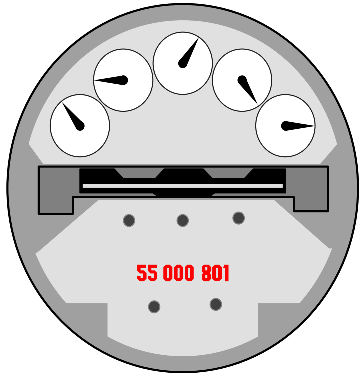
Gas meter

Water meter

Also chilled, hot water & steam meters

(See also: http://en.wikipedia.org/wiki/Utility_submeter)

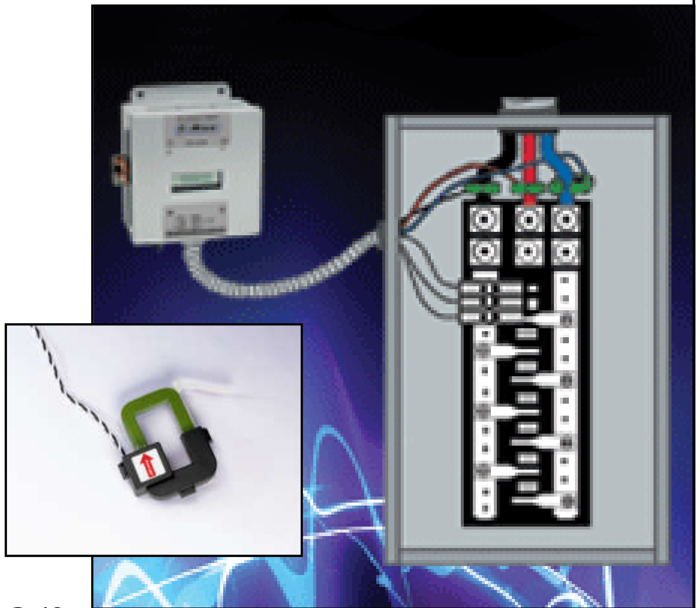
Submetering



- Electro-Mechanical Meter
  - Typical utility type meter
  - Available in various amperages
  - Power passes through meter, then to distribution panel
  - Requires substantial physical space for installation
- One meter per building
  - Restricted ability to sell multiple meters per customer site

Submetering

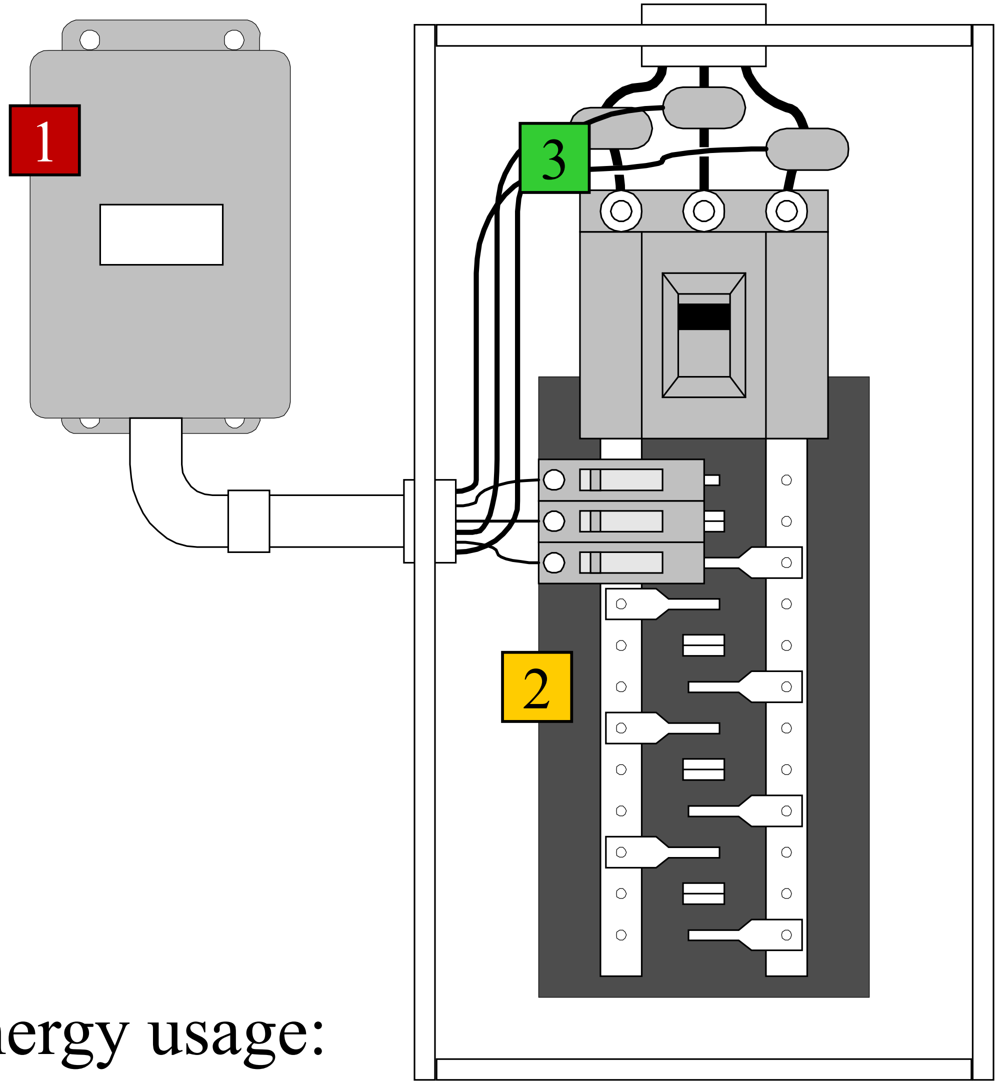
- [Sensor-Based Submeters]
  - Non-socket, current sensor based technology
    - Limited or no power interruption
    - Lower installed cost
      - No current transformer (CT) cabinets
      - No meter socket
      - Reduced cabling and conduit
    - 1/10 the time to install
    - Space saving and flexibility in location



  - Multiple submeters per location increases revenue stream

Electronic kWh Meter Installation

1. Mount meter at desired location
2. Connect voltage inputs – fuse/provide disconnect according to code
3. Install split-core current sensors
4. Power up meter



Three major components of energy usage:
(a) HVAC
(b) Lighting
(c) Receptacle loads

Submetering

- Accurate energy monitoring
  - Electronic submetering equipment: ease & flexibility of installation

    - Metering installs in practically any available space
    - Any size circuit from main distribution to a single 15 ampere branch can be monitored
    - No changes to building wiring required
    - Using split-core current sensors will allow installation without disconnecting cables

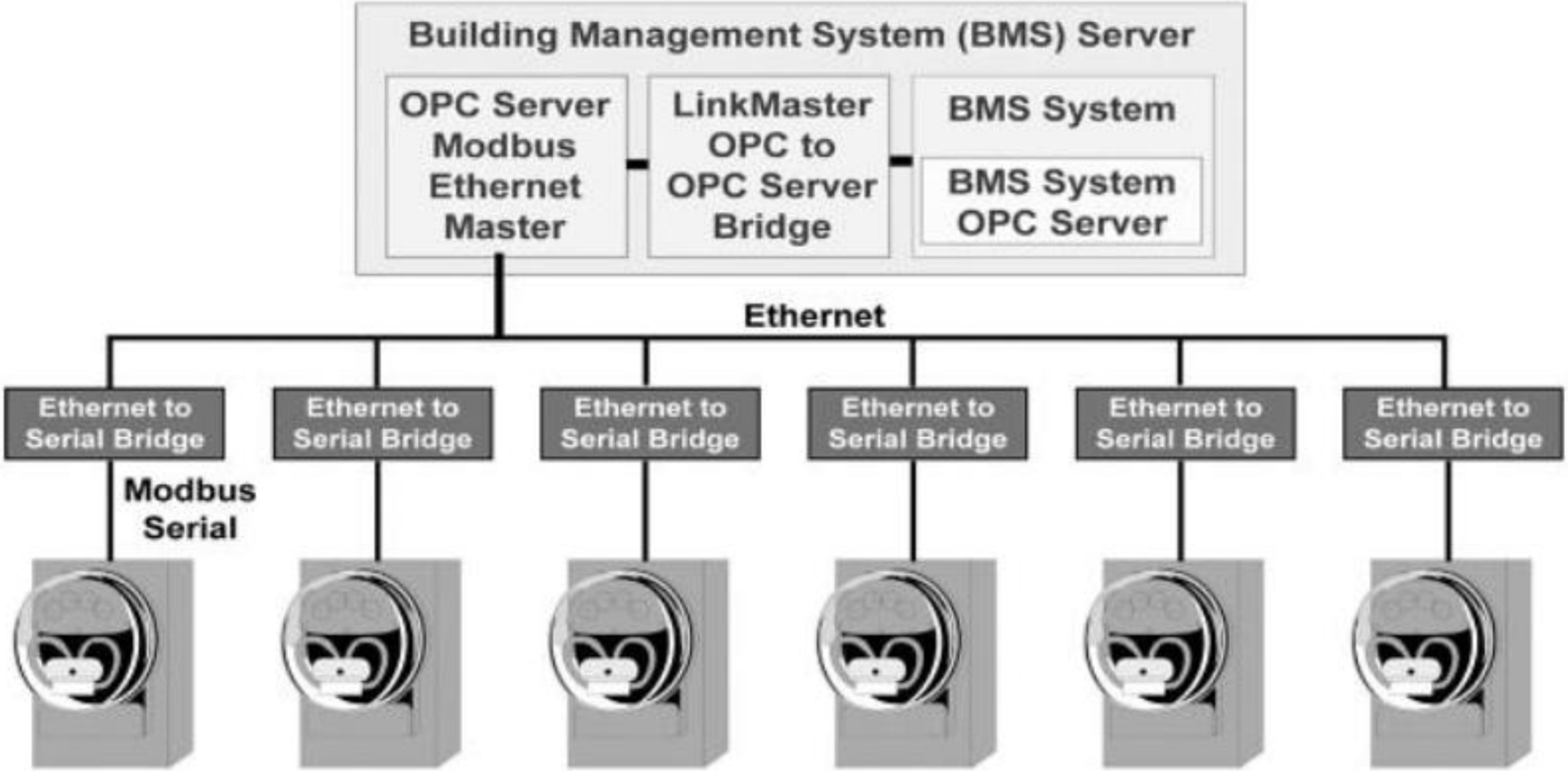
Submetering

- Benefits of submetering:
  - Accurate energy monitoring
  - Ease & flexibility of installation
  - Concise energy management tool
  - Promotes energy savings
  - Positive environmental impact
  - Automatic Meter Reading (AMR) capable
  - Provides time of use (T.O.U.) graphs & charts

Submetering

- Submetering easily ties into building/energy management equipment
- Detailed energy data gives system maximum control over energy usage, etc.
- Remote monitoring by Automatic Meter Reading (AMR) system acts as "watchdog" to keep an eye on performance
- Maximum control = Maximum savings

Metering data from a BMS server made available to a local area network using an OPC server



(OPC = Object Linking and Embedding (OLE) for Process Control)

(Source: Capehart, B. L. and Middelkoop, T., 2011. *Handbook of Web Based Energy Information and Control Systems*)

Submetering

- Promote energy management & savings
- Benchmarking
  - Accurate knowledge of where energy is being consumed is the first step in creating a savings program
- Continuous commissioning
  - Constant monitoring allows the user to gauge the results of an energy savings program

(See also: Building energy use benchmarking http://energy.gov/eere/slsc/building-energy-use-benchmarking
Continuous Commissioning http://www.encom.co.nz/Commissioning/Continuous+Commissioning.html)

Submetering

- Positive environmental impact
  - Better efficiency delays need for new generating facilities (costs stay lower)
  - Lower pollution provides environmentally friendly image

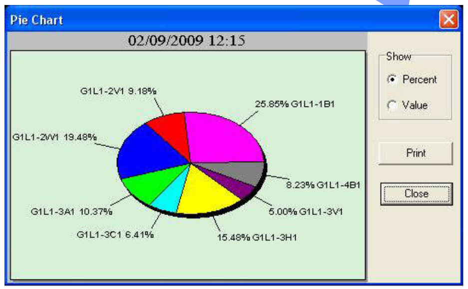
Each kilowatt-hour of electrical energy saved reduces pollution by:

☞ 0.62 kg carbon dioxide (CO_2)
☞ 5.8 grams sulphur dioxide (SO_2)
☞ 2.5 grams nitrous oxides (NOx)

Submetering

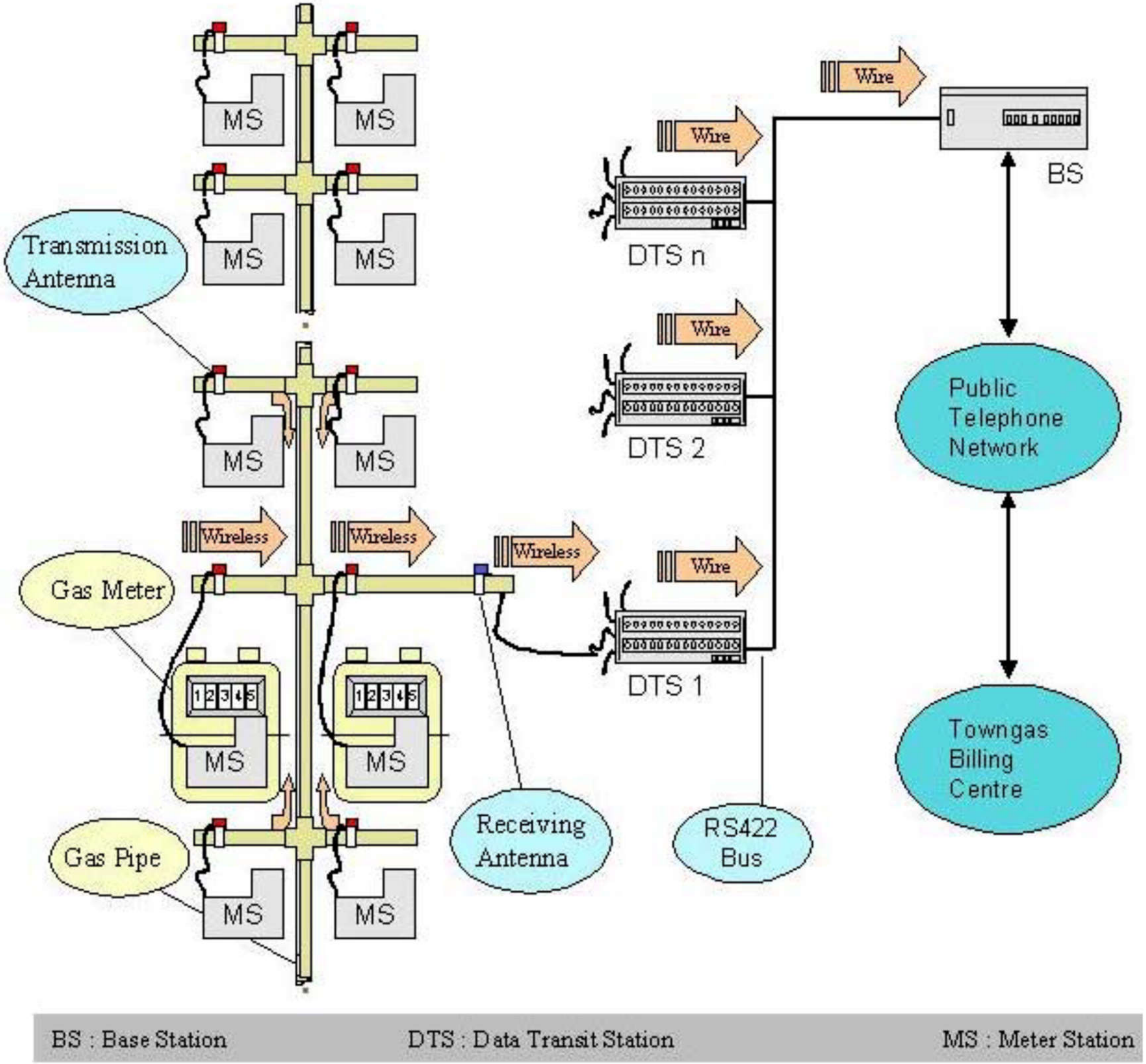
- [Automatic meter reading (AMR)](http://en.wikipedia.org/wiki/Automatic_meter_reading)

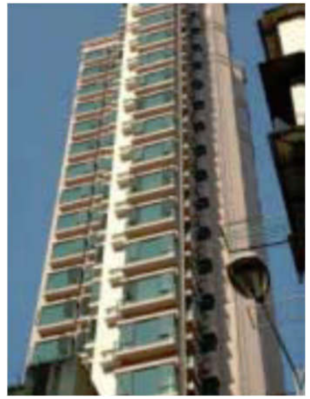
  - Allows reading of meters at any time, day or night
  - Allows meter reading in all weather conditions
  - Allows reading of meters anywhere in the world from your computer
  - AMR provides "time-of-use" data
    - For "real-time" pricing of energy
    - For event analysis
    - For demand side management programs
    - For energy program planning and performance analysis



(See also: http://en.wikipedia.org/wiki/Automatic_meter_reading)

System architecture of automatic meter reading (AMR) of Towngas





(Source: http://www.towngas.com/Eng/Cust/Business/ResidentialProjects/AMRSystem.aspx)

Smart Energy Online (energy saving service) from CLP

基於香港天文台最新天氣資料的用電量預測

Consumption Forecast based on latest weather information from HKO

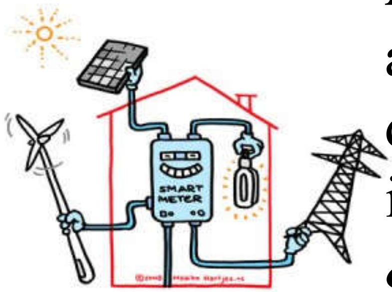
日期 Date	星期五 Friday	星期六 Saturday	星期日 Sunday	星期一 Monday	星期二 Tuesday	星期三 Wednesday	星期四 Thursday	星期五 Friday	星期六 Saturday
天氣 Weather Outlook									
預測溫度 Forecast Temperature	29°C	29°C	29°C	29°C	29°C	29°C	29°C	28°C	27°C
預測濕度 Forecast Humidity	78%	80%	79%	70%	63%	68%	69%	72%	76%
預測最高需求量 Forecast Max. kVA	3,963 @ 13h 3,958 @ 12h 3,883 @ 11h	4,222 @ 13h 4,144 @ 14h 4,126 @ 12h	3,736 @ 12h 3,704 @ 11h 3,684 @ 13h	3,444 @ 12h 3,428 @ 13h 3,409 @ 19h	3,341 @ 19h 3,311 @ 20h 3,230 @ 14h	3,401 @ 13h 3,394 @ 19h 3,392 @ 14h	3,375 @ 19h 3,346 @ 20h 3,335 @ 13h	3,299 @ 13h 3,280 @ 14h 3,275 @ 12h	3,273 @ 19h 3,245 @ 20h 3,214 @ 13h
預測用電量 Forecast Consumption (kWh)	45,637	47,715	43,300	40,685	36,480	37,954	37,711	37,706	37,686
預測與過去的比較 Forecast vs Historical	1,473 ↑	1,513 ↑	-2,022 ↓	-4,638 ↓	-7,685 ↓	-6,211 ↓	-2,126 ↓	2,508 ↑	-78 ↓

Features:
- Forecast the occurring time of peak demand
- Provide 9-day regional consumption forecast
- Load profile download (every half hour)
- Proactive energy management, load monitoring, benchmarking, energy analysis

(Source: https://www.clp.com.hk/en/business/low-carbon-solutions/energy-management/smart-energy-online)

Submetering

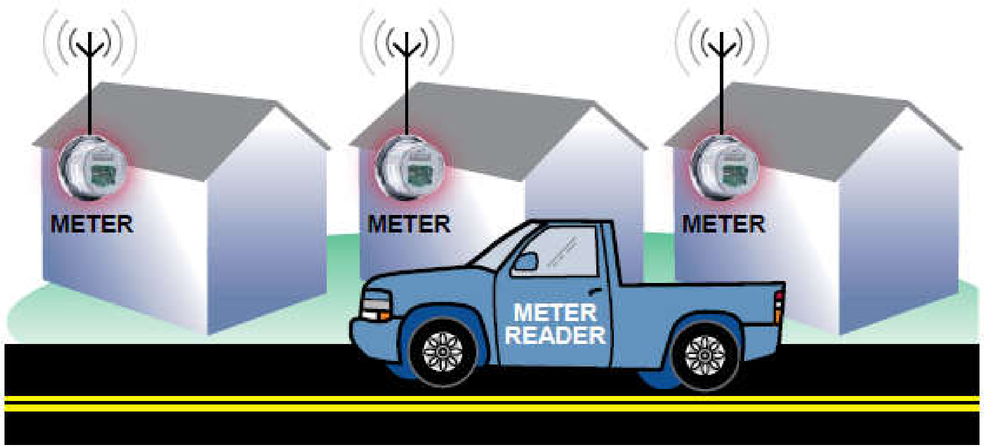
- [Advanced Metering]
  - Advanced meters (or "smart" meters)
    - Have the capability to measure & record interval data (at least hourly for electricity), & communicate the data to a remote location in a format that can be easily integrated into an advanced metering system
  - Advanced metering systems (AMS)
    - A system that collects time-differentiated energy usage data from advanced meters via a network system on either an on-request or defined schedule basis. It is capable of providing usage information on at least a daily basis & can support desired features & functionality related to energy use management, procurement & operations



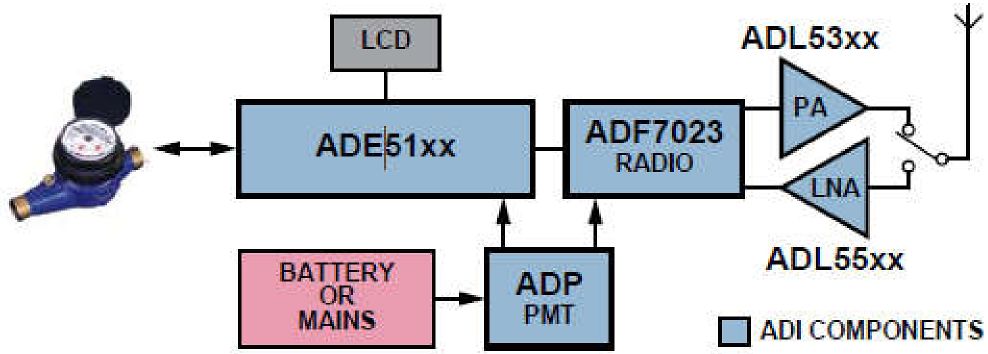
(* See also http://en.wikipedia.org/wiki/Smart_meter)

Advanced metering systems & infrastructure

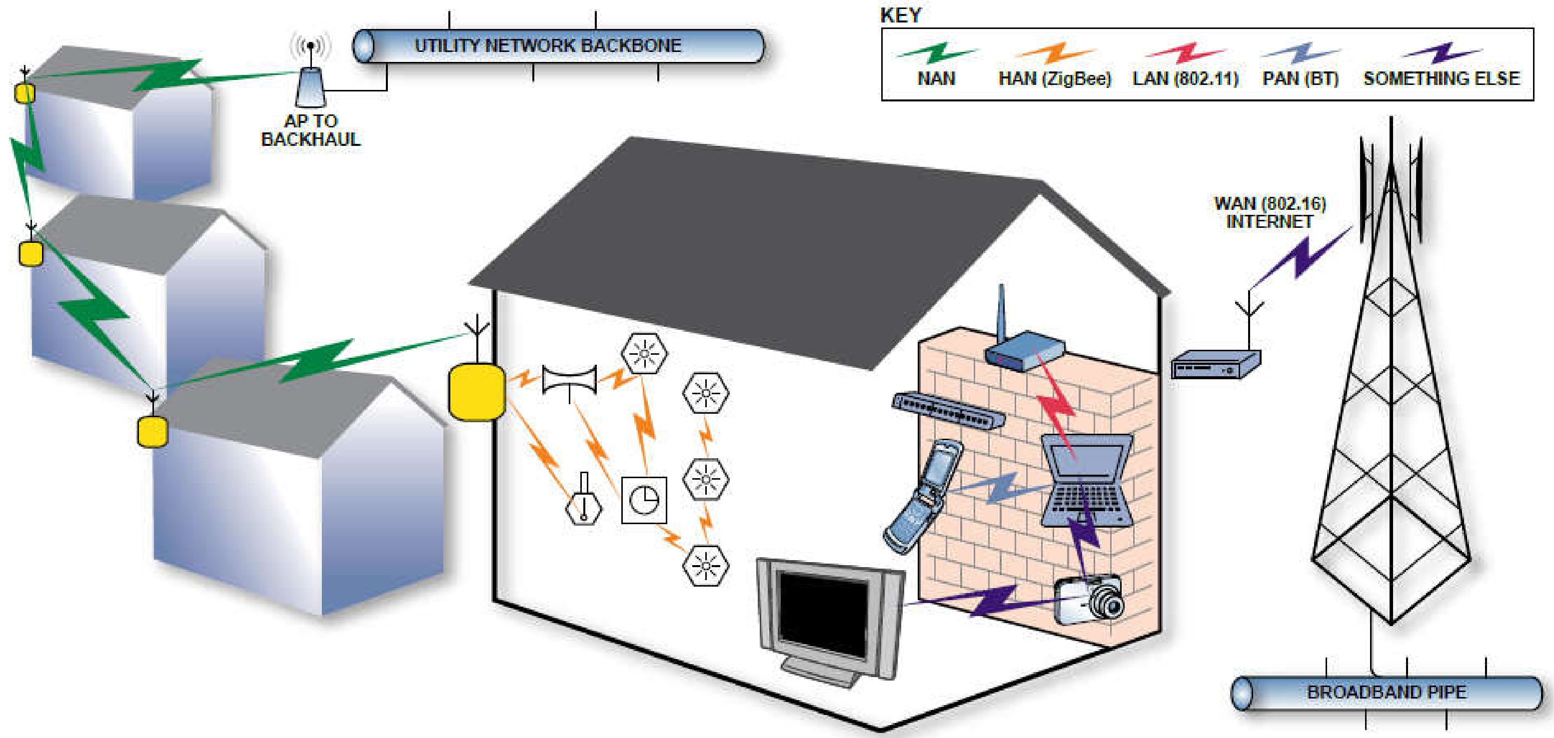
Drive-by meter reader



AMR-enabled utility meter

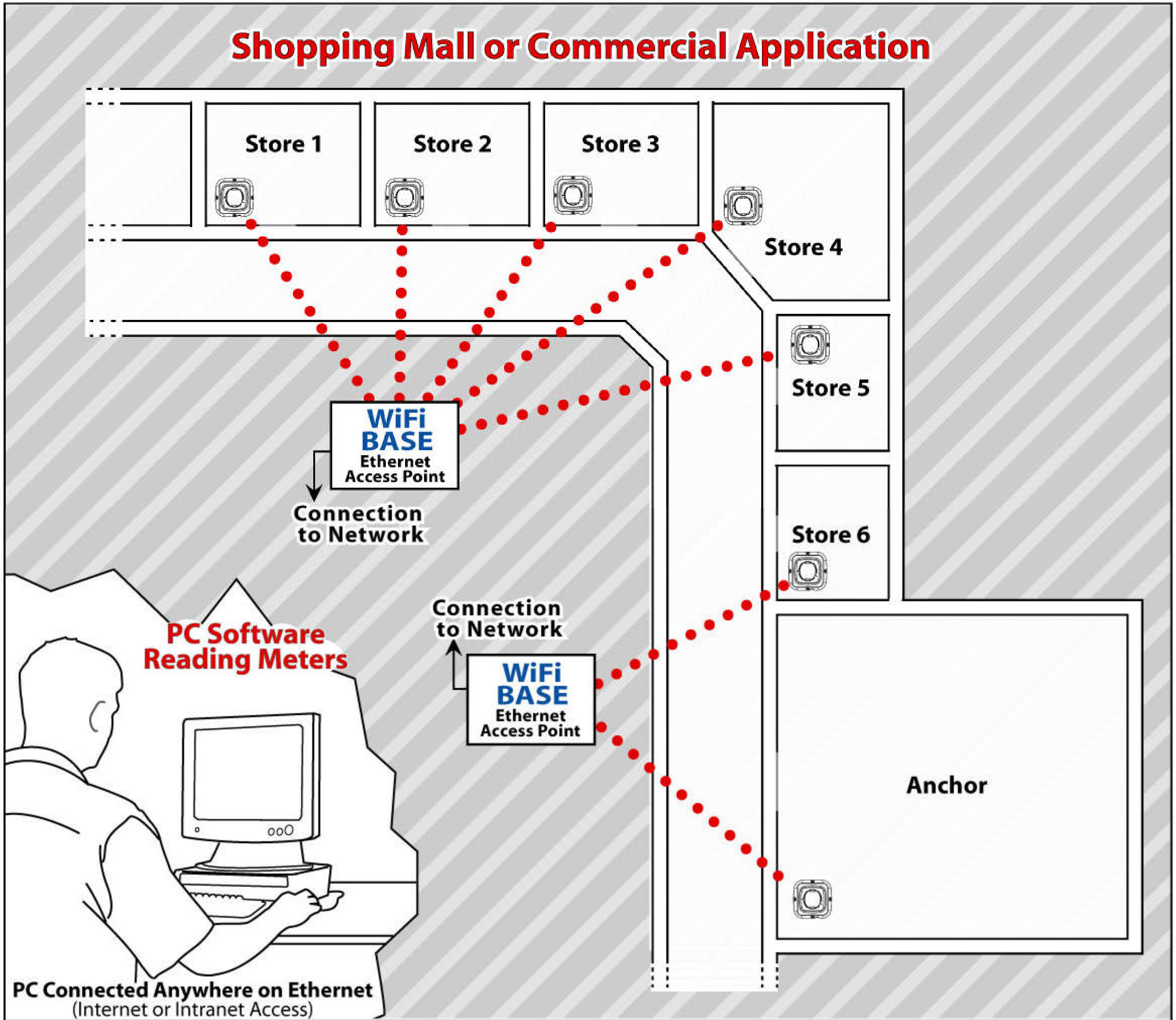


"Smart grid" & home area network (HAN) using communication-enabled meter



(Source: https://www.analog.com/en/resources/analog-dialogue/articles/smart-metering-tech-promotes-energy-efficiency.html)

Using wireless ethernet WiFi networking for submetering



(Source: www.electroind.com)

Submetering

- <u>Uses of metered data</u>
  - Energy billing & procurement
    - Measure tenant energy use, verify utility bills, identify best utility rate tariffs, and participate in demand response programs
  - Measure, verify & optimize performance
    - Diagnose equipment & systems operations; benchmark utility use; identify potential retrofit/ replacement projects; and monitor, diagnose & communicate power quality problems

Submetering

- Uses of metered data (cont'd)
  - Manage utility use
    - Monitor existing utility usage & utility budgeting support
  - Baseline development and measurement & verification (M&V) of savings
    - Such as in energy savings performance contracts (ESPC) & utility energy services contracts (UESC)
  - Promote energy use awareness for building managers & occupants

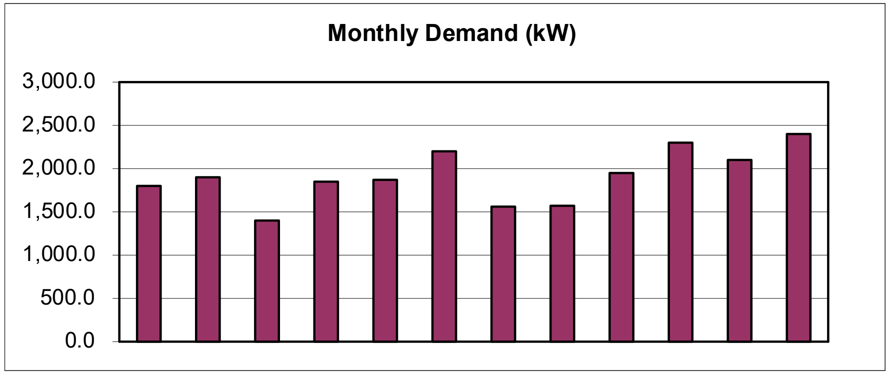
Example of analysing the electricity billings

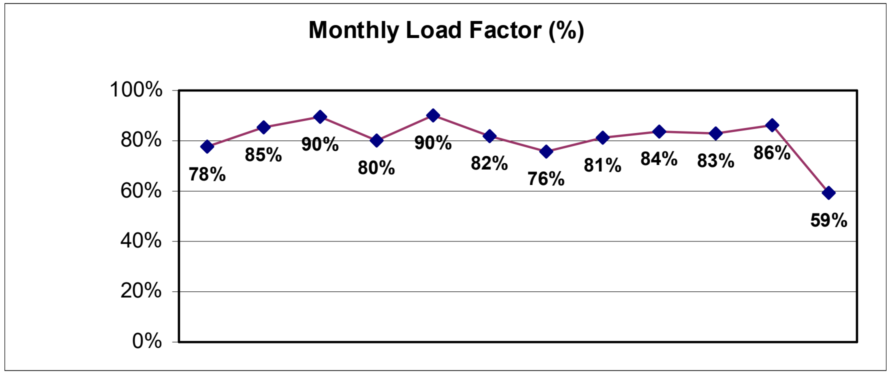
Electricity Consumption Data

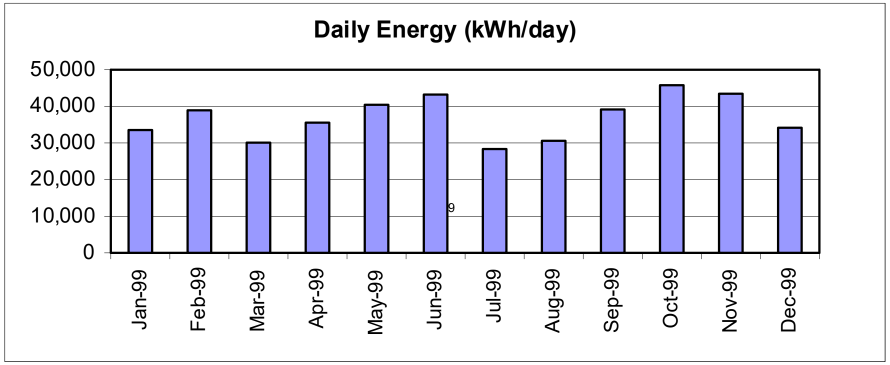
Location: ABC Facility

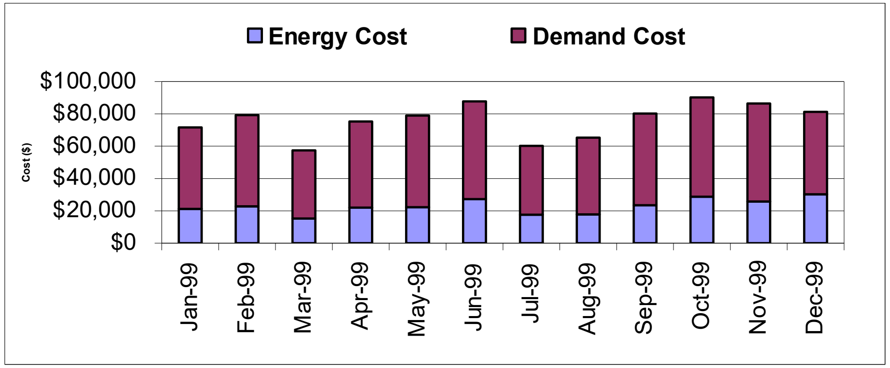
[C:\Project Files\Audit Manual\Spreadsheets\[Electricity Cost.xls]Electicity Consumption Data]

Billing Date	Metered kVA	Metered kW	Power Factor	Billed kW	Energy kWh	Days	Daily kWh	Load Factor	Demand Cost	Energy Cost	Adjust (+/-)	Sub Total	Total Cost
01/01/99		1,800.0		1,800.0	1,006,703	30	33,557	78%	$21,250	$50,365	($11,147)	$71,615	$64,701
02/01/99		1,900.0		1,900.0	1,206,383	31	38,916	85%	$22,750	$56,441	($13,204)	$79,191	$70,607
03/01/99		1,400.0		1,400.0	842,286	28	30,082	90%	$15,250	$42,144	($9,263)	$57,394	$51,501
04/01/99		1,850.0		1,850.0	1,102,176	31	35,554	80%	$22,000	$53,315	($12,132)	$75,315	$67,606
05/01/99		1,870.0		1,870.0	1,213,021	30	40,434	90%	$22,300	$56,641	($13,252)	$78,941	$70,287
06/01/99		2,200.0		2,200.0	1,339,599	31	43,213	82%	$27,250	$60,438	($14,716)	$87,688	$78,080
07/01/99		1,560.0		1,560.0	850,195	30	28,340	76%	$17,650	$42,540	($9,438)	$60,190	$54,304
08/01/99		1,570.0		1,570.0	948,747	31	30,605	81%	$17,800	$47,467	($10,429)	$65,267	$58,677
09/01/99		1,950.0		1,950.0	1,213,798	31	39,155	84%	$23,500	$56,664	($13,308)	$80,164	$71,536
10/01/99		2,300.0		2,300.0	1,373,054	30	45,768	83%	$28,750	$61,442	($15,111)	$90,192	$80,337
11/01/99		2,100.0		2,100.0	1,347,059	31	43,454	86%	$25,750	$60,662	($14,731)	$86,412	$76,699
12/01/99		2,400.0		2,400.0	1,024,475	30	34,149	59%	$30,250	$50,984	($11,685)	$81,234	$74,418
Totals/Max		**2,400.0**		**2,400.0**	**13,467,496**	**364**			**$274,500**	**$639,104**	**($148,415)**	**$913,604**	**$818,752**



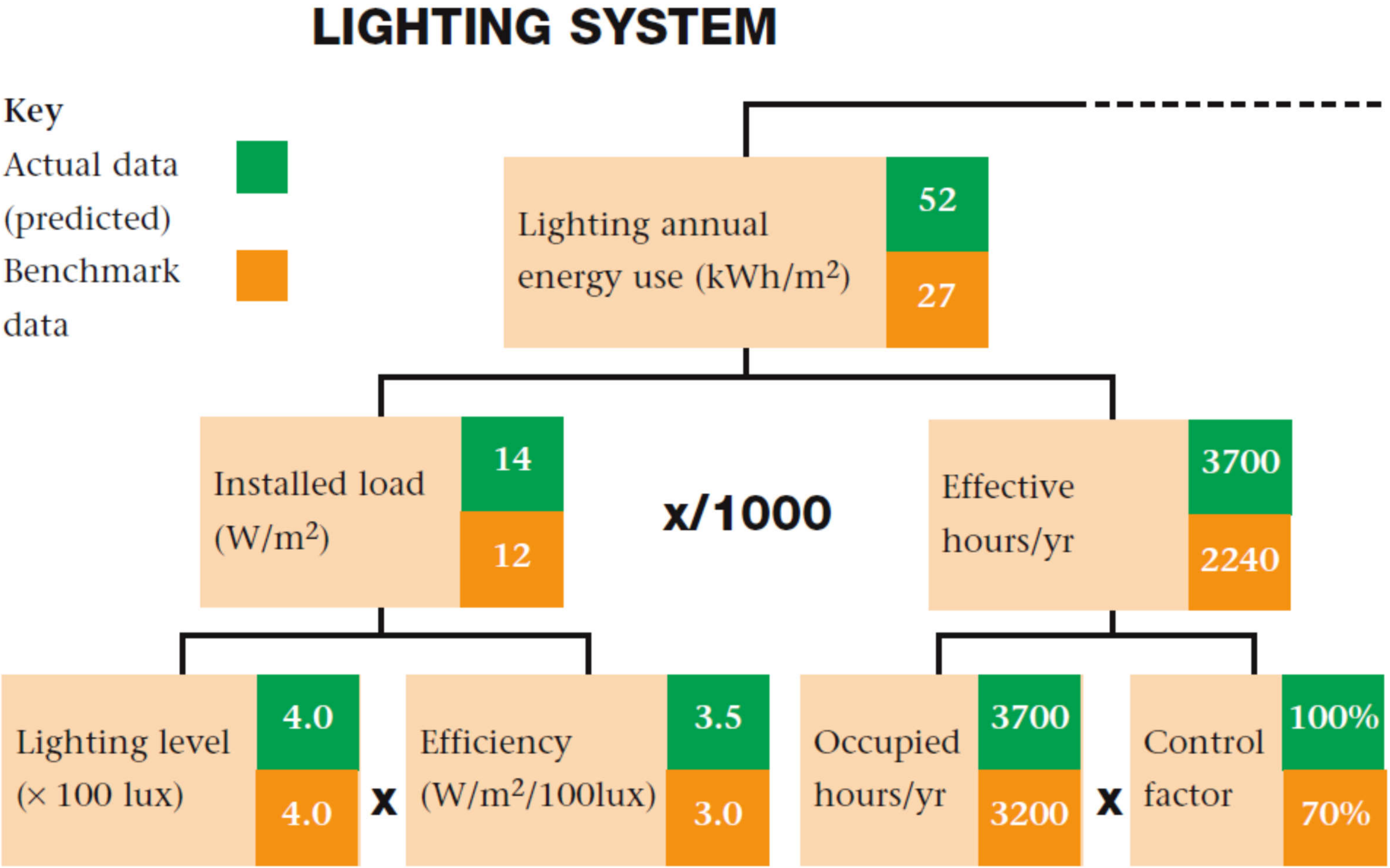






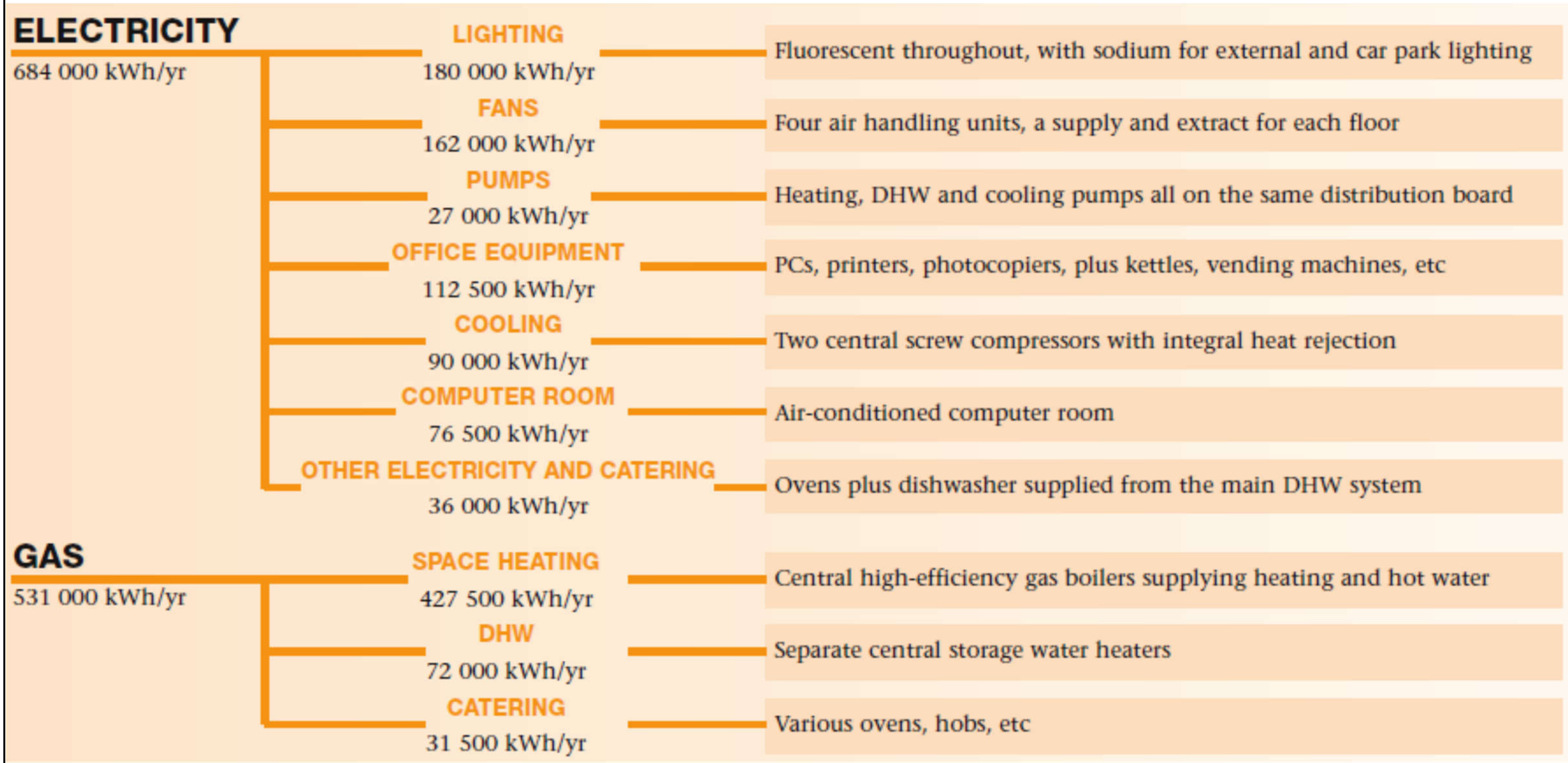
(Source: Department of Minerals and Energy, South Africa)

Comparing predicted energy use & benchmark data for lighting system



(Source: GIL65 Metering energy use in new non-domestic buildings https://shmmetershop.co.uk/wp-content/uploads/2018/07/gil065.pdf)

Estimated energy usage breakdown in an example building



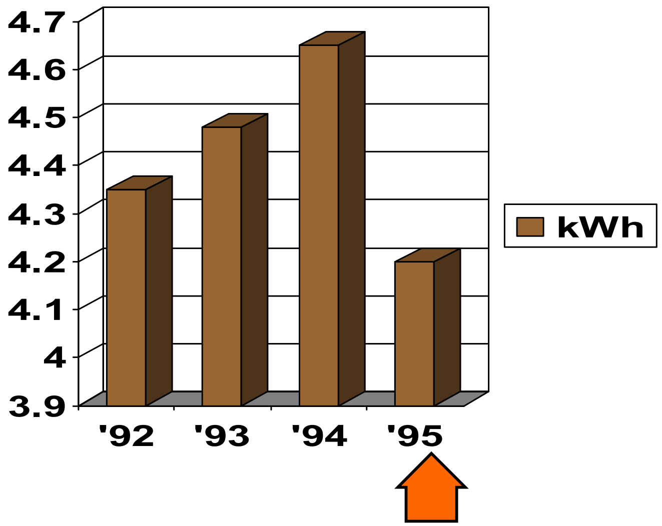
(Source: GIL65 Metering energy use in new non-domestic buildings https://shmmetershop.co.uk/wp-content/uploads/2018/07/gil065.pdf)

Submetering

- Positive contributions of metering:
  - Measurement & verification (M&V)
    - Use meters for base building, tenant submetering & energy system performance
  - Building Operations & Maintenance (BO&M)
    - Use meters & software system to educate staff, continuously track performance & optimize systems
  - Performance Measurement
    - Enhanced metering - use electric, water & gas meters & software system for ongoing accountability & optimization of building energy performance over time

Submetering

- Hawthorne Effect* (observer effect)
  - A phenomenon whereby workers improve or modify an aspect of their behavior in response to the fact of change in their environment, rather than in response to the nature of the change itself
- Example: Submetering added
  - Changes due to tenant awareness
  - Much kWh energy saved
  - Reduce CO_2 in atmosphere



(* See also http://en.wikipedia.org/wiki/Hawthorne_effect)

Metering savings ranges

Action	Observed Savings
Installation of meters	0 to 2% – initial impact, but savings will not persist
Bill allocation only	2½ to 5% – improved occupant awareness
Building tune-up and load management	5 to 15% – improved awareness, identification of simple operations & maintenance improvements, & managing demand loads per electric rate schedules
Ongoing commissioning*	15 to 45% – improved awareness, ongoing identification of simple operations & maintenance improvements, & continuing management attention

* Commissioning: Process by which an equipment, facility, or plant (which is installed, or is complete or near completion) is tested to verify if it functions according to its design objectives or specifications

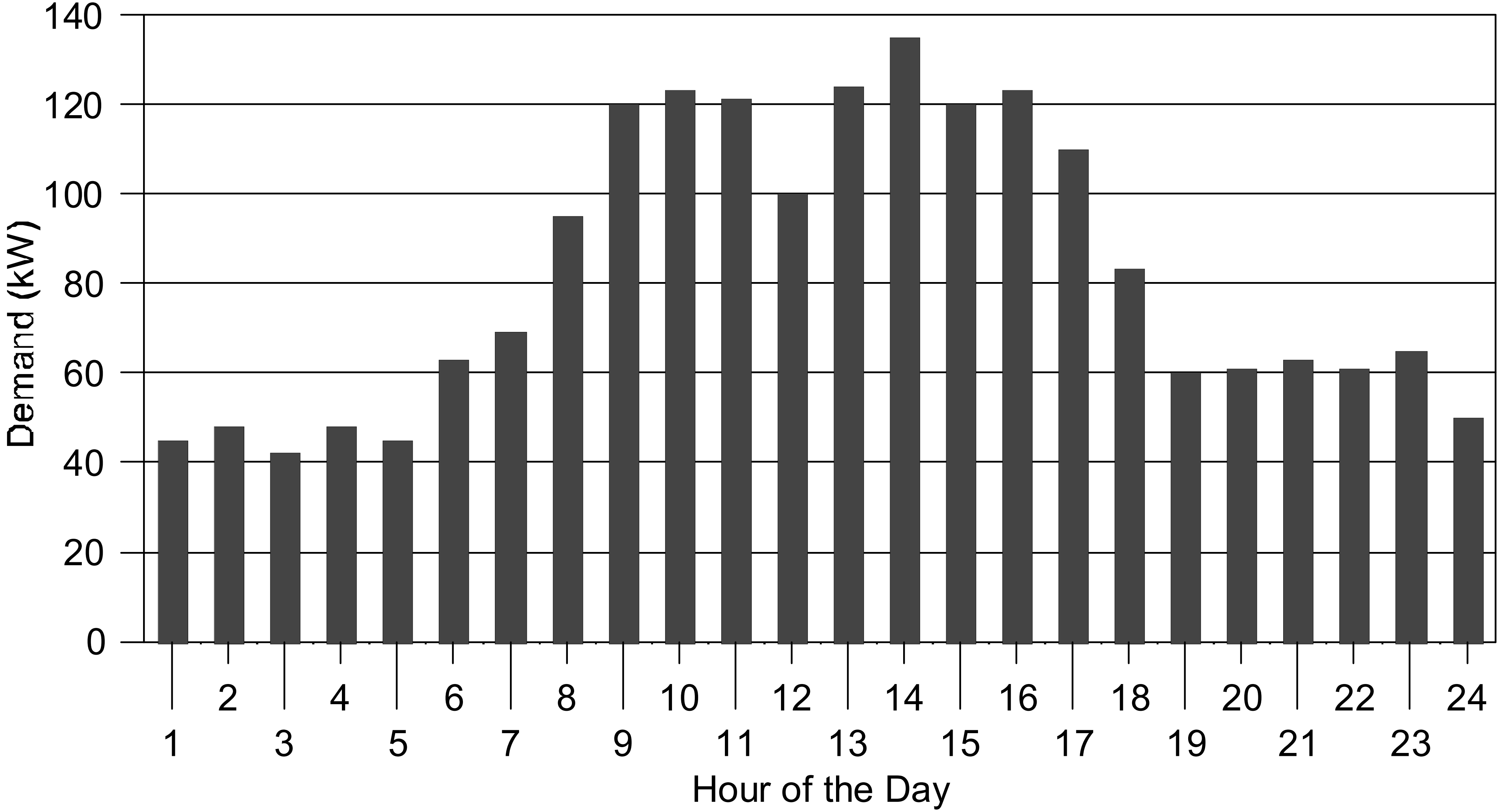
(Source: FEMP, 2006. Guidance for Electric Metering in Federal Buildings https://www.energy.gov/sites/prod/files/2013/10/f3/adv_metering.pdf)

Demand analysis

- Energy assessment & demand analysis
  - Hourly demand profile
  - Peak demand profile
- Understanding the time patterns of energy use
  - Study the electrical demand profile & identify possible energy management opportunities
  - Identify opportunities for power factor correction

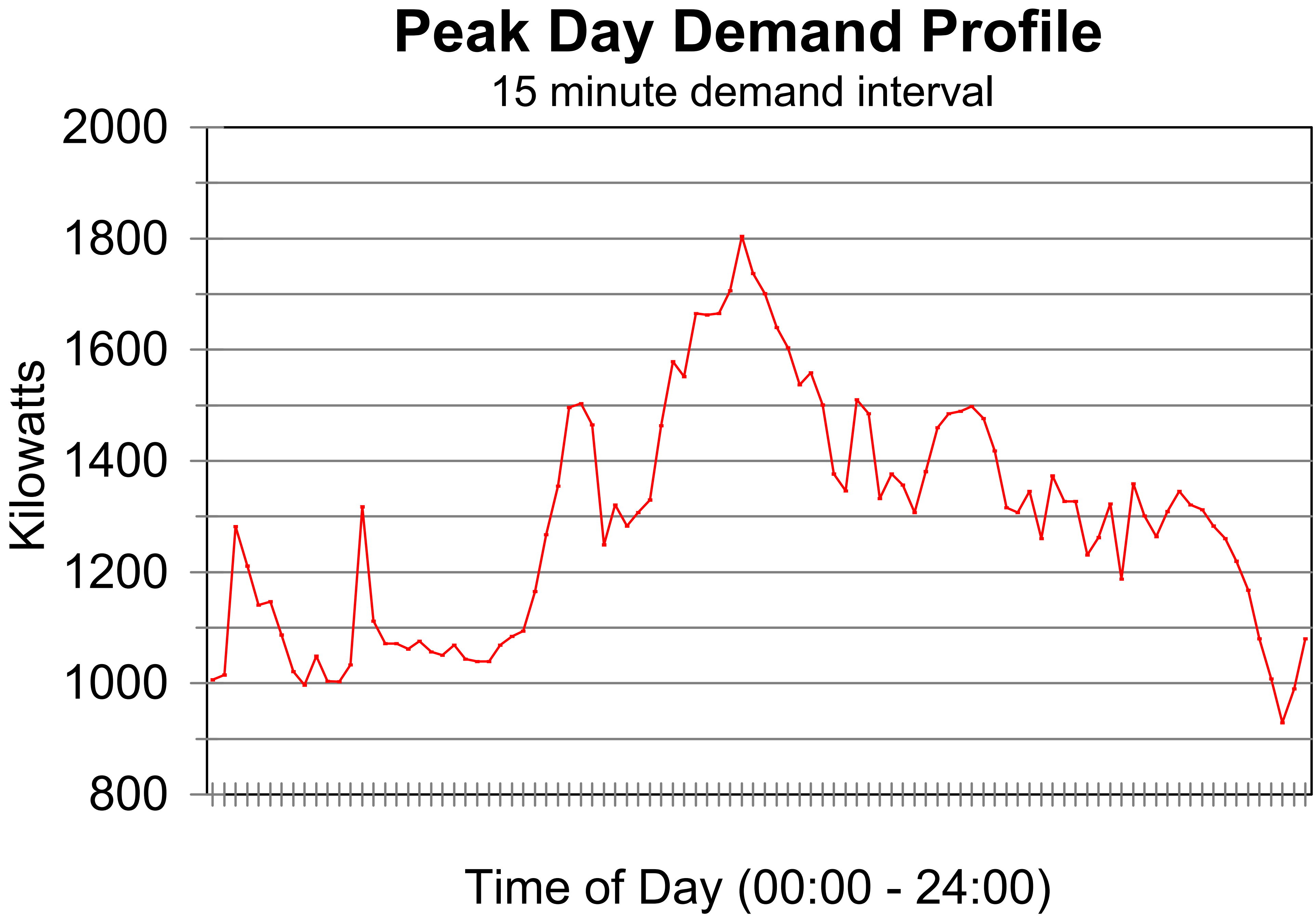
(* See also: How to Use Energy Profiles to Find Energy Waste http://www.energylens.com/articles/identify-energy-waste)

Hourly Demand Profile



(Source: Department of Minerals and Energy, South Africa)

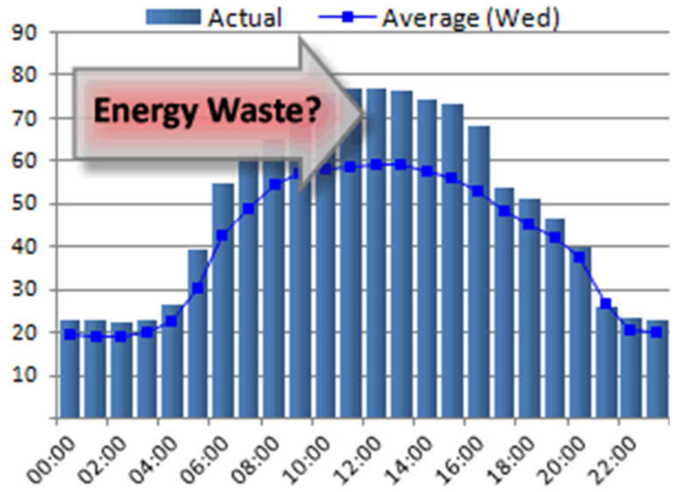
An Electrical Fingerprint

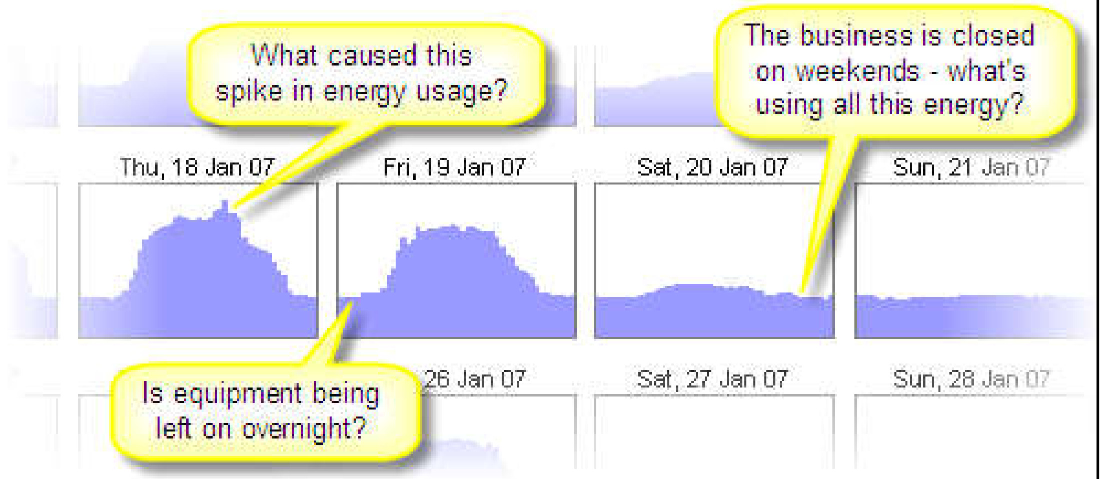


(Source: Department of Minerals and Energy, South Africa)

Demand analysis

- Patterns revealed:
  - Peak demand
  - Night load
  - Start-up & shut-down
  - Weather effects
  - Loads that cycle
  - Interactions
  - Occupancy effects
  - Problem areas





(* See also: Energy Monitoring Charts and Tables http://www.energylens.com/outputs)

Demand analysis

- Analysing the profile
  - Requires facility operational knowledge
  - Mark scheduled events on the profile
  - Correlate events with:
    - Demand increase, decrease, cycling, peaks
  - Reconcile with demand on utility bills
  - Investigate unknown patterns

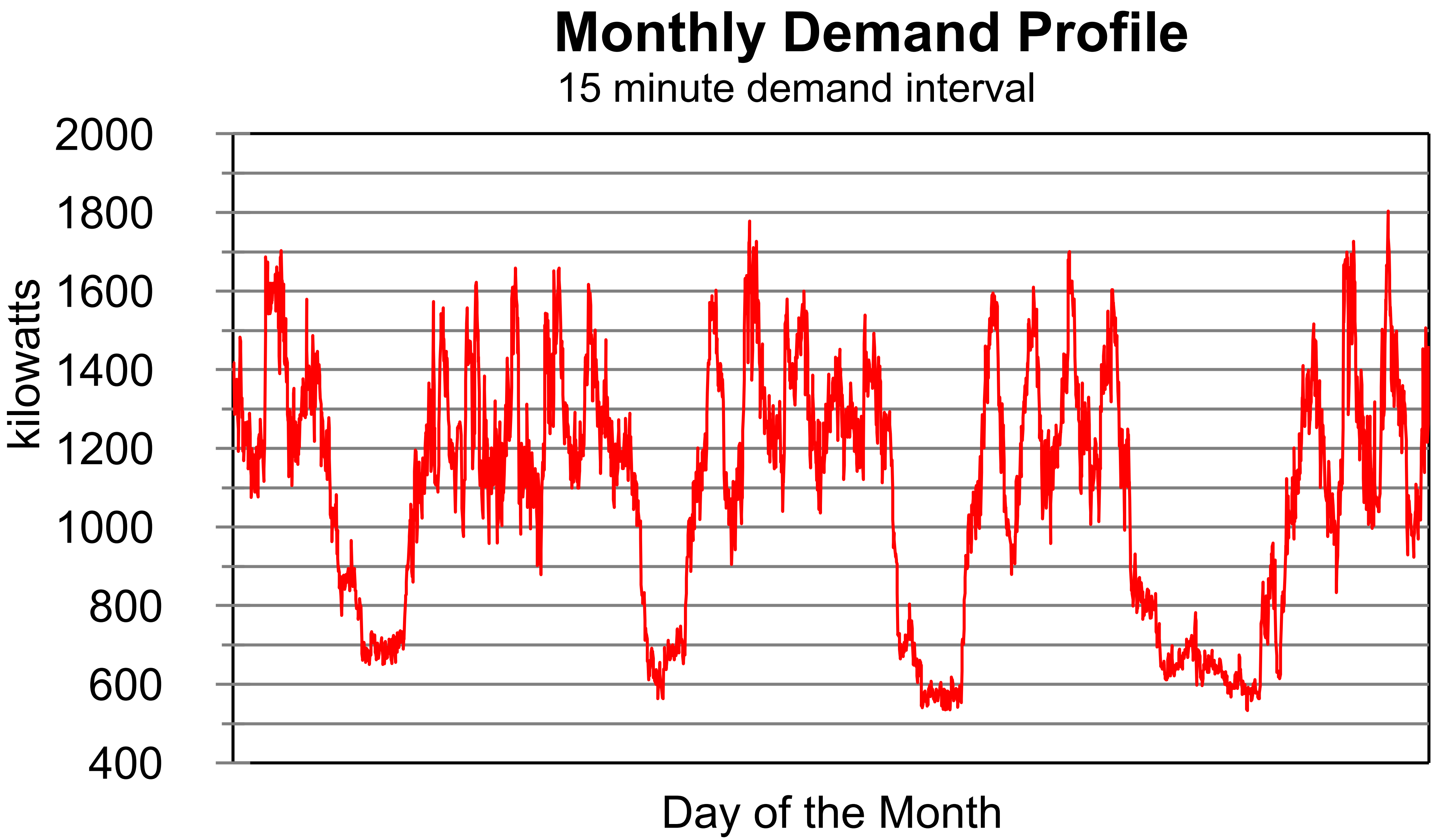
"There's always a savings opportunity in a new demand profile"

Demand analysis

- Obtaining a demand profile
  - Periodic utility meter readings
  - Recording clip-on ammeter measurements
  - Basic recording power meter
  - Multi-channel recording power meters
  - A facility energy management or SCADA (supervisory control & data acquisition) system
  - A dedicated monitoring system

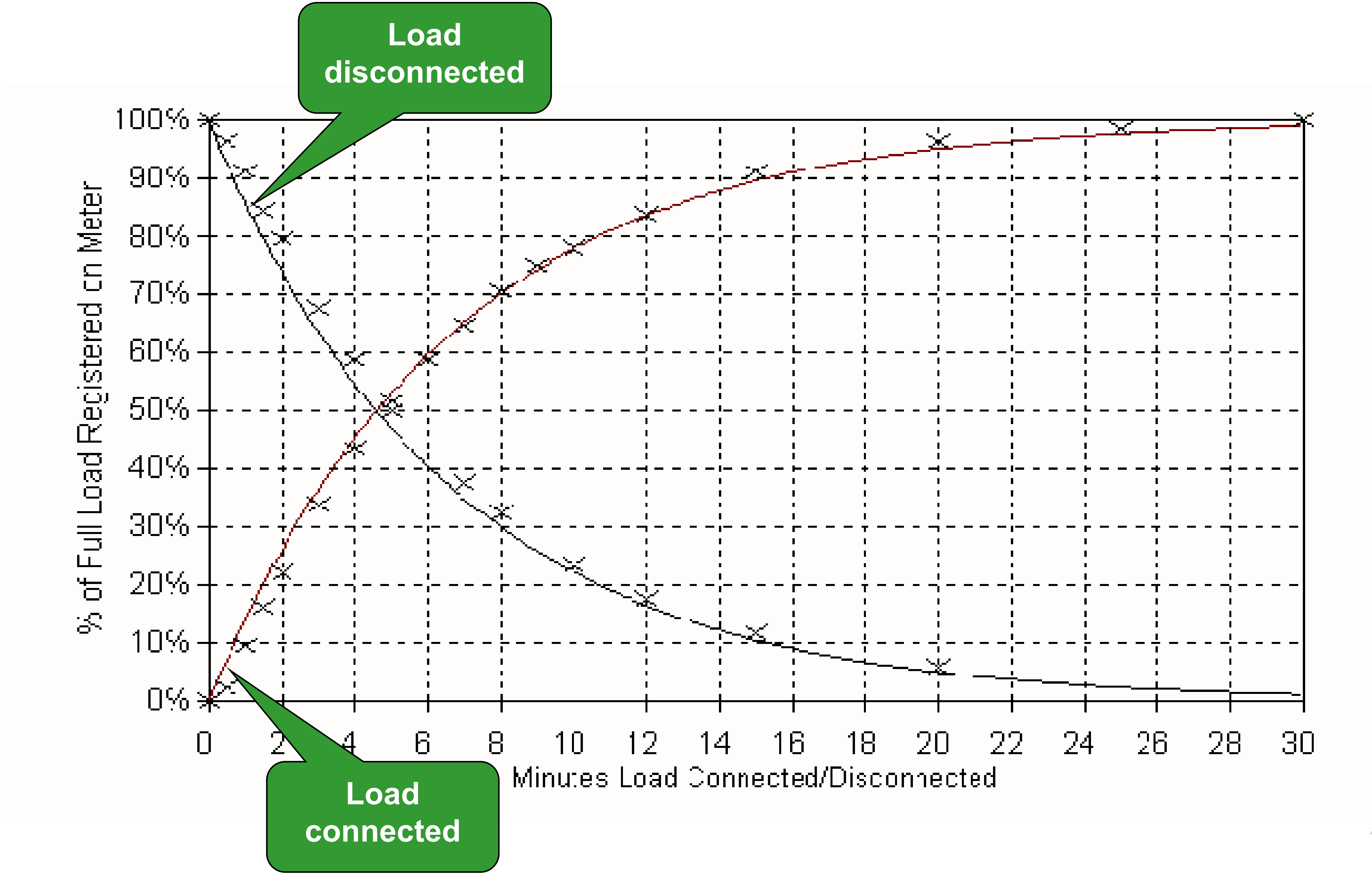
(* Videos: Analyzing energy data (9:09) & loading energy data (6:54) with Energy Lens http://www.energylens.com/videos/)

Study of daily or monthly profile



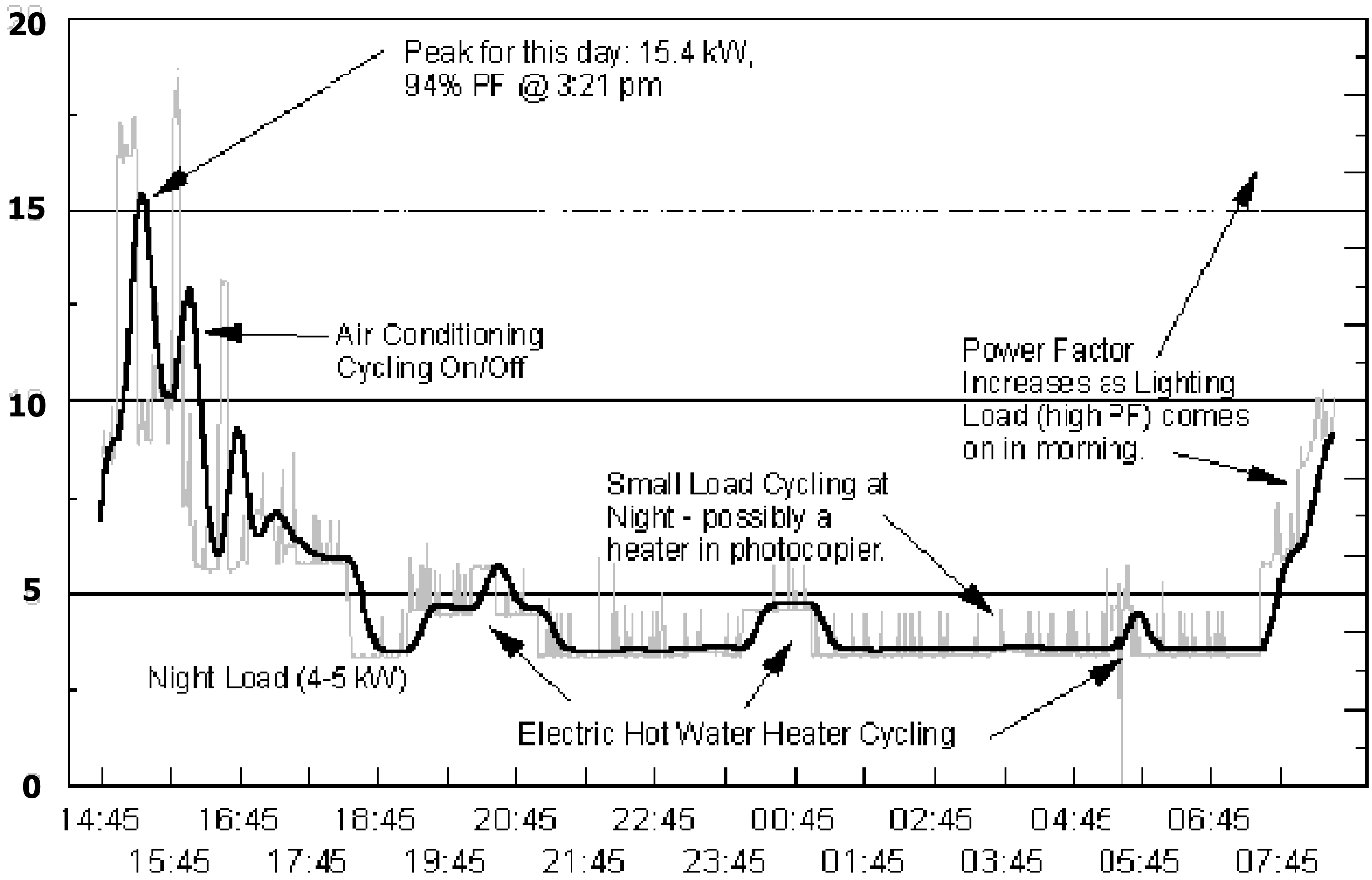
(Source: Department of Minerals and Energy, South Africa)

Meter response (time delay)



(Source: Department of Minerals and Energy, South Africa)

What the demand meter sees



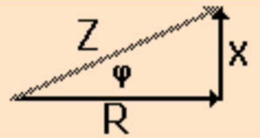
(Source: Department of Minerals and Energy, South Africa)

Demand analysis

- Savings opportunities
  - Scheduling – reduce startup peaks
  - Infrequent demand peaks – avoidable
  - Shift on-peak to off-peak usage pattern
  - Equipment loading – consider sequencing
- Correct power factor – on peak
  - At service entrance
  - In the distribution system
  - At the point of use power factor (PF)

$$P_{avg} = VI \cos \varphi$$

$$\text{POWER FACTOR} = \cos\varphi = \frac{R}{Z}$$

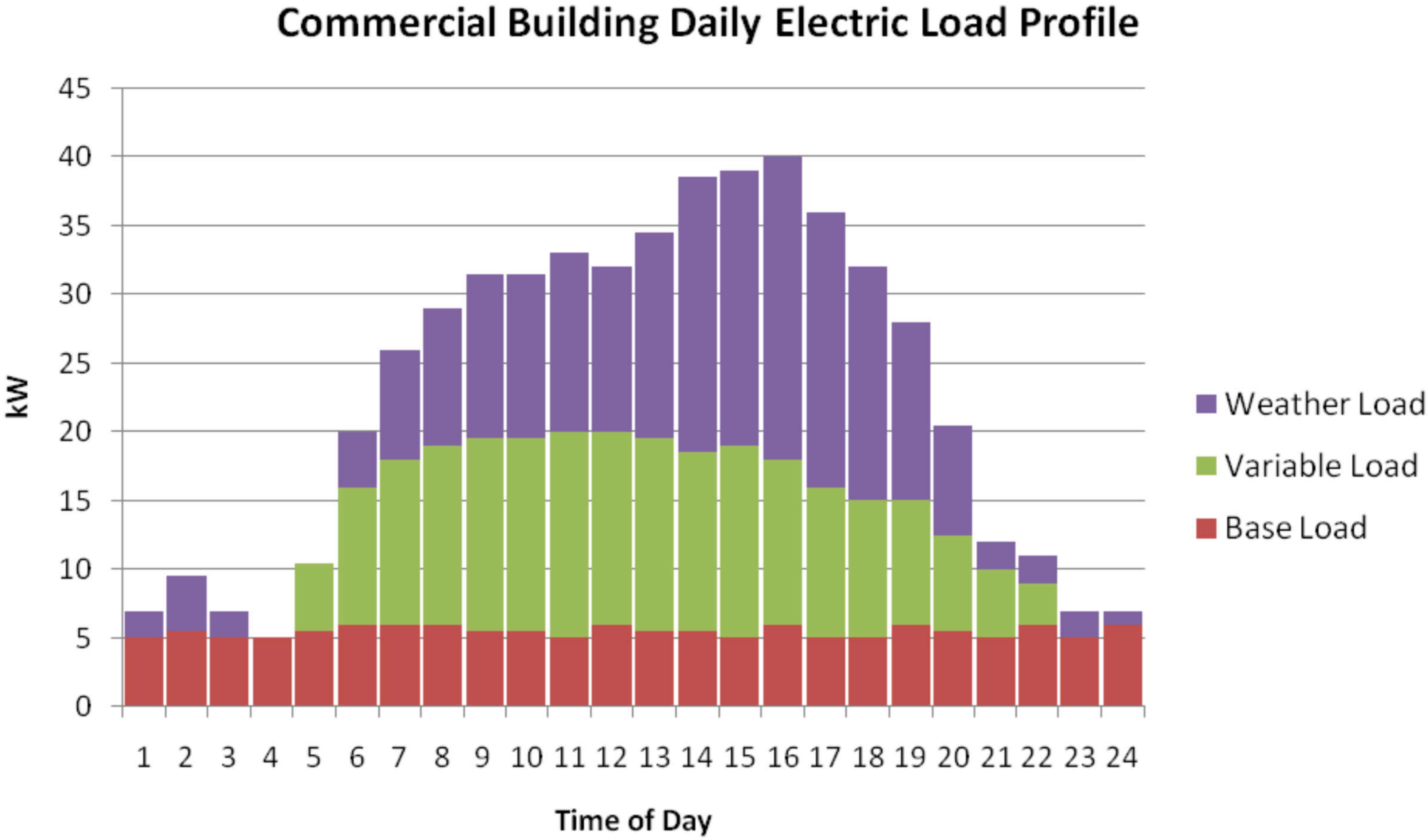


Demand analysis

- Peak demand control
  - Eliminate accidental peaks
  - Shift activity “off-peak”
  - Peak demand warning for staff
  - Interlock equipment
  - Load shedding system
  - Use generator to “clip” the peak

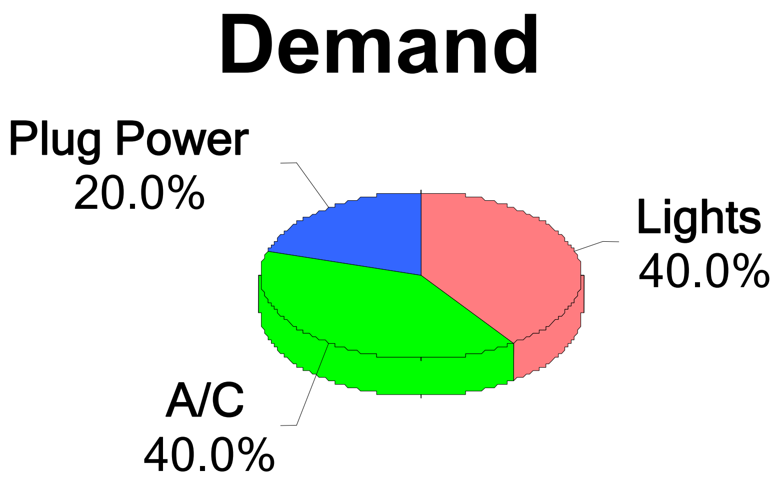
Typical commercial building daily electric load profile

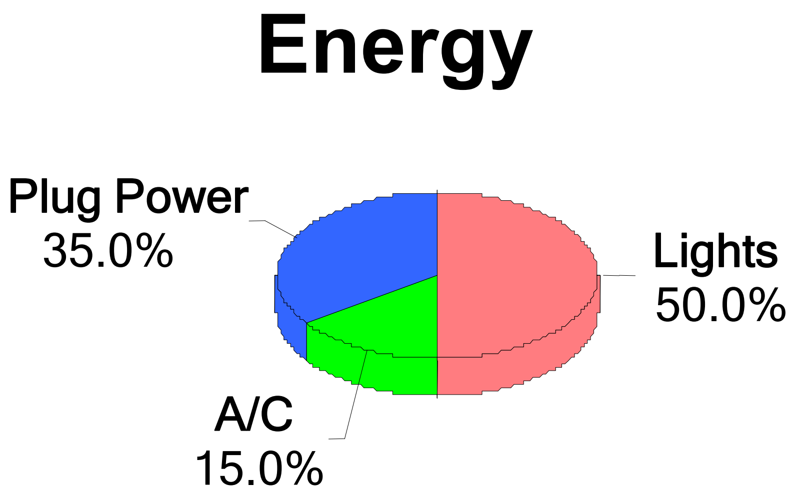
Could you interpret & explain this?



Load inventory

- Understanding where energy is used
  - Create an energy load inventory & reconcile it to consumption data
- Analyse the load inventory
  - Where is electricity used?
  - How much - i.e. consumption
  - How fast - i.e. demand
- Why inventory? Focus your efforts; establish a basis for savings calculations

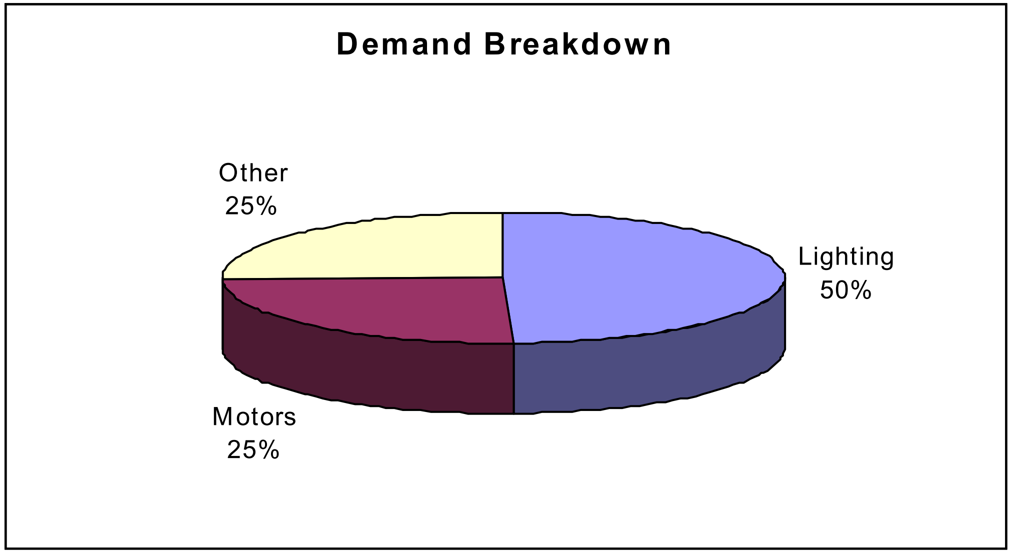


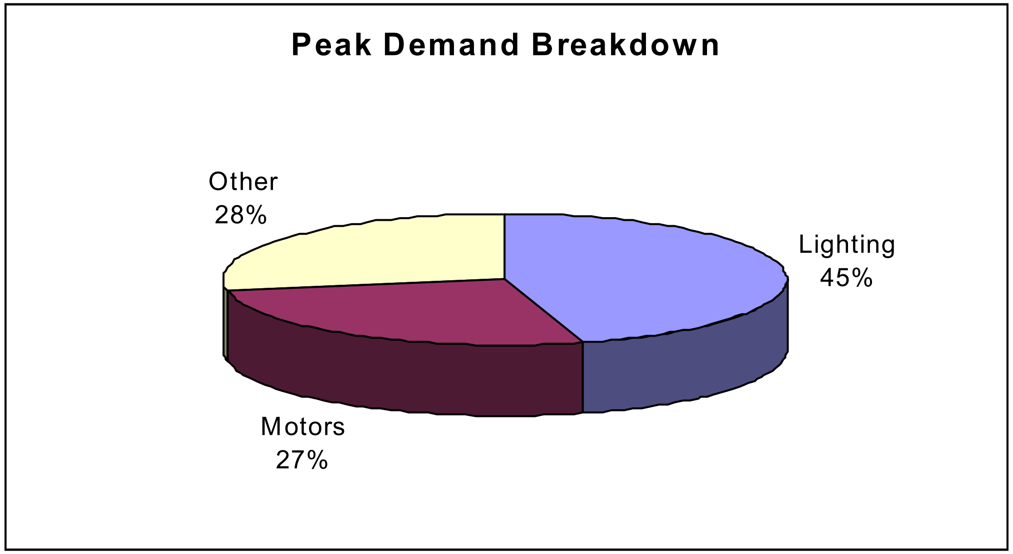


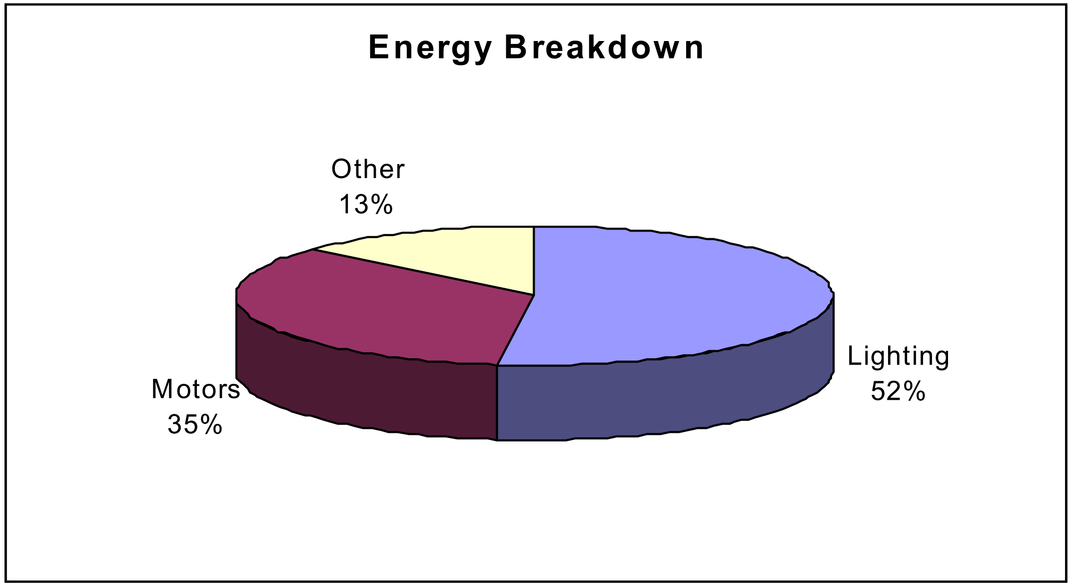
Item	Units	Formula
Quantity	(a number)	
Unit Load	kW	
Total kW	kW	Quantity. x Unit Load.
Hrs/Period	hours	
kWh/Period	kWh	Total kW x Hrs/Period
Diversity Factor (Div'ty Factor)	0 - 100%	
Peak kW	kW	kW x Diversity Factor

(Source: Department of Minerals and Energy, South Africa)

Breakdown of demand, peak demand & energy







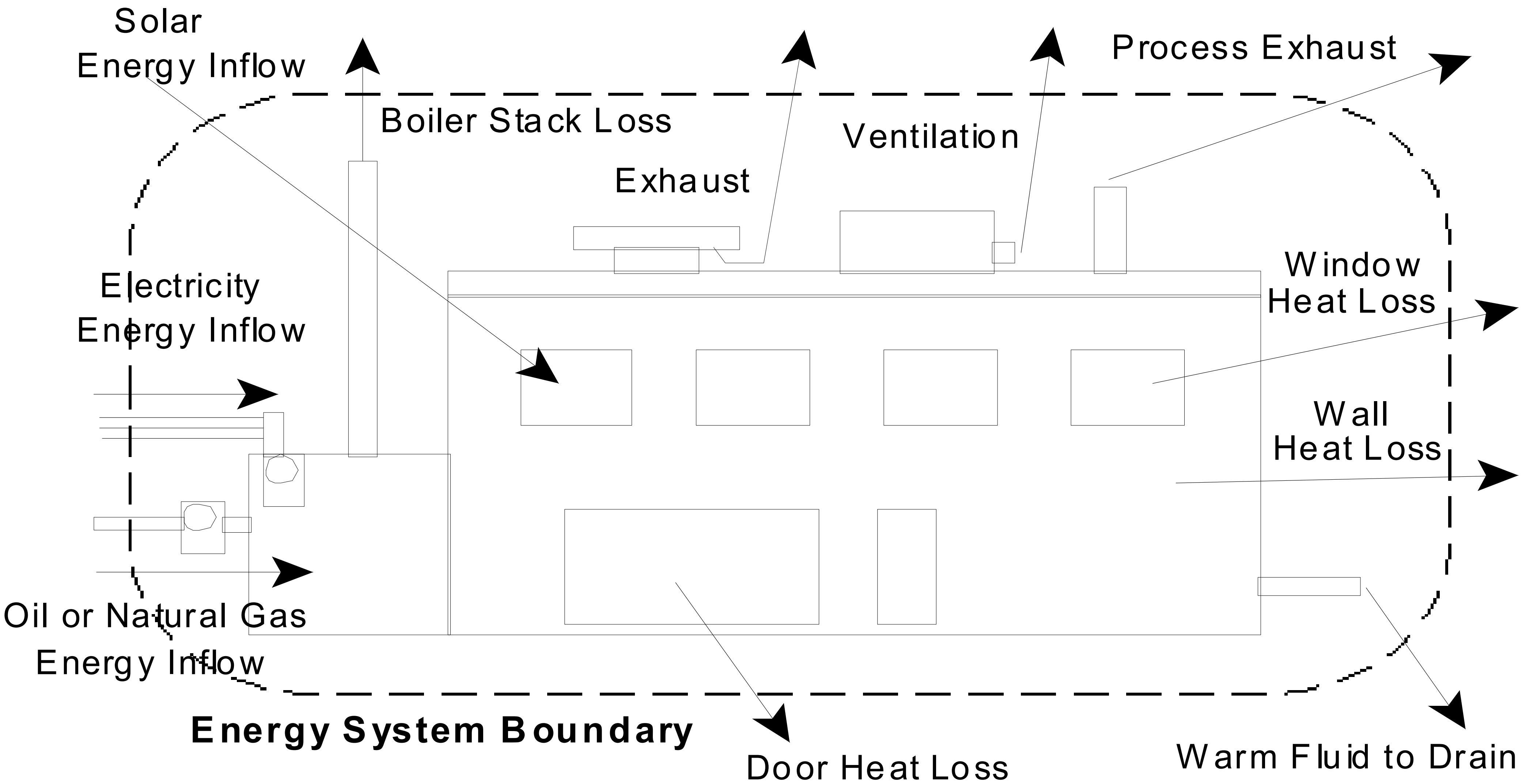
(Source: Department of Minerals and Energy, South Africa)

Load inventory

- An example of inventory:

Loads	Qty	Unit KW	Total KW	Diversity Factor	Peak KW	Hours	KWH
Fluorescent F96	4	0.165	0.66	1	0.7	300	198
Incandescent 100 w	24	0.1	2.4	0.9	2.2	100	240
400w MH Lights	21	0.465	9.765	1	9.8	420	4,101
Compressor.(60HP)	1	50	50	1	50.0	400	20,000
Pump (20 HP)	1	16	16	0.75	12.0	400	6,400
Micro-Wave	1	0.75	0.75	0.1	0.1	2	2
Coffee Machine	2	1.5	3	1	3.0	200	600
Total			**83**		**77.7**		**31,541**

Energy flow diagram



(Source: Department of Minerals and Energy, South Africa)

Thermal energy inventory

Energy Flow Type	Example	Equipment/Functions
Conduction	Wall, windows	Building structure.
Air Flow - Sensible	General exhaust	Exhaust and makeup air systems, combustion air intake.
Air Flow - Latent	Dryer exhaust	Laundry exhaust, pool ventilation, process drying equipment exhaust.
Hot or Cold Fluid	Warm water to drain.	Domestic hot water, process hot water, process cooling water, water cooled air compressors.
Pipe Heat Loss	Steam pipeline.	Steam pipes, hot water pipes, any hot pipe.
Tank Heat Loss	Hot fluid tank.	Storage and holding tanks.
Refrigeration system output heat	Cold storage.	Coolers, freezers, process cooling, air conditioning.
Steam Leaks and Vents	Steam vent	Boiler plant, distribution system, steam appliance.

(Source: Department of Minerals and Energy, South Africa)

Finding opportunities: Start at the end-use

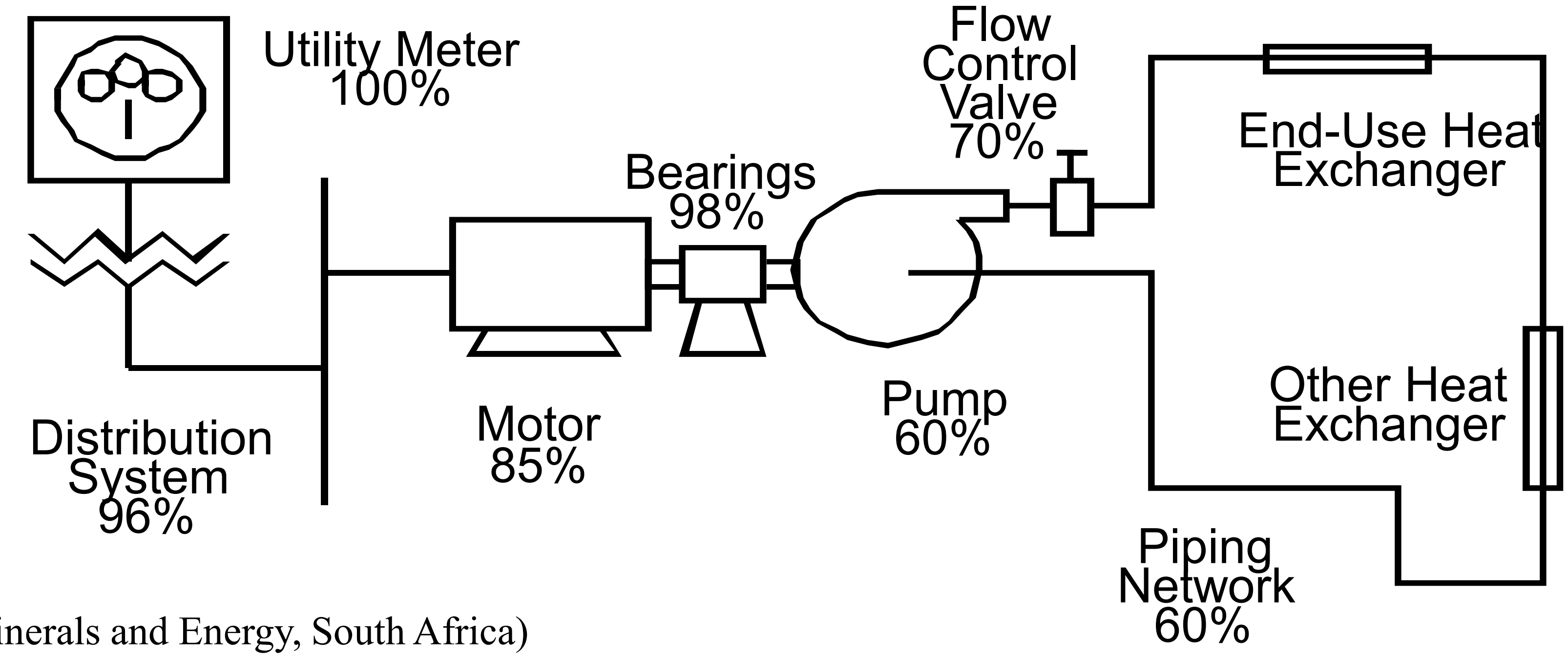
Meter

1st Analyze Present Usage →

← **2nd Identify and Quantify the Savings Opportunities**

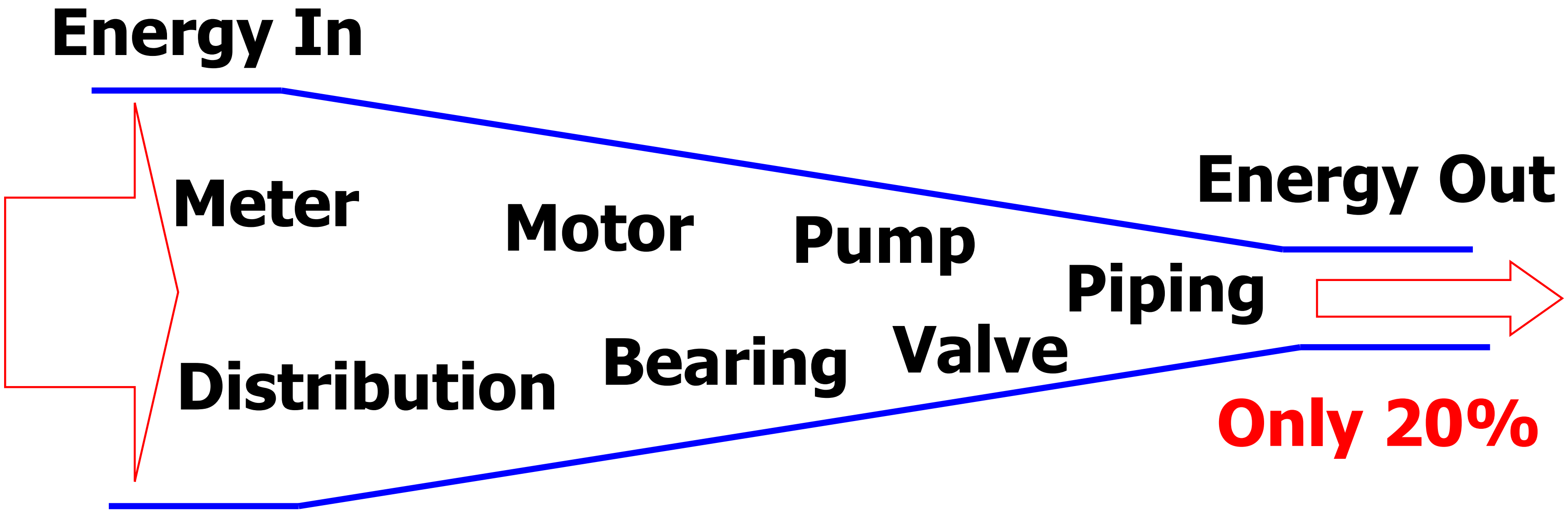
End-Use

Component efficiencies:



(Source: Department of Minerals and Energy, South Africa)

Component & system efficiencies



Component	Typical Efficiency
Meter	100%
Distribution	96%
Motor	85%
Bearing	98%
Pump	60%
Valve	70%
Piping	60%
Overall	20%

(Source: Department of Minerals and Energy, South Africa)

Further reading

- How to Use Energy Profiles to Find Energy Waste http://www.energylens.com/articles/identify-energy-waste
- Energy Monitoring Charts and Tables http://www.energylens.com/outputs
- Combining Energy and Building Management Systems to Improve Asset Performance https://www.automatedbuildings.com/news/aug17/articles/optergy/170724024606optergy.html