Energy Information Systems

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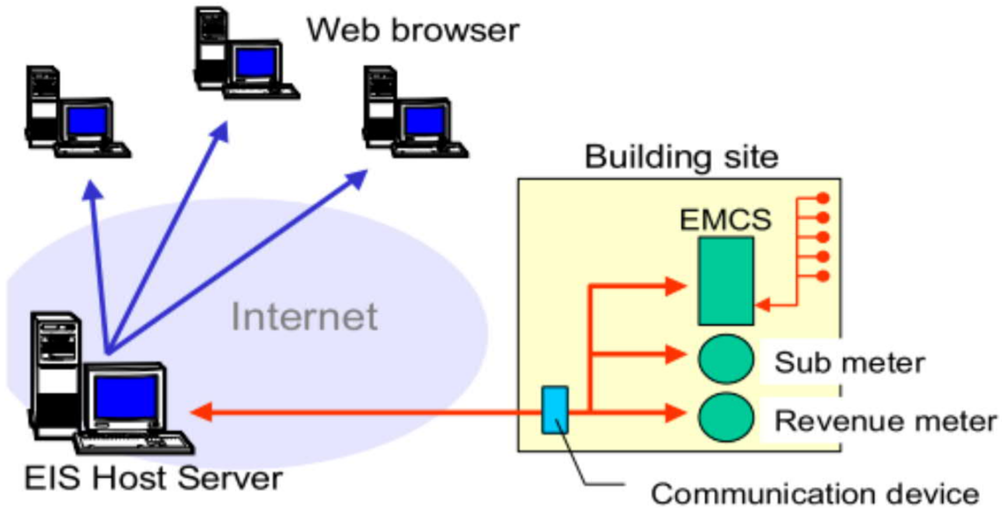
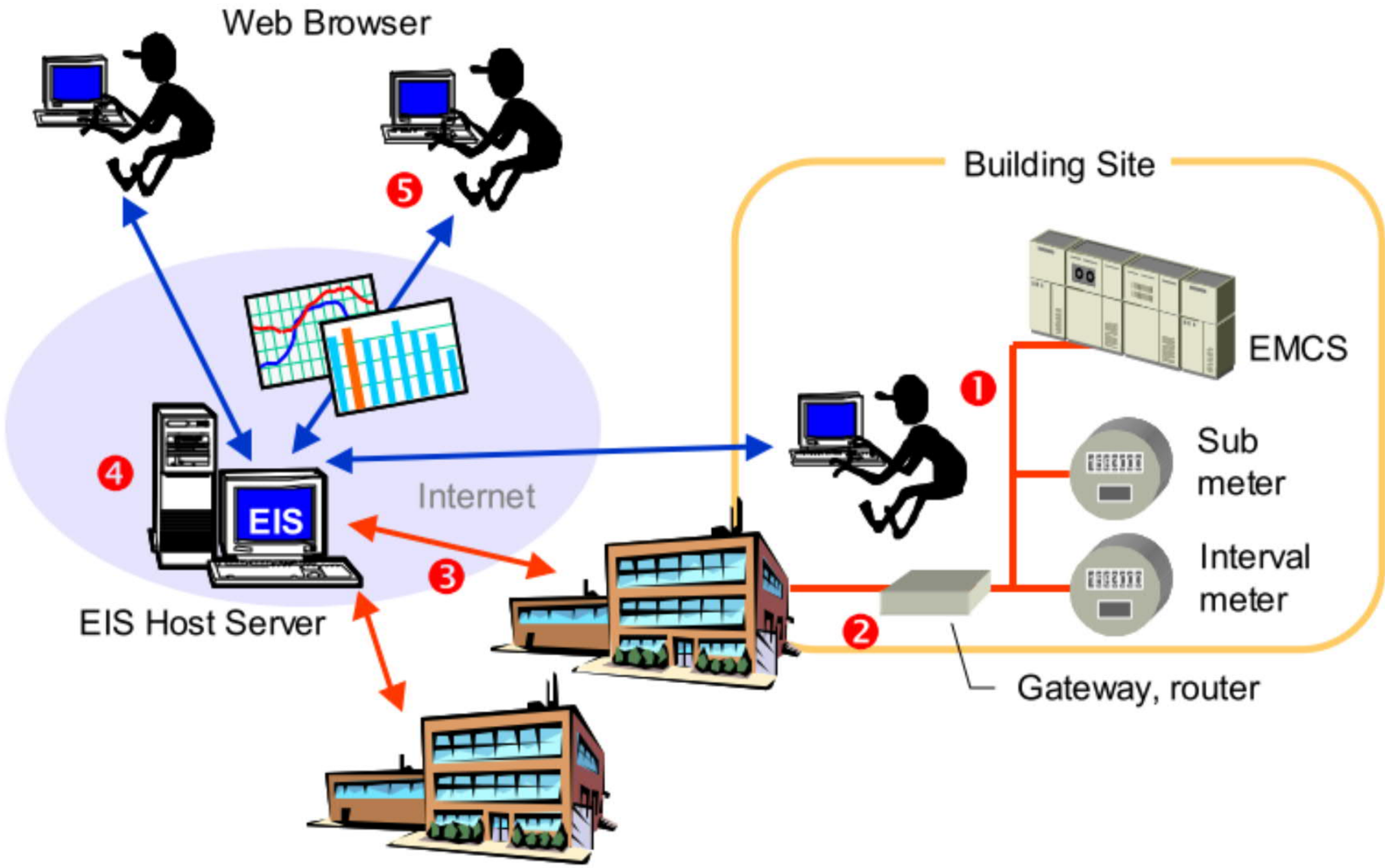


Energy Information System

- Energy Information System (EIS)
  - A system for the collection, analysis and reporting of data relating to energy performance that supports energy management & decision making
  - May be stand-alone, part of an integrated system or a combination of several different systems
  - Typical elements include sensors and instruments, data infrastructure and software tools
    - Such as meters, software, billing data, bldg info, etc.
    - Include external and internal sources of data

Typical architecture of an energy information system (EIS)



(1) Data are collected at the building

(2) A communication device dispatches data

(3) The data is sent to a database server via Internet.

(4) The database server stores and archives the data

(5) EIS users access the server remotely by a web browser

(Source: Motegi, N., Piette, M. A., Kinney, S. and Dewey, J., 2003. Case studies of energy information systems and related technology: operational practices, costs, and benefits, In *Proceedings of the International Conference for Enhanced Building Operations*, October 13-15, 2003, 10 pages.)

Energy Information System

- Basic features of EIS:
  - Monitoring and collection of energy data
  - User-friendly web browser interface accessible from anywhere via Internet
  - Visualization of the time-series data
  - Tools to assist in understanding energy consumption trends and energy saving opportunities

Energy Information System

- Possible benefits of EIS:
  - Early detection of poor performance
  - Effective performance reporting
  - Auditing of historical operations
  - Identification and justification of energy projects
  - Evidence of success
  - Support for energy budgeting and management accounting
  - Energy data to other systems

Energy Information System

- Impact of technology
  - Computers: desktop, notebook PC, “tablet” PC
  - Communication: mobile/smart phones, wireless local area network (LAN)
  - Internet: E-mail, Web-based
  - Metering & electronic data collection
  - Building simulation & modelling
- How would building/facility managers be affected?

New Paradigm of Facility Manager

The evolving role of the facility manager ...

Focus on asset management

Global vision (world class benchmarking)

Reports to operations (supports business)

May be in-house or from an IFM company

Focus on equipment

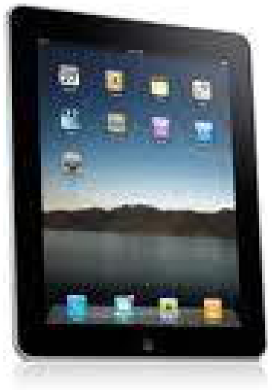
Isolationist (only looks at his building)

Reports to finance (controls overhead)

In-house emperor

(* Slides from Rob Moult, Johnson Controls)

New Paradigm of Facility Manager



Software focus on business activity such as Tenant Management

Energy Auditor

Performance measurements and benchmarking

Self-optimizing controls

Alarm reporting

Time scheduling

Historical data collection (no analysis tools)

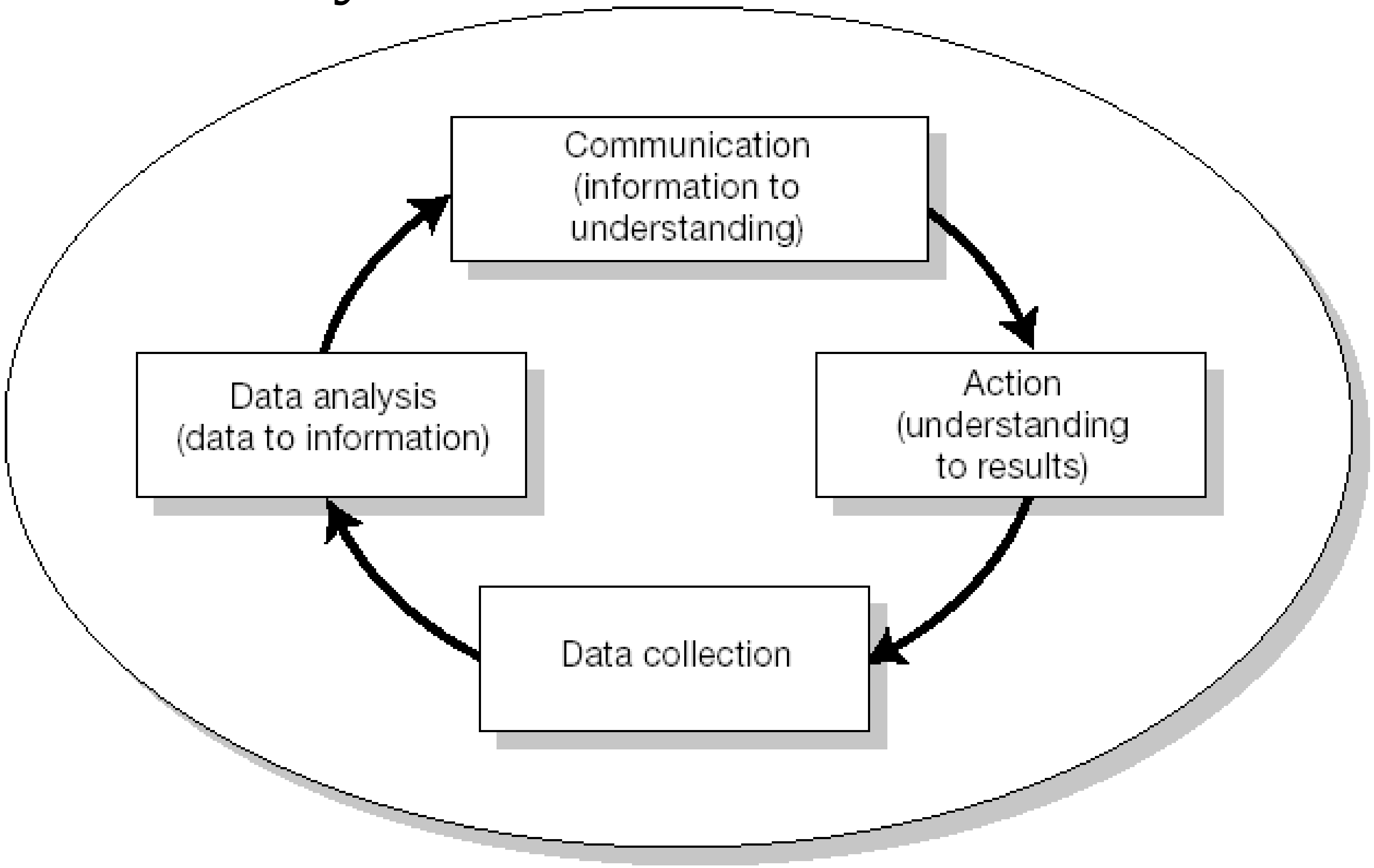
Graphical presentation of building systems

… requires a new set of tools.

(* Modified slides from Rob Moult, Johnson Controls)

Energy Information System

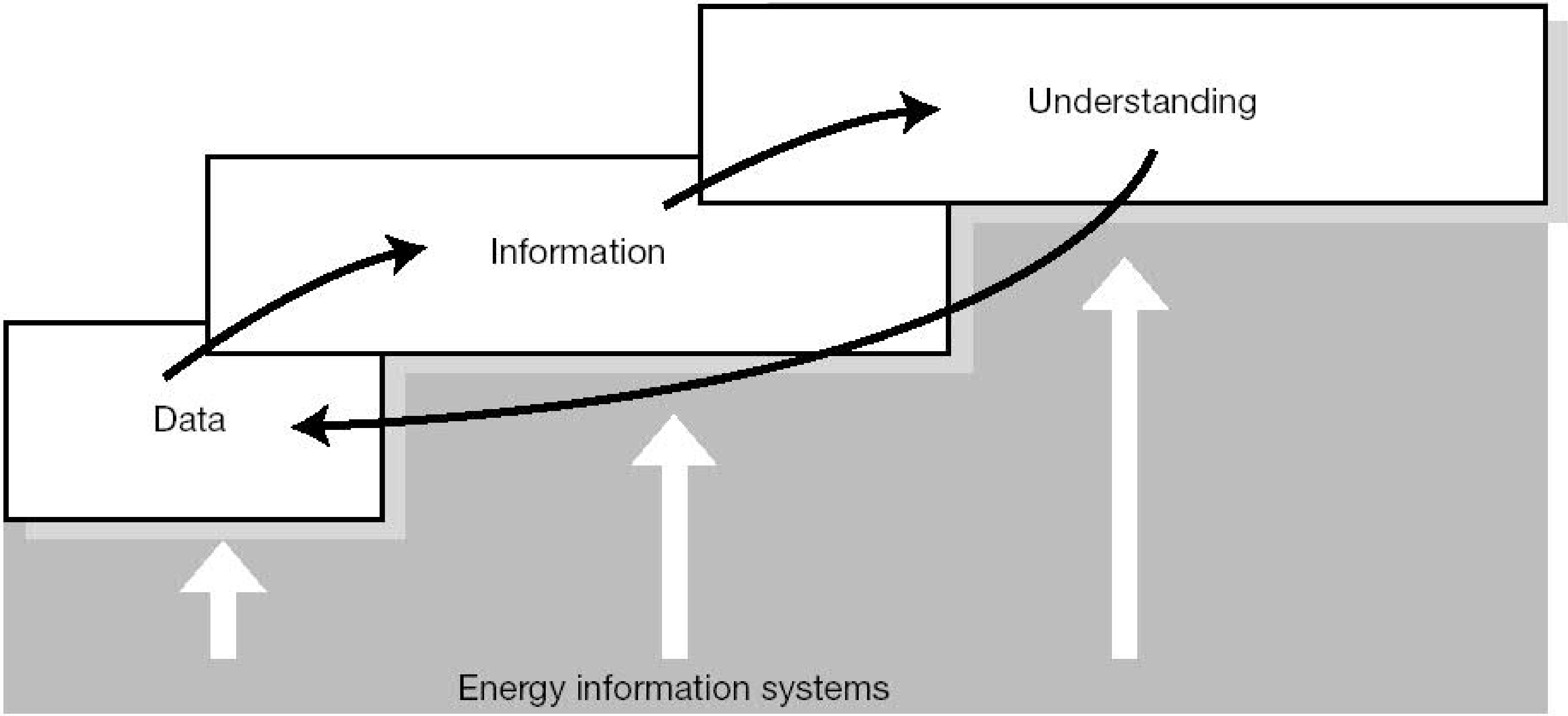
- Operational cycle



Energy Information System

- Data, information & knowledge
  - DATA: raw materials, e.g.
    - A listing of energy meter readings
    - A record of max. & min. external temperatures
    - A log of activity & equipment conditions
  - Do not become totally immersed in data!
  - Must gain/create value from data
    - Transform data into INFORMATION (to support knowledge development) and UNDERSTANDING (to support actions for energy savings)

EIS system hierarchy

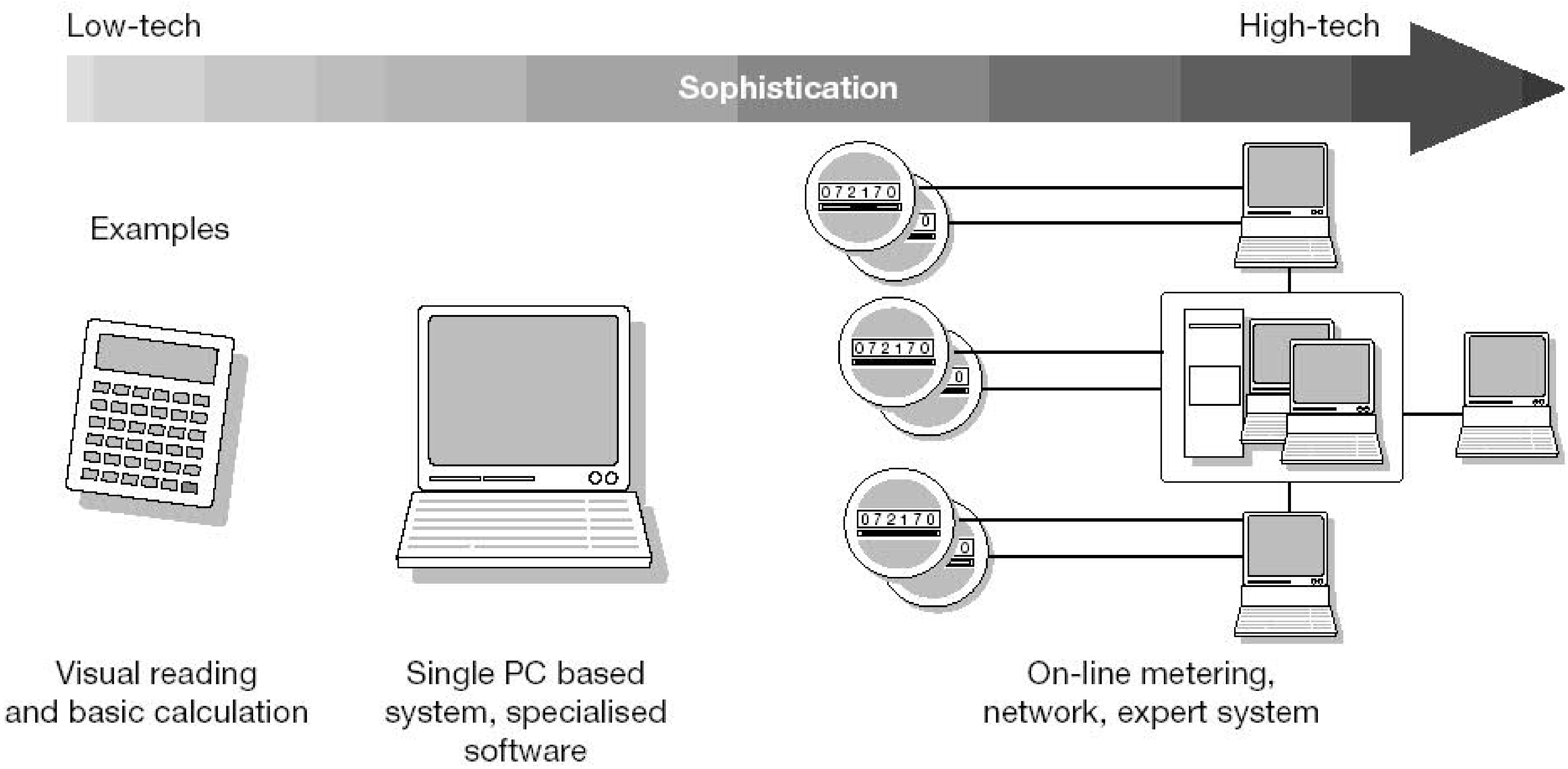


"Knowledge is information learned from patterns in data"

Energy Information System

- Other valuable info from EIS
  - For improved allocation of energy expenditure
    - Useful for internal accounting & budgeting
- Range of solutions
  - Simple graph or chart
  - Computer spreadsheet developed in-house
  - Networked, real-time data system
  - Remote operation/report by an outside contractor
  - Expert- or knowledge-based system

The range of solutions



Energy Information System

- Data types and sources
  - Consumption
    - Essential for energy & environmental management
    - Electricity & gas; sometimes also water & fuels
    - Through metering & sub-metering
  - Cost $$
    - From tariffs or actual billings
  - Drivers (variables or influencing factors)
    - Any factor that influences energy consumption, e.g. weather & indoor conditions

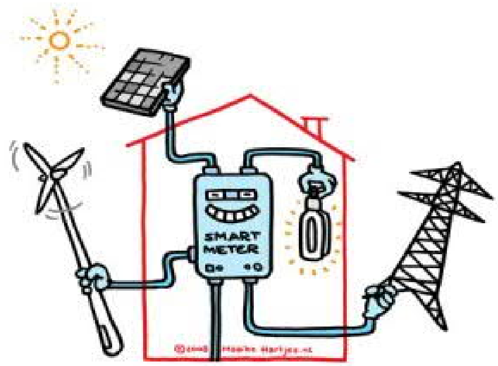
Energy Information System

- Two main types of drivers:
  - *Activity drivers*: features of the organisation's activity, e.g. hours worked, tonnes produced, nos. of guests, opening hours
  - *Condition drivers*: the influence not determined by the activity but by prevailing conditions, e.g. weather (like temperatures)

Energy Information System

- Metering
  - Main meters: supply meter provided by utility for charging for supply

  - Sub-meters: installed after the main meter
    - Building energy codes often recommend the number
  - Metering periods
    - By month, by week, by day?
    - What is the problem with monthly data?
  - Smart meters
    - = Metering + Info. & Comm. Tech. (ICT)



Energy Information System

- Complexity of data collection depends on
  - Nos. of data collection points
  - Method of data collection
  - Frequency of data collection
- Consumption data sources
  - From invoices (for both energy & accounting)
  - From meters (manually or electronically)

Energy Information System

- Data on driver
  - Activity or production-related drivers
    - From business management info system
    - Such as output volume
  - External climate
    - Such as daily max./min. temperatures, cooling/heating degree days (*DD*) = cumulative number of degrees in a month or year above/below a base temp. (18.3 °C)

$$DD = (1\,\text{day}) \cdot \sum (t_{outdoor} - t_{base})^{+}$$

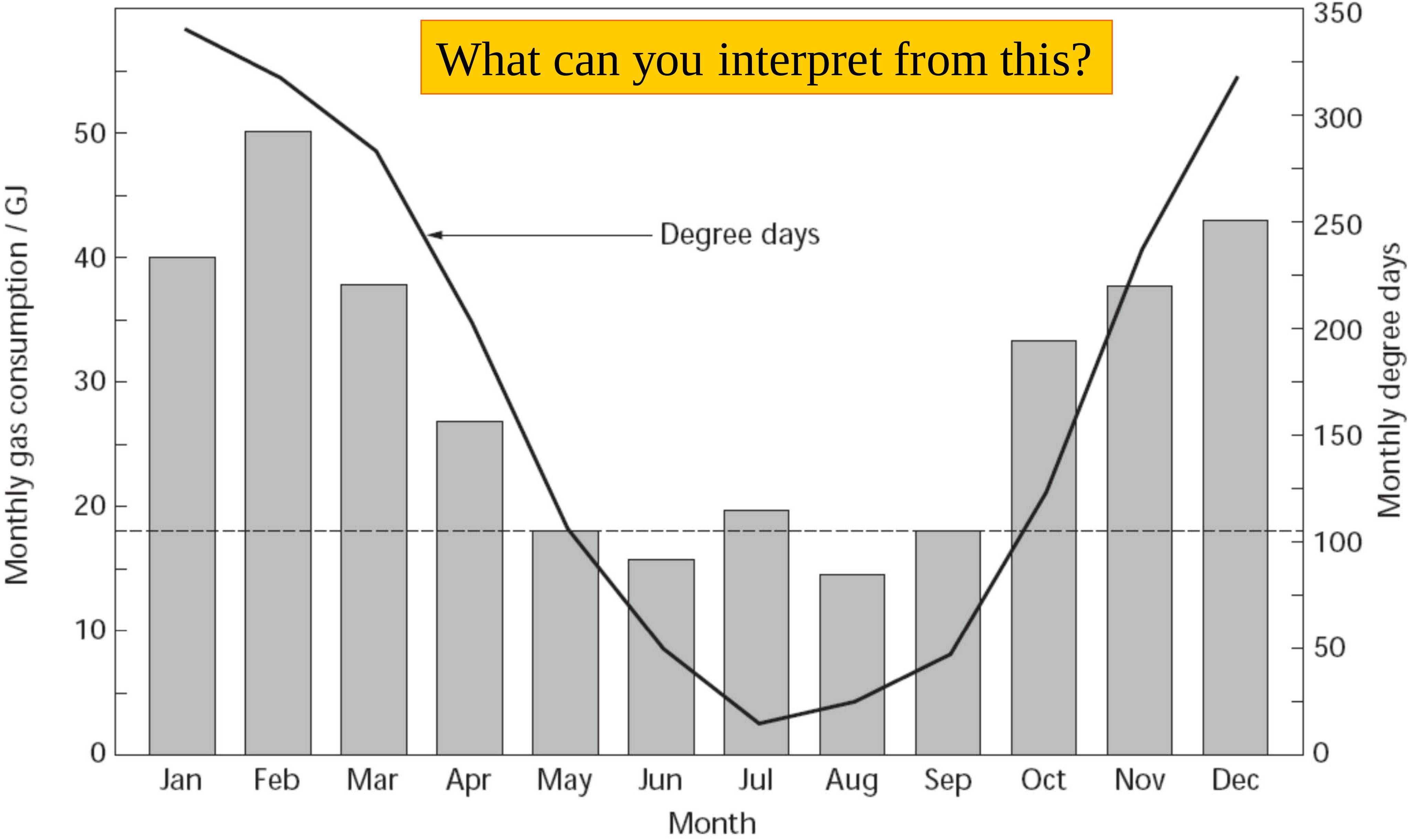
Energy Information System

- Cost of data collection (incl. time & money)
  - Meter reading & calibration
  - Software & software support
  - Hardware & hardware support
  - System operators
  - External contracts
- Data quality
  - Good quality data ≠ High accuracy data
  - Must be repeatable & dependable

Data Analysis Techniques

- "***Unanalysed data is information overload***"
- *Transform* data into information
  - The desired info output will influence which analytical techniques are used
- Two stages of data analysis
  - Stage 1. Looking only at energy
    - Convert meter readings to consumption figures
    - Compare current period with same period previous year
  - Stage 2. The use of energy data and drivers

Histogram of monthly fuel consumption versus degree-days

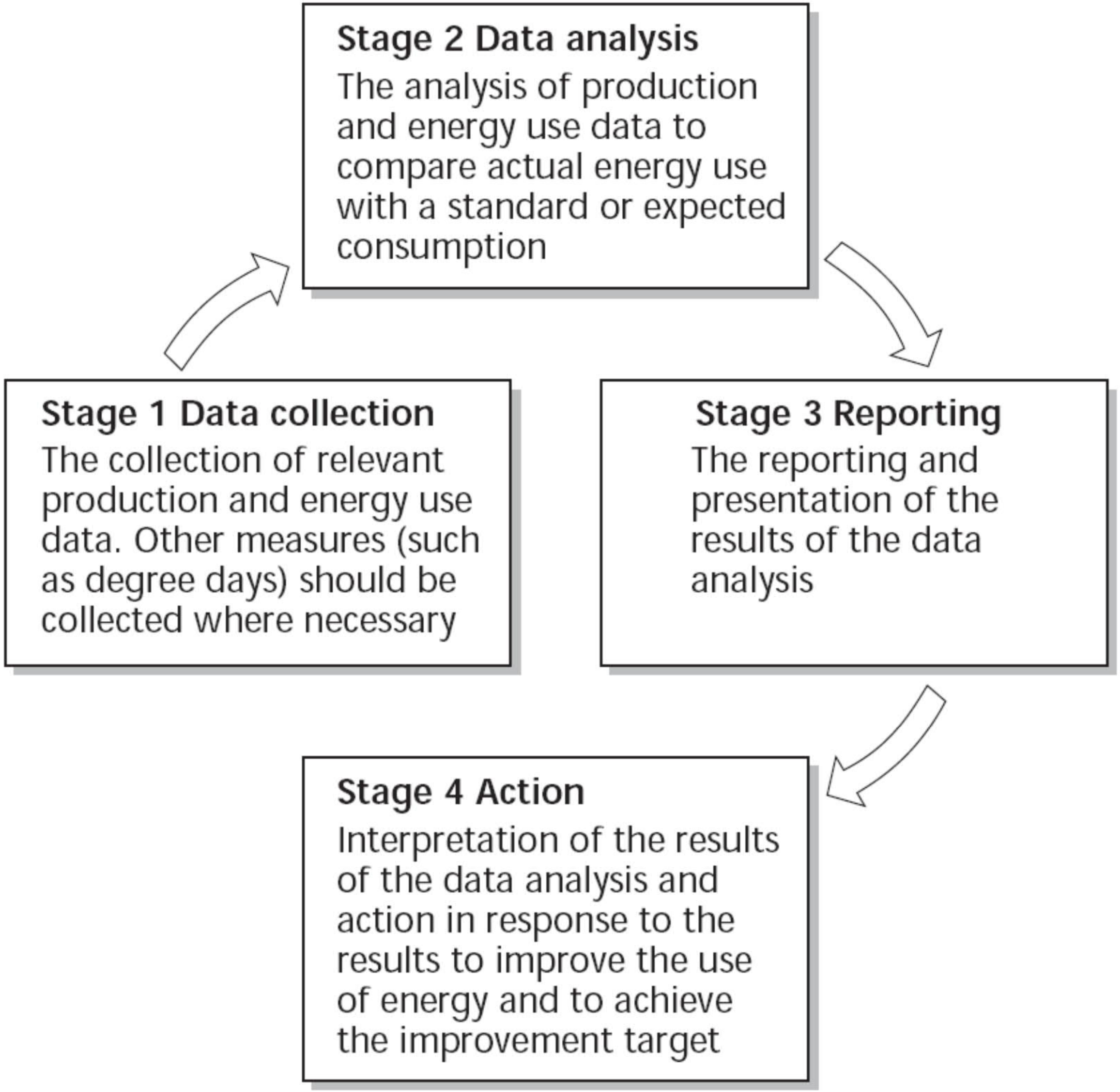


(Source: Energy Efficiency in Buildings: CIBSE Guide F)

Data Analysis Techniques

- Leading questions, e.g.
  - Why does this (consumption) happen?
  - Should that happen?
  - Is that what we expect?
  - Can we do better?
  - How well do we compare?
  - What are the key influencing factors?
  - How can they be improved?

Monitoring and targeting (M&T) process



(Source: Energy Efficiency in Buildings: CIBSE Guide F)

Data Analysis Techniques

- Typical energy data
  - Day time, night time & total consumption (kWh)
  - Maximum or peak demand (kW or kVA)
  - Power factor, price of electricity, total cost
- Immediate analysis to be carried out
  - Simple histograms, averages, statistical summary
  - Seasonal trends, load profile shape
  - Day/night ratios, base load, load factor

Data Analysis Techniques

- Two ways to apply the analytical techniques
  - Routinely: regular output & routine analysis, often automated
  - Investigative: investigate the process periodically to review the system effectiveness (like an audit)
- Which technique(s) to use?
  - Depends on the organisation, activity or situation
  - Data volume & availability
    - Always try to study available data first

Data Analysis Techniques

- Key questions for selecting techniques
  - Which techniques are appropriate to my situation?
  - What do others use in my sector?
  - Which techniques can I use to benchmark my performance?
  - What do I want/need from the analysis?
  - How much data is required?
  - Do I have that data? If not, can it be obtained economically?

Data Analysis Techniques

- Common techniques
  - Statistical techniques
  - Profile analysis & contour mapping
  - Modelling & simulation
- The techniques selected depends on your aims
  - As the process goes along, they may change & become more sophisticated
  - Look at existing data in a different way (try different techniques to see what they show)

Data analysis techniques

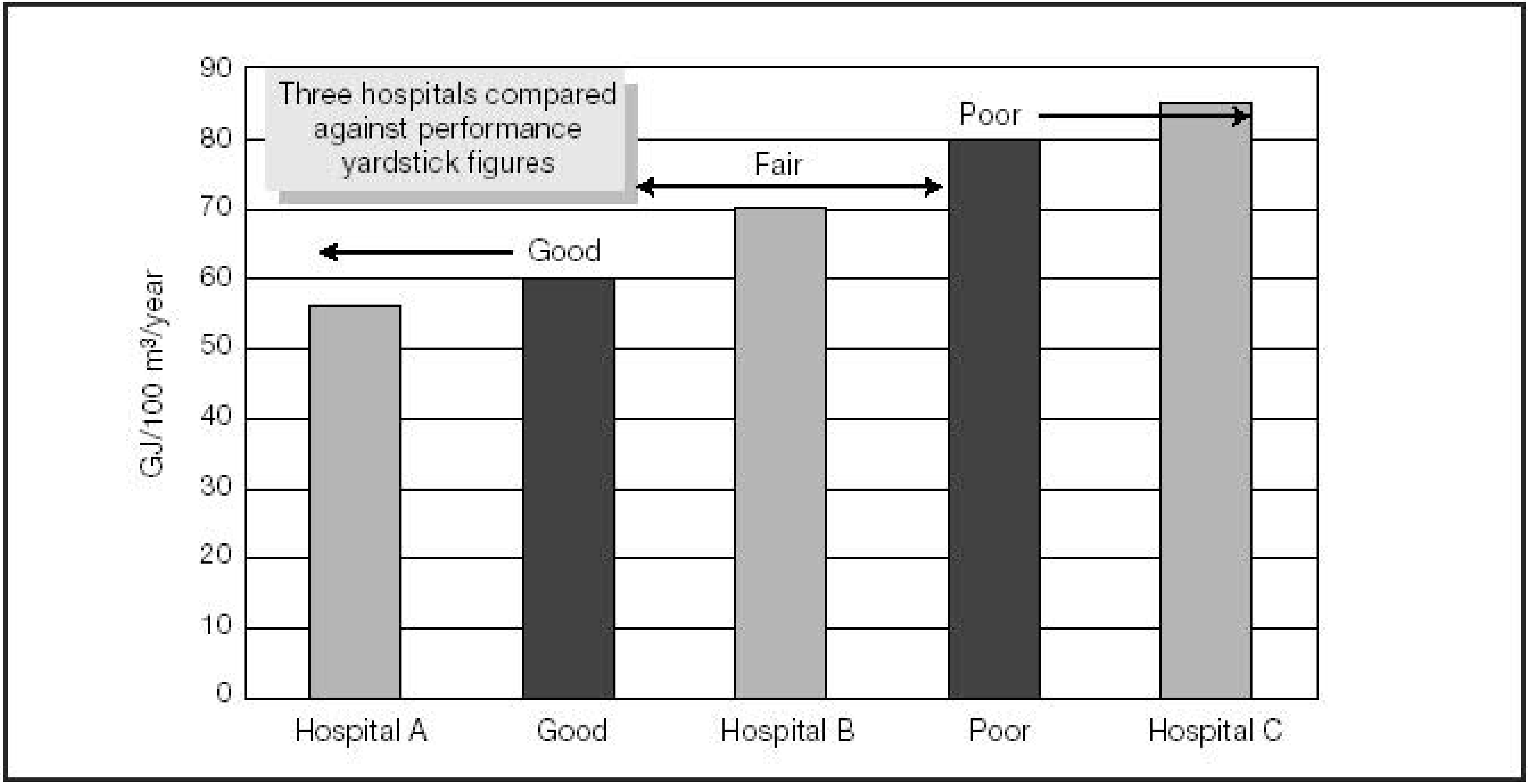
Analysis technique	Buildings	Industrial sites	Description
Normalised Performance Indicators (NPI)	✓		benchmarking against buildings of similar type.
Specific Energy Ratio (SER)		✓	simple industrial process benchmarking.
Current and Past Comparison	✓	✓	comparisons against previous energy performance.
Trend Line	✓	✓	graphical display of energy use against time.
Profiles	✓	✓	to show consumption patterns over specific time periods.
Contour Mapping	✓	✓	3-D way of displaying of energy profiles.
Lines of Best Fit	✓	✓	for approximating simple mathematical relationships between energy consumption and key drivers.
Variances	✓	✓	to show deviation from anticipated energy performance.
CUSUM	✓	✓	CUmulative SUM of variances from standard performance - useful to identify changes in the pattern of energy use.
Control Charts	✓	✓	using predetermined control limits to alert exceptions to planned performance.

Data Analysis Techniques

- Normalised performance indicator (NPI)
  - For buildings, calculated annually – **kWh/m²/year**
    - Total annual energy consumption / floor area
    - Normalised for operating hours, weather, etc.
  - NPI can be for total energy, energy types (electricity, gas, oil) & by use (A/C, light, heat)
  - Allows comparison of buildings of a similar type
- Questions: What floor area shall be used? GFA or UFA? Are they accurate?

What can you interpret from this?

Normalised Performance Indicator (NPI)

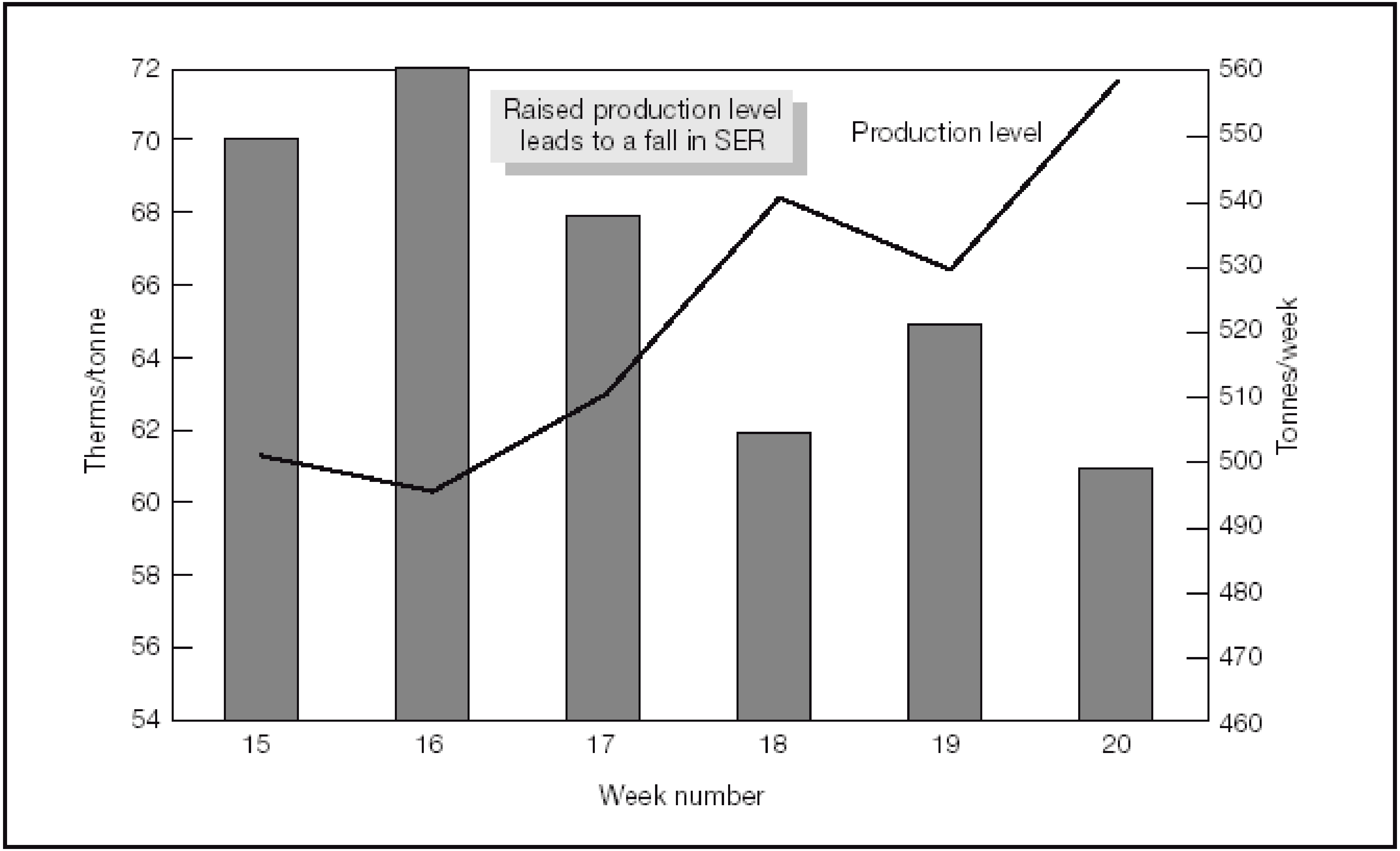


Data Analysis Techniques

- Specific energy ratio (SER)
  - Also known as specific energy consumption (SEC)
    - The energy use divided by an appropriate production measure (i.e. a driver)
  - Used in industry or for industrial process
    - For process benchmarking
    - Easy to calculate, understandable, straightforward
  - Drawbacks:
    - Sometimes may be too simplistic & flawed

Specific Energy Ratio

What can you interpret from this?



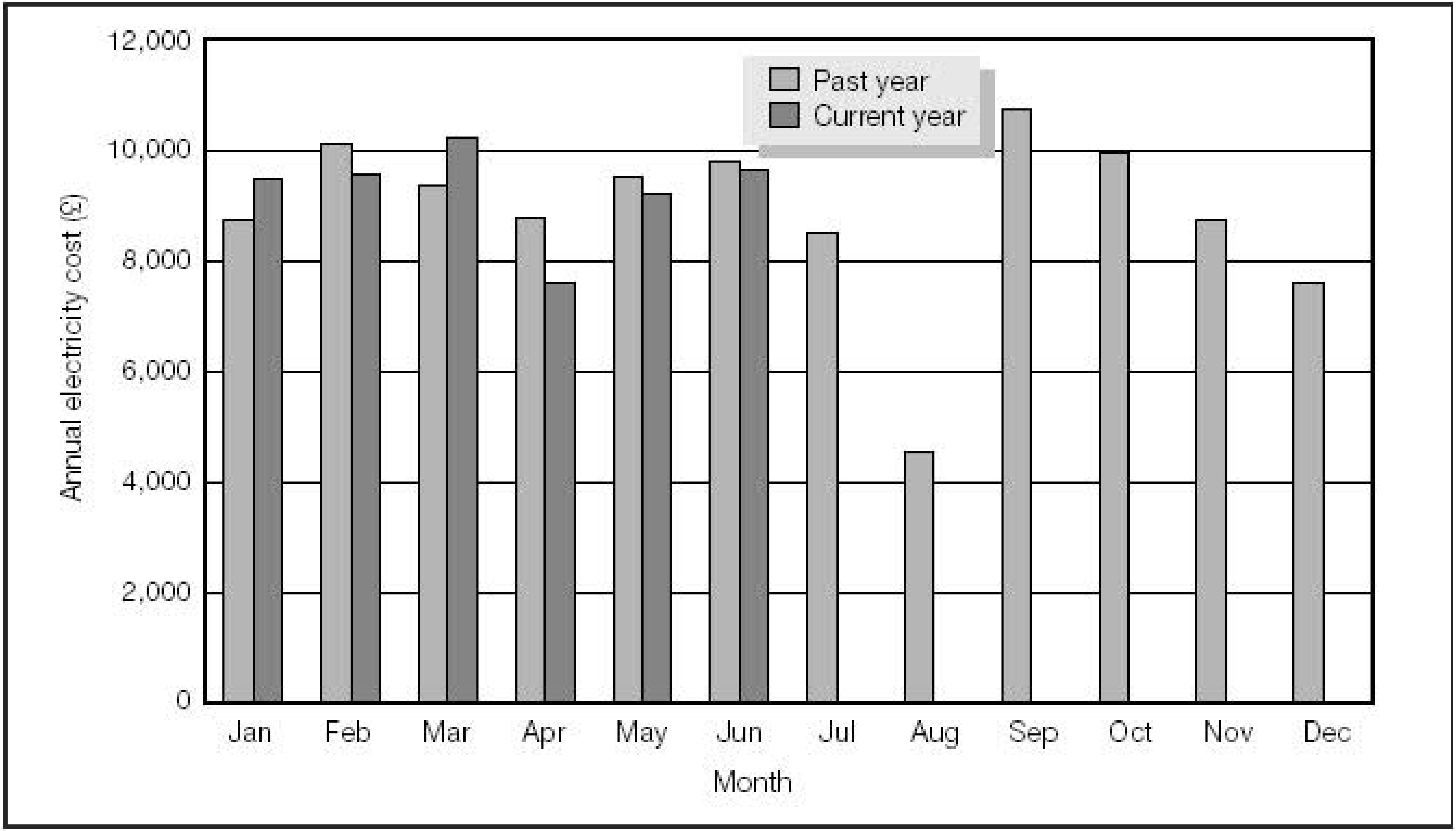
Specific energy requirement for glass melting

Data Analysis Techniques

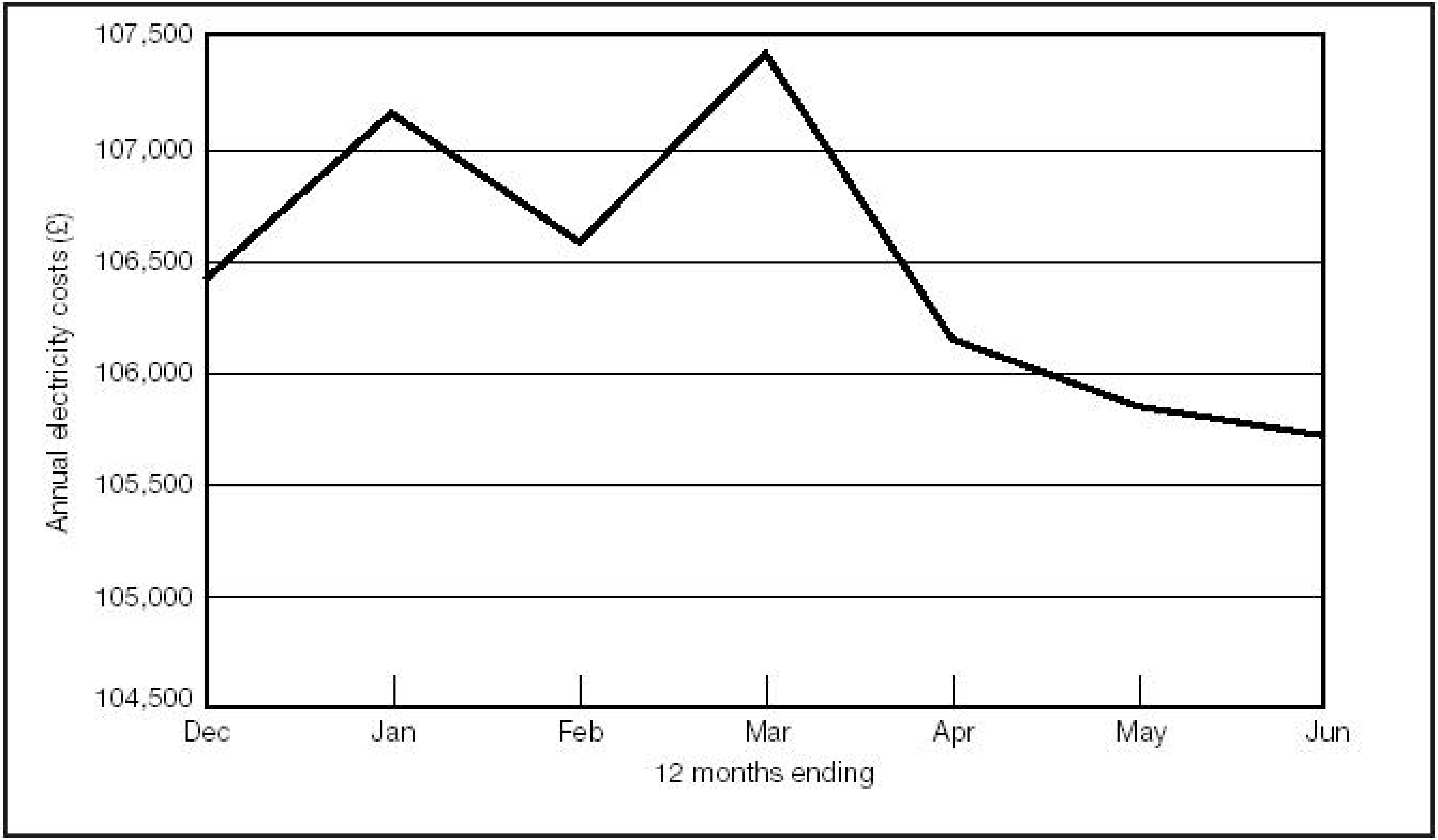
- Current & past comparison
  - Bar or column chart, or tabular form
  - For year-on-year changes & cyclic patterns
- Trend line
  - Presents trend of consumption or cost, over time
  - Moving averages or annual totals can also be used
    - Reduce seasonal influence
  - Useful for early stage investigation

What can you interpret from this?

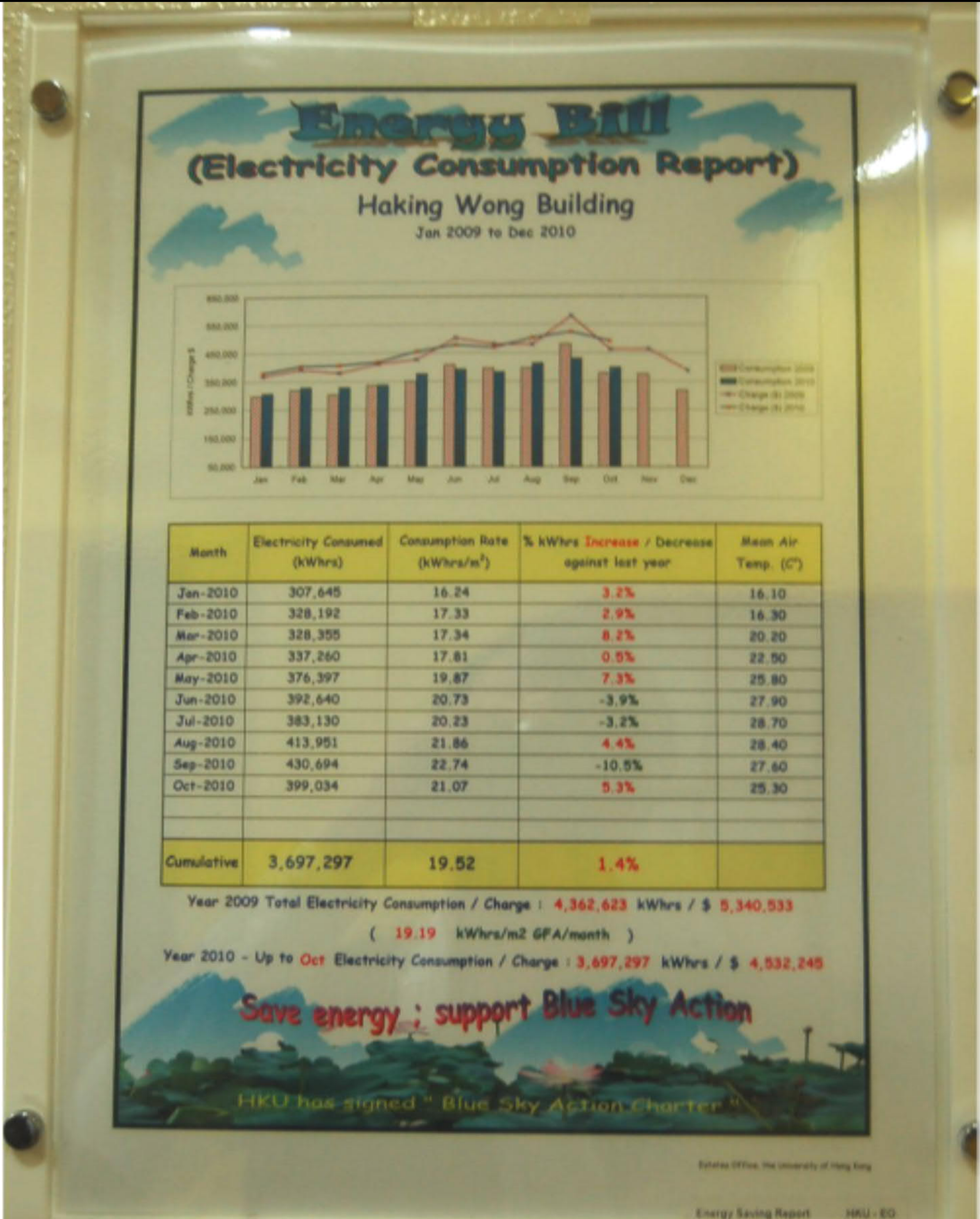
Current and Past Comparison



Trend Line



Moving annual costs



<u>Real-life example</u>:

Electricity consumption report (Haking Wong Building, HKU)
Jan 2009 to Dec 2010

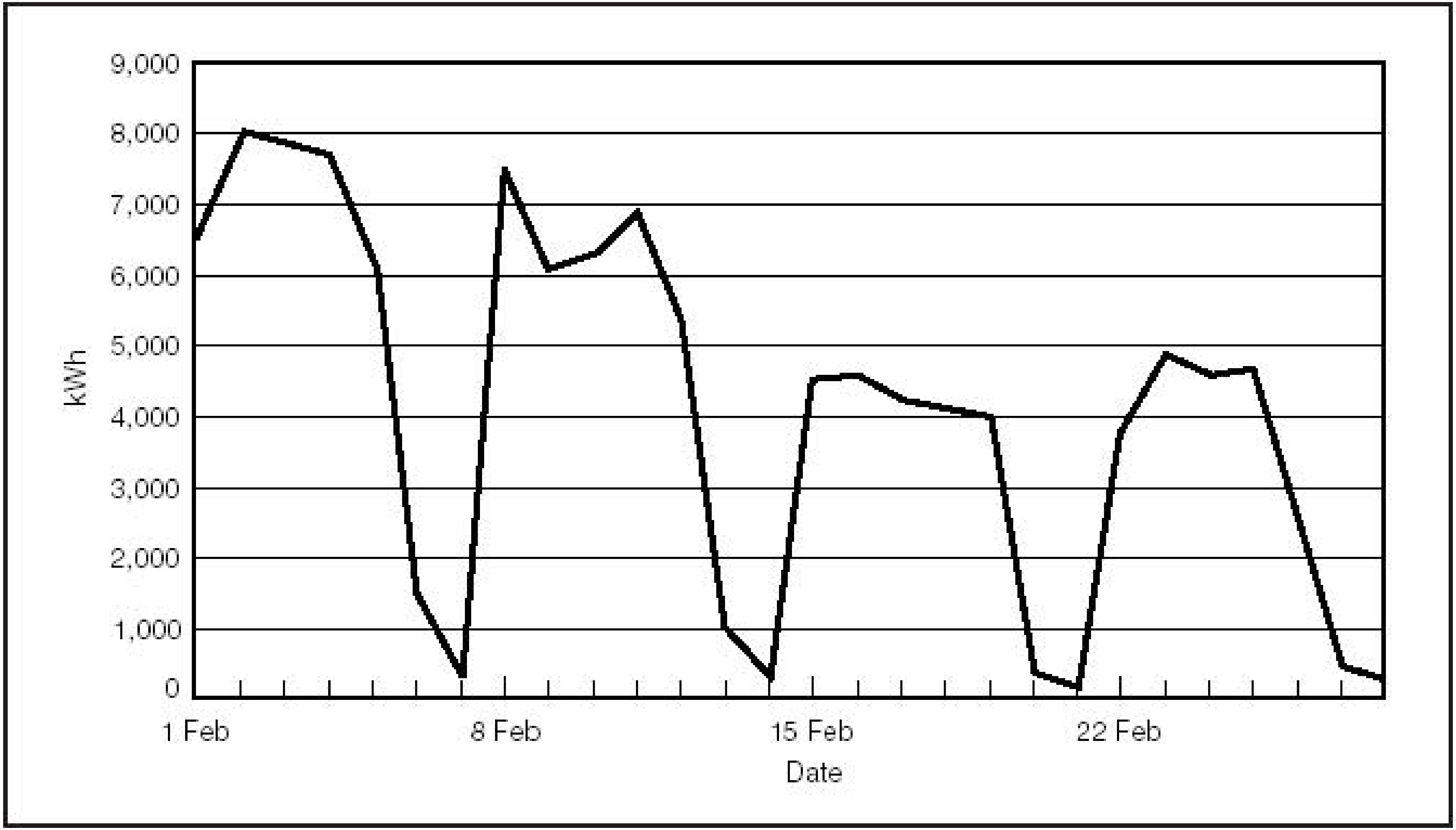
What can you interpret from this?

Data Analysis Techniques

- Profiles
  - For the day, week, month or year
  - Can be expanded by comparing current & past profiles, average profiles, or checking against variation on a based profile
  - Useful when consumption pattern is repeatable
  - Being used visually, or arithmetically (e.g. by subtracting two profiles)

Profiles

What can you interpret from this?



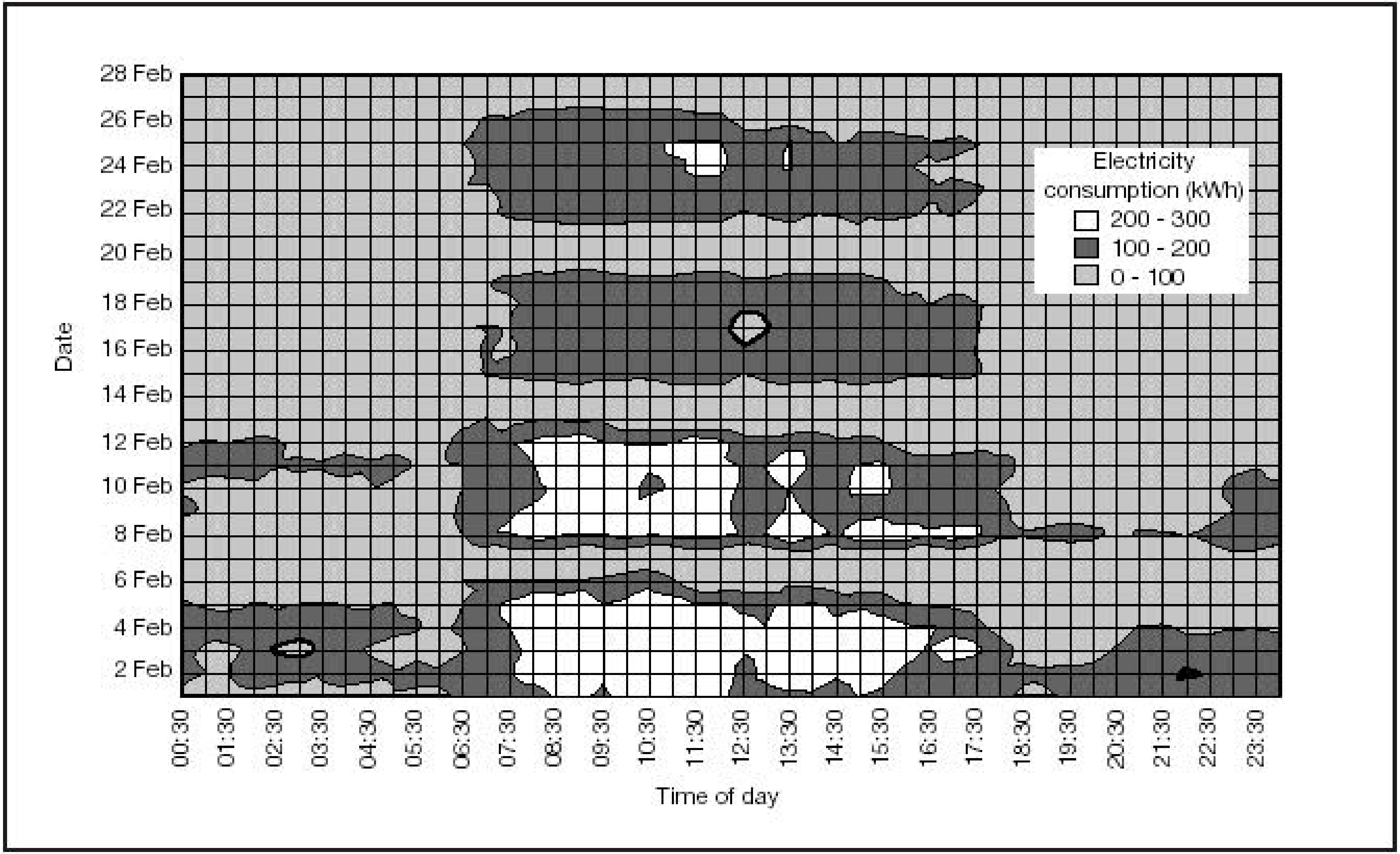
Site electricity profile

Data Analysis Techniques

- Contour mapping
  - Offer a more pictorial use of profile info
- Lines of best fit (i.e. regression lines)
  - Plot energy vs driver (variable) on a X-Y chart
  - Assess if a straight line is a reasonable relationship
  - Produce an equation by inserting a straight line in the scatter (Y = m X + c)
    - Regression by means of least square (R^2)
    - Suspect points should be checked out & if necessary eliminated from the analysis

Contour Mapping

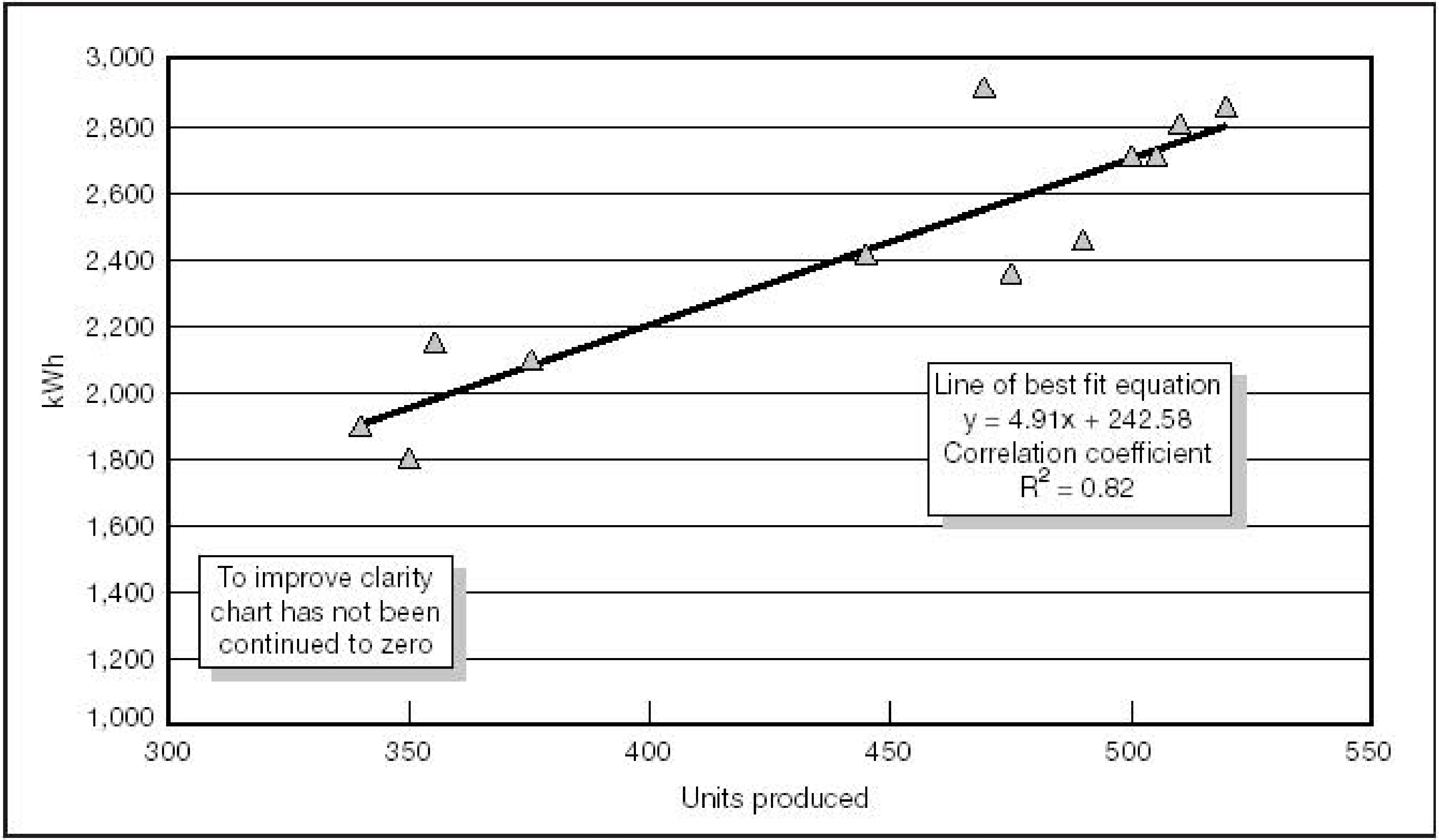
What can you interpret from this?



Electricity contour map

Lines of Best Fit

What can you interpret from this?



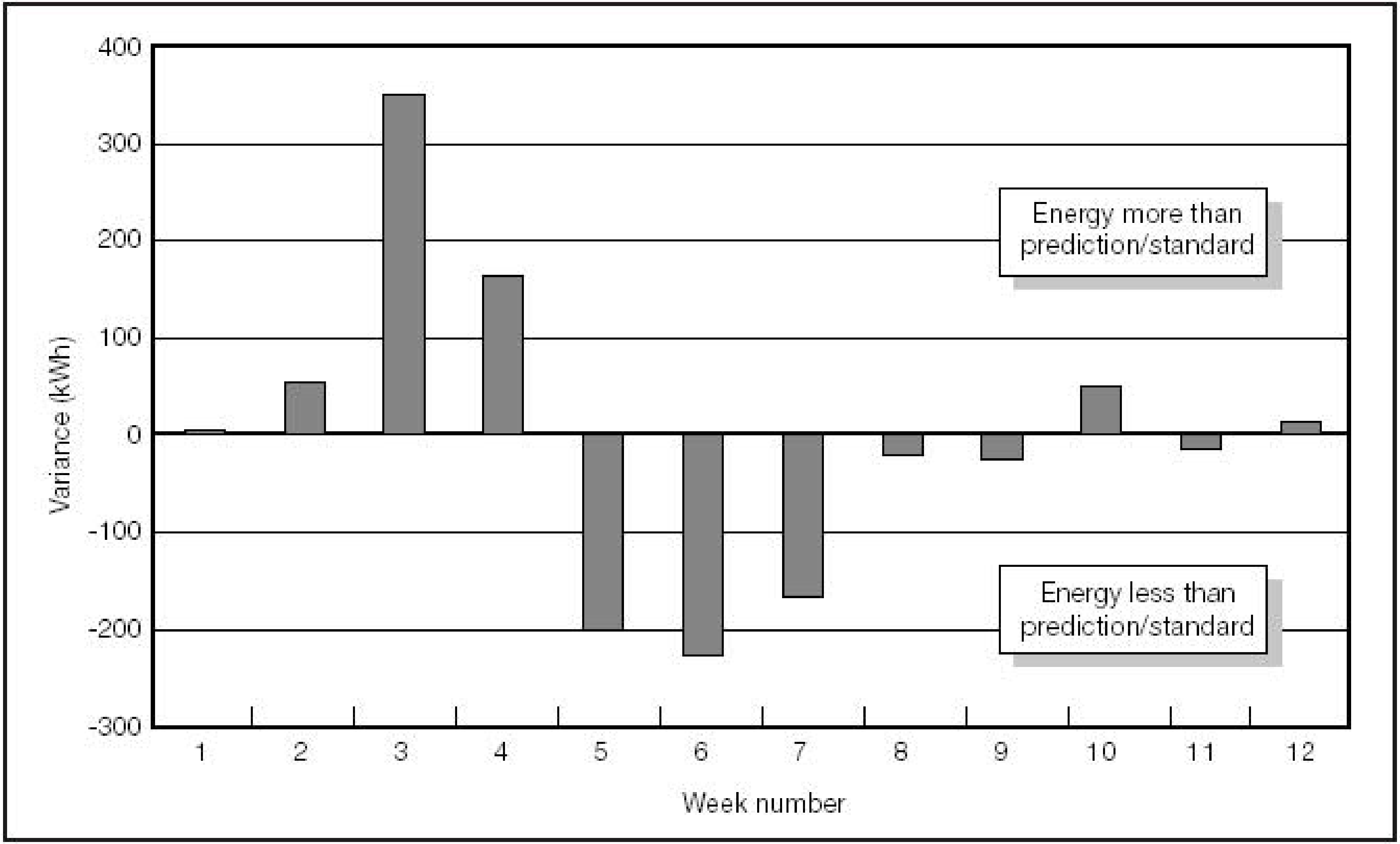
Line of best fit - energy vs. production

Data Analysis Techniques

- Variance
  - Deviation from expected/standard consumption
- Cumulative sum (CUSUM) of differences from standard or predicted performance
  - Originates from quality control
  - Sharp kinks will indicate events which change the underlying pattern
    - Identify & quantify the impact of changes in the pattern of energy use
    - Identify the time of the last change in pattern

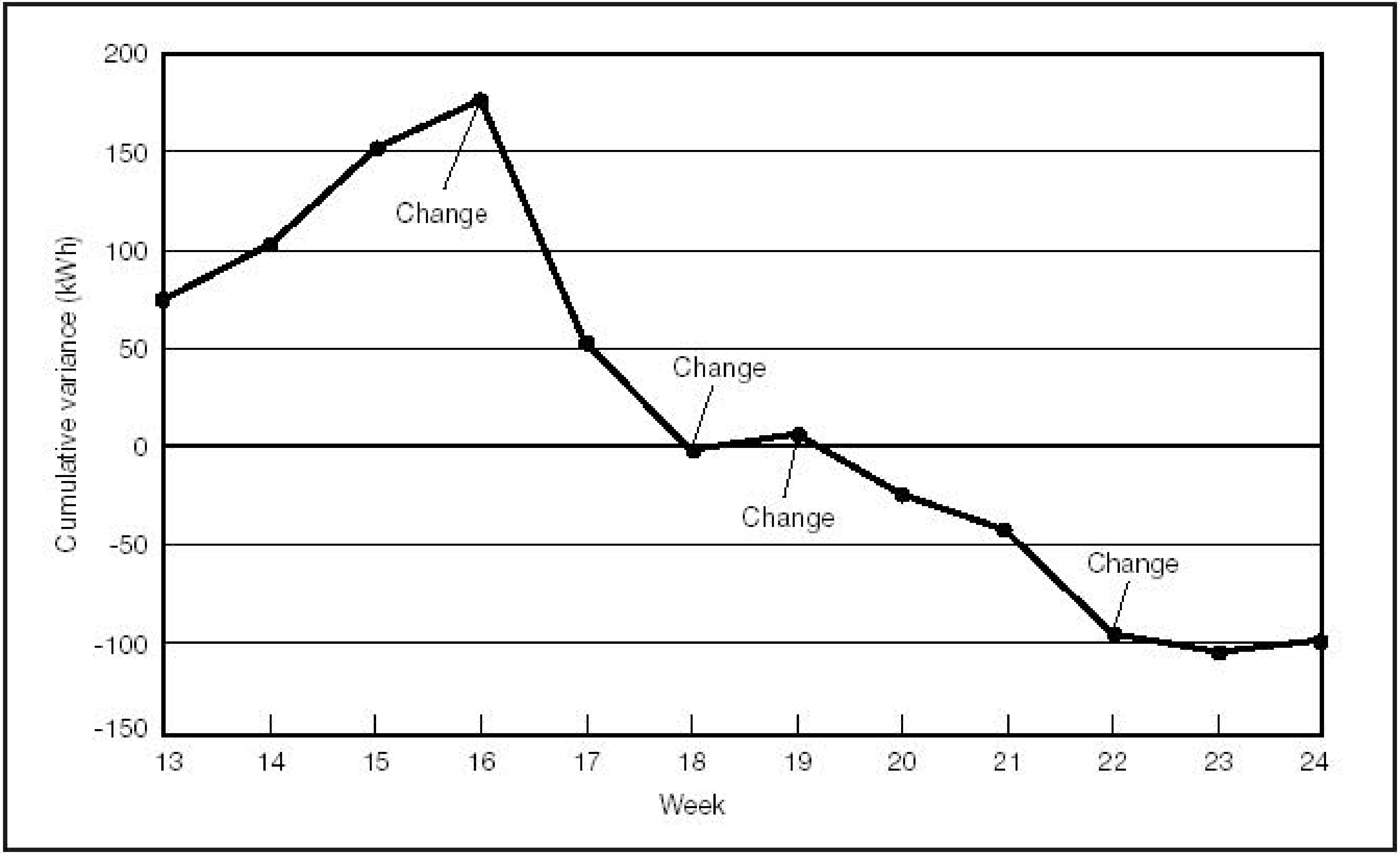
Variances

What can you interpret from this?



Weekly variance chart

CUmulative SUM of differences (CUSUM)



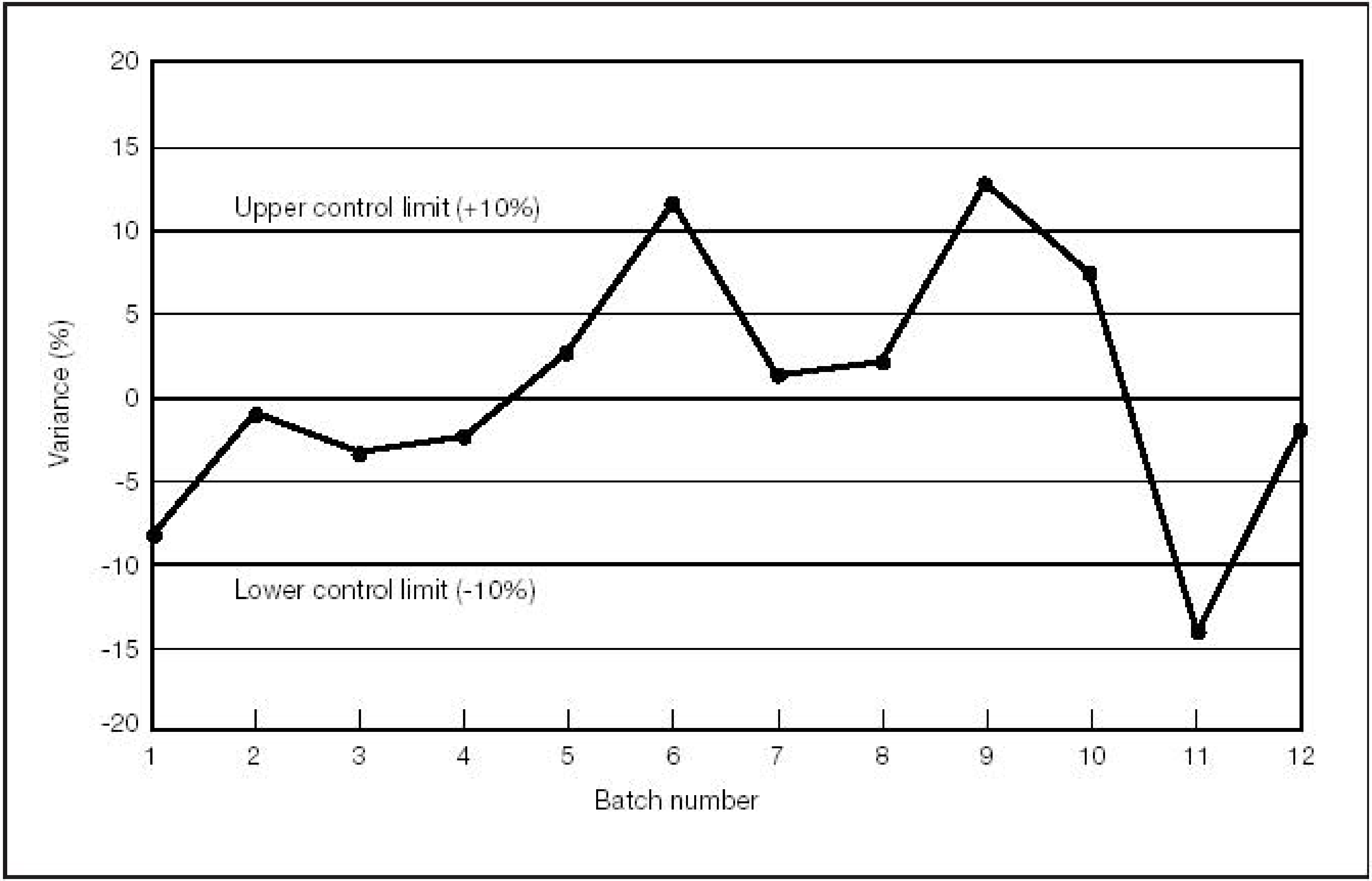
CUSUM chart

Data Analysis Techniques

- Control charts
  - Also from quality control
  - Statistical process control (from manufacturing)
  - A ‘baseline’ value is required
  - Control limits are then established
  - Useful if a large no. of meters are being monitored & exception reporting is required

Control Charts

What can you interpret from this?



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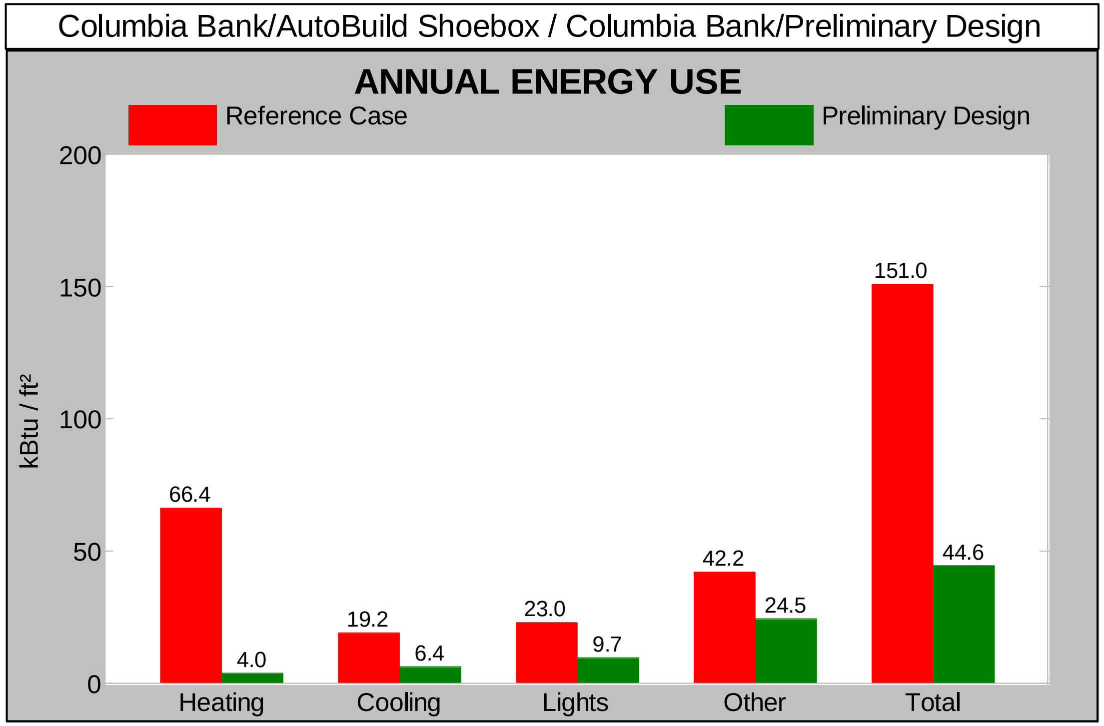
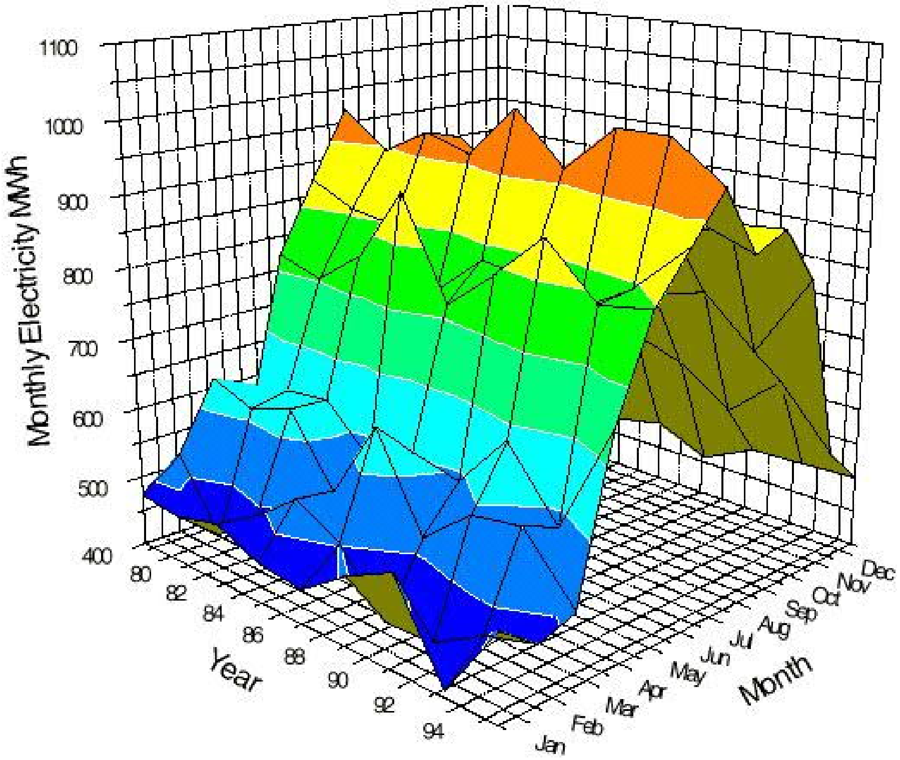
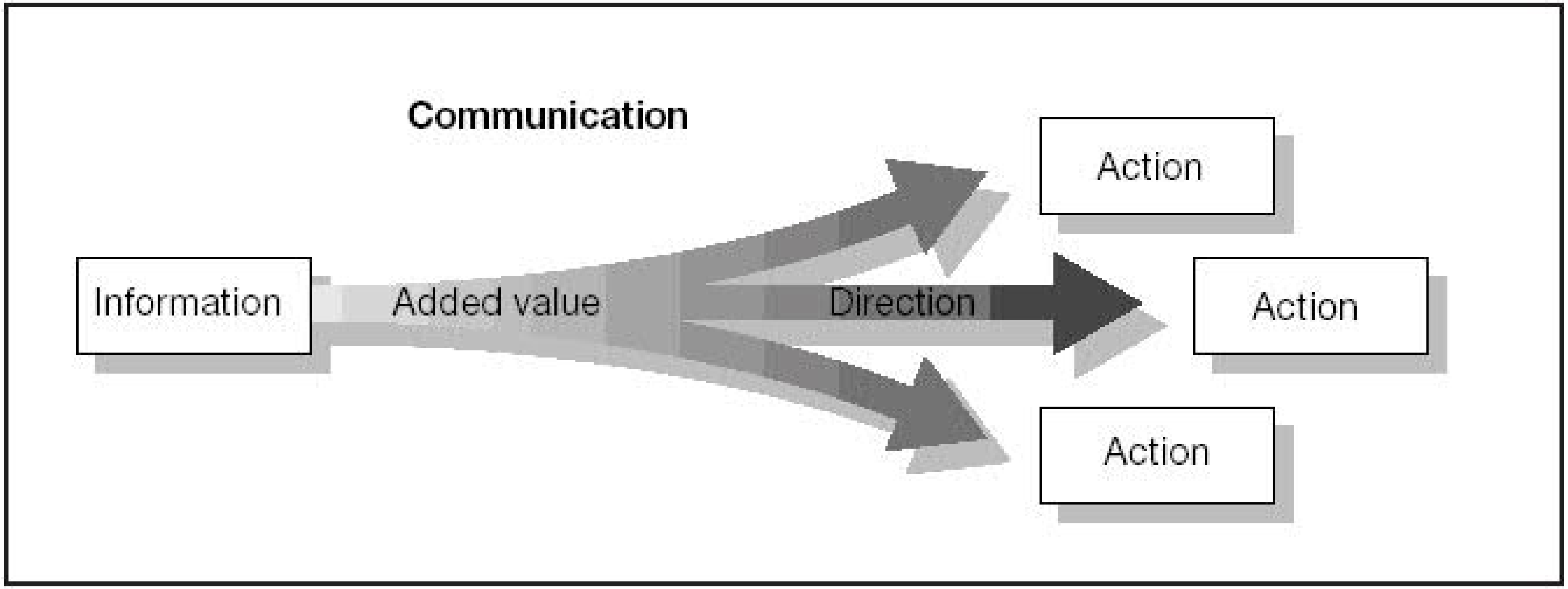




Presentation of results from building energy simulation

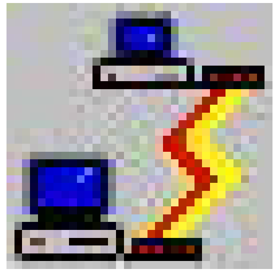
Data Analysis Techniques

- Communication: Transformation from data to understanding
  - The system can add "*value*" to the data



Communicating data

Data Analysis Techniques



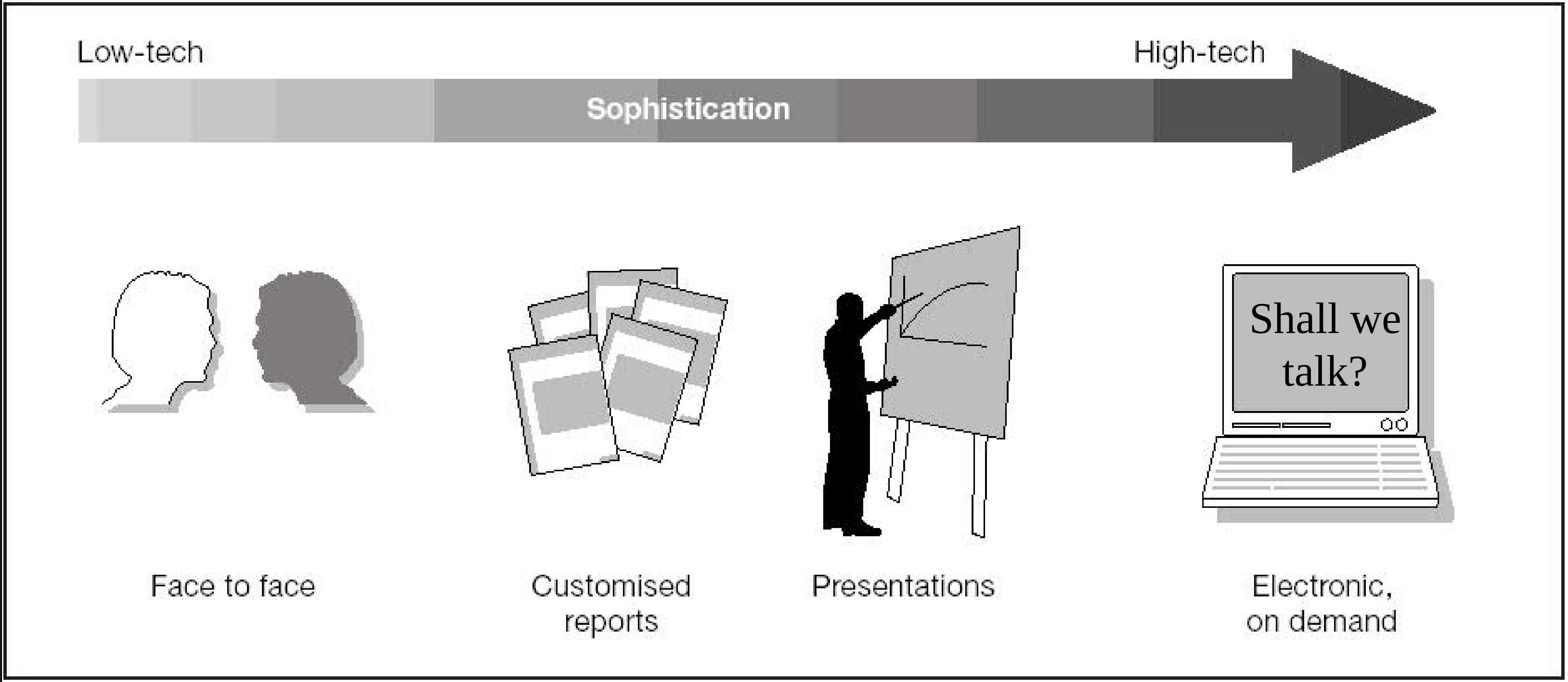
- Three categories of communication:
  - Regular – weekly or monthly report
  - Exception – produced when something wrong
  - Ad-hoc – initiated by request or for investigation
- Identify information needs
  - Who needs energy information?
    - All those that can influence energy performance
  - What information do recipients need?
    - The minimum necessary to enable them to consider/improve energy performance

	Annual report	Monthly report	Weekly report	Key indicators	Exception report
Chief executive	■			■	
Accountant	■	■		■	
Department heads	■		■	■	■
Purchasing	■			■	
Supervisors		■	■	■	■
Workforce				■	

What information do recipients need?

Data Analysis Techniques

- Timing of communication
  - *<u>Speed</u>* – the value of info is time dependent
  - *<u>Frequency</u>* – too often → info overload; too infrequently → the interest is lost
- Communication methods
  - The chosen method is often pre-determined by the software used or organisational practices
    - The options chosen shall match the need of the body, achieve results



Communication methods

Data Analysis Techniques

- General principle of (good) reporting:
  - The right info should reach the person who has control of the resource to which it refers
  - They should be able to understand what it means to them
  - There should be a min. of extraneous info that prevents them from noticing what they need to see
  - There is some means of ensuring that action is taken when it is needed

Practical Applications

- Worked example in the further reading info
  - Good Practice Guide No. 231
- Process of assessing energy information system needs
  - Defining the system
  - Gathering information
  - Selecting analysis techniques
  - Assessing existing systems
  - Taking action

Action Plan

SITE DETAILS: . . . .

Item	Responsibility	Start date	Completion date
System definition			
Information gathering			
Analysis			
Assessment			
Implement			
Next audit			

Date Prepared: ______________________________

Utility spend and savings estimates

Savings potential				
Utility	**Annual spend £k**	**% of total spend**	**% savings potential**	**Savings £k**
Electricity	510	50.0	4	20.4
Gas	220	21.6	6	13.2
Water	180	17.6	15	27.0
Diesel - transport	110	10.8	10	11.0
TOTAL	**1,020**	**100**		**71.6**
Total savings/annual spend			**7%**	

Estimated by consultant

Practical Applications

- Gathering information - data gathering should include:
  - Raw data – meter reading and invoices
  - Analysis – calculations and assessments
  - Communication – reports and other outputs

Practical Applications

- Gathering information
  - Common questions to ask yourself:
    - What raw data is already available?
    - Which analysis processes are used and why?
    - Where is data and information stored?
    - How is information communicated?
    - Do people get what they want?
    - Is information delivered on time?
    - Is the information both of good quality and reliable?

Metered supply - main meters

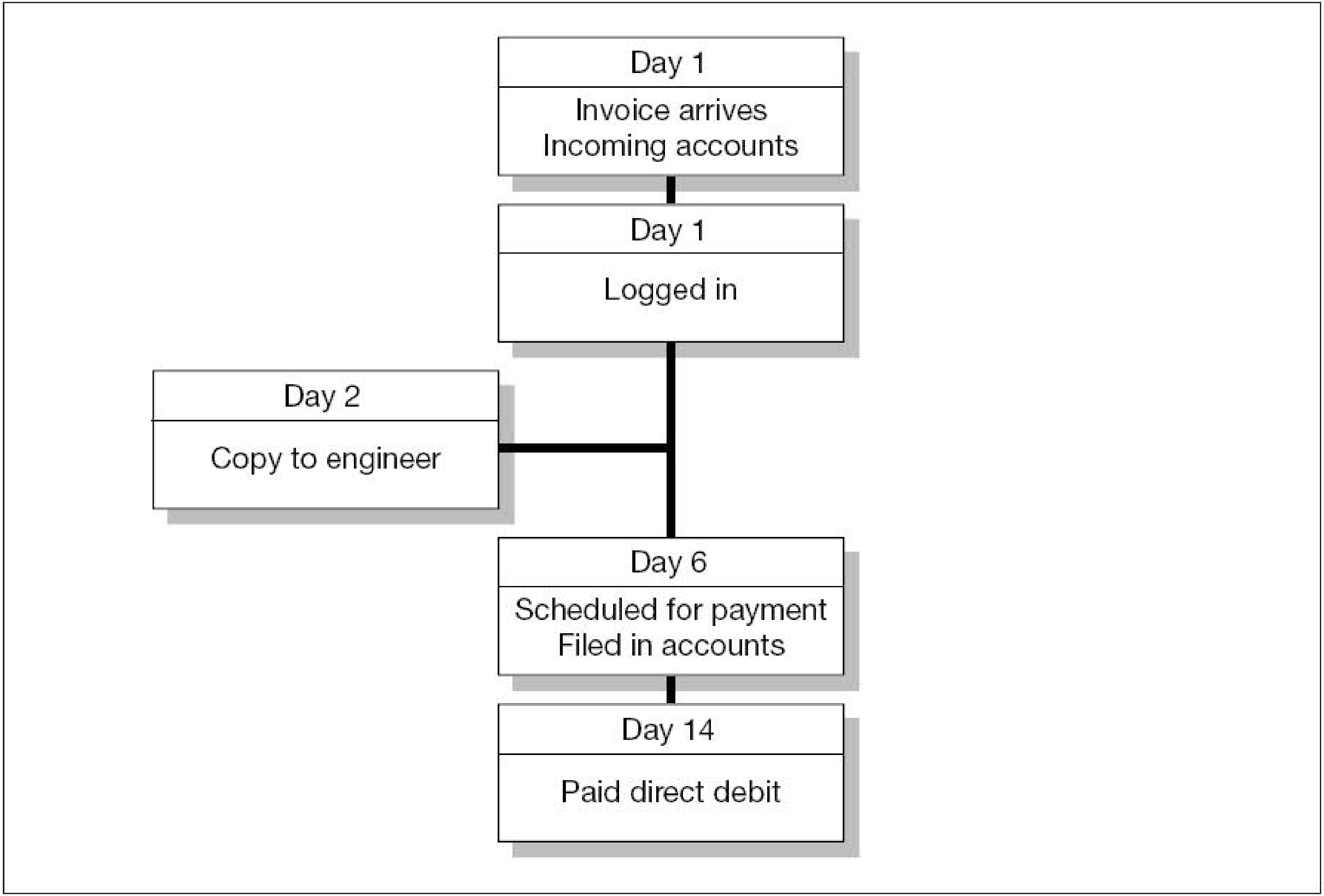
Utility	Number of meters	ID/ location	Type A = on-line metering B = (Basic) manually read; Other - specify	Reading frequency Q = quarterly; M = monthly W = weekly; D = daily 30 = 30 minutes Other - specify	
				By utility	By organisation
Electricity	1	M186 Main gate	A	30	W
Gas	2	M0875 M67899 Gas house	B B	M M	W W
Water	1	12567 Entrance road	B	M	W
Total	**4**				

Bulk supply - unmetered

Utility	Method of charging	Frequency of charging	Consumption metering
Road diesel	By delivery	By delivery	At point of use

Invoice tracking

Detail	Gas	Electricity	Water	Total
Invoices per month	2	1	1	4 (48 per year)
Paper or electronic? P/E	P	P	P	
Estimated readings? Y/N	Y	N	Y	
Direct debit payment? Y/N	Y	Y	Y	



Invoice flow chart

Why sub-metering is important?

Sub-meters			
Metered utility	**Number of sub-meters**	**Type** A = on-line metering B = (Basic) manually read;	**Reading frequency** Q = quarterly; M = monthly W = weekly; D = daily A = on-line, X = not read
Electricity	5	B	W
Gas	0		
Water	0		
Diesel	2	B	Tank filling
Total	**7**		

Energy drivers can help to develop indicators for comparing and benchmarking.

Energy drivers		
Driver	**Process affected and energy type**	**Source of data**
Tonnage	Furnaces and machinery - electricity and gas	Production control system
Weather degree days	Heating - gas and electricity	Energy management magazine
Mileage	Fuel consumption - diesel	Transport log books

Make sure the reports are read and understood.

Communication			
Report	**Frequency**	**From**	**To**
Company Energy Report	Annual	Energy Manager	Managing Director and Department Heads
Energy Indicators	Monthly	Energy Manager	Department Heads
Budget Report	Monthly	Accountant	Relevant Department Head
Fuel Economy	Monthly	Fleet Manager	Accountant

Evaluate the cost-benefit of EIS

Audit of energy information system running costs

Item	**Annual Cost** **(A)**ctual or **(E)**stimated
Meter reading	£825 (E)
Meter calibration	Nil
Software and software support	£100 (A)
Hardware and hardware support	£145(A)
System operators	£600(E)
External contracts	Nil
TOTAL COST	**£1,670/year**

Evaluate the types and numbers of meters

Energy spend per meter	
Total energy spend	£1,020k/year
Total main meters	4
Total sub-meters	7
Total meters	11
Annual energy spend £k/Meter	**£93k/year**

Evaluate the operating cost and savings potential

Information system ratios	
Operating cost/meter	£152/year
Operating cost/total energy spend	0.2%
Operating cost/savings potential	2.3%
Savings potential/total energy spend	7.0%
Based upon the following data:	
Operating cost	£1,670/year
Number of meters	11
Total energy spend	£1,020k/year
Savings potential	£71.6k/year

Frequent audits & reviews of the progress

Progress Record

SITE DETAILS: . . . .

	Audit 1	Audit 2	Audit 3
Date			
Annual energy spend £k			
Savings potential %			
Total savings/total spend %			
No. of main meters			
No. of sub meters			
System operating cost £k			
Spend/meter £k			
Operating cost/meter £k			
Energy savings achieved £k			

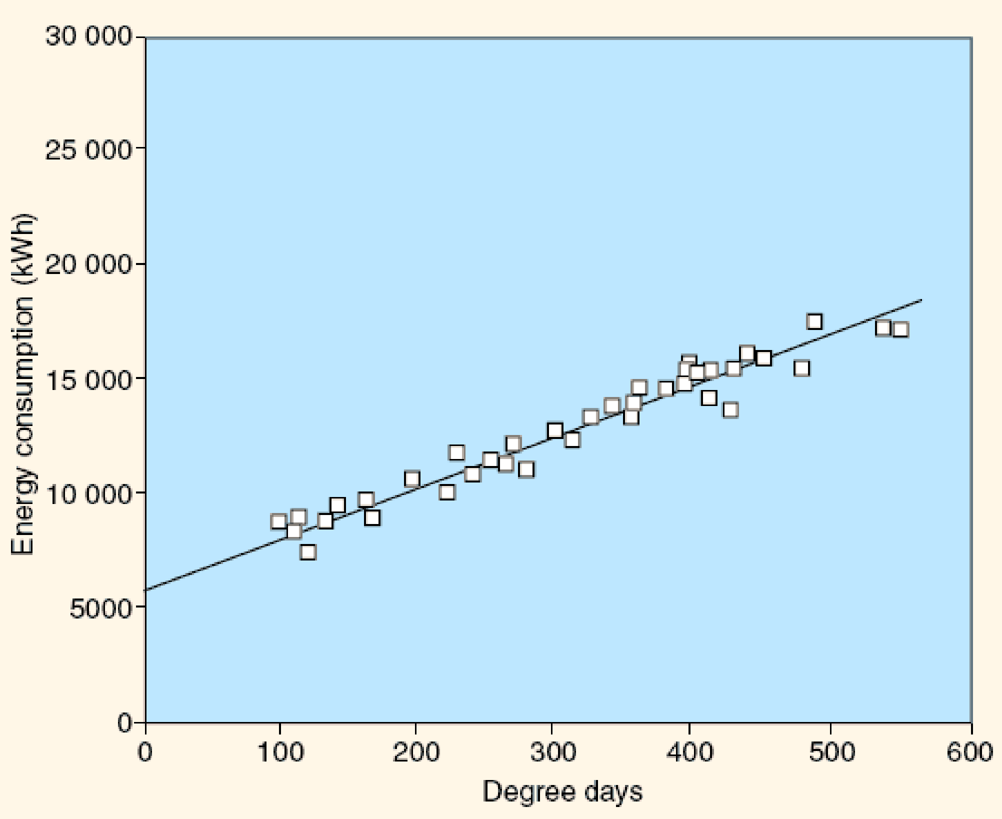
Practical Applications

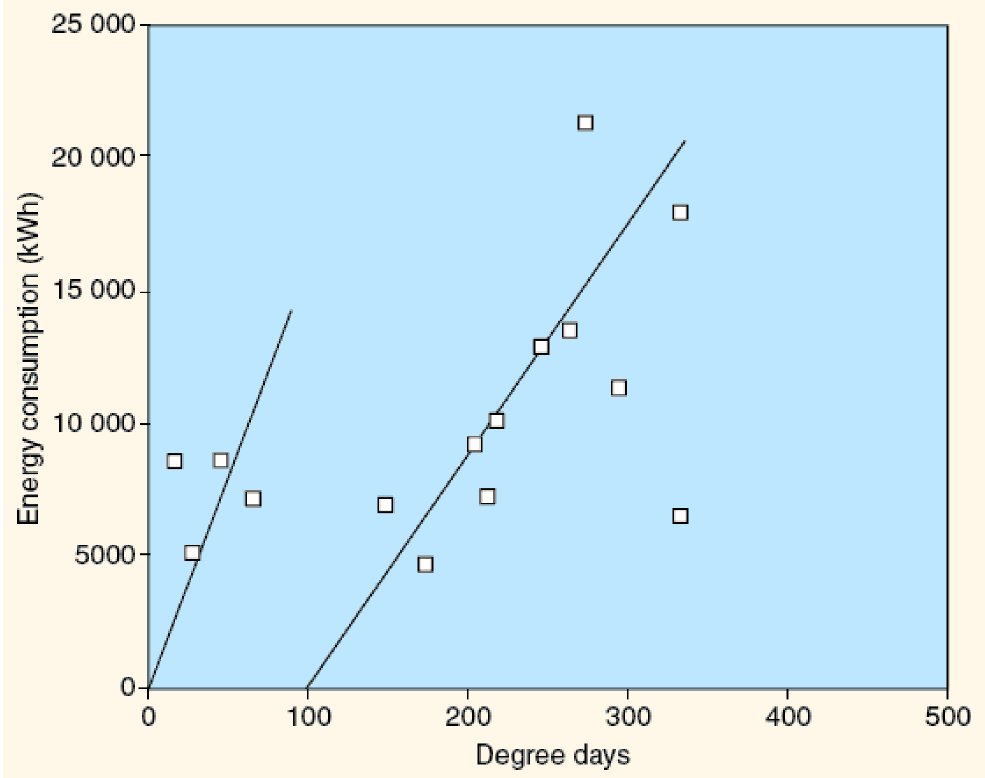
- General Information Leaflet 50
  - Energy Saving in Buildings – Methods for Quickly Identifying Opportunities
    - Two different approaches
      - A physical survey
        - Focuses immediately on tangible faults
      - Data-based methods
        - Can be less expensive
        - Can initially be based on existing data
        - Can identify intermittent faults

Just like an "Energy Detective" (節能偵探)

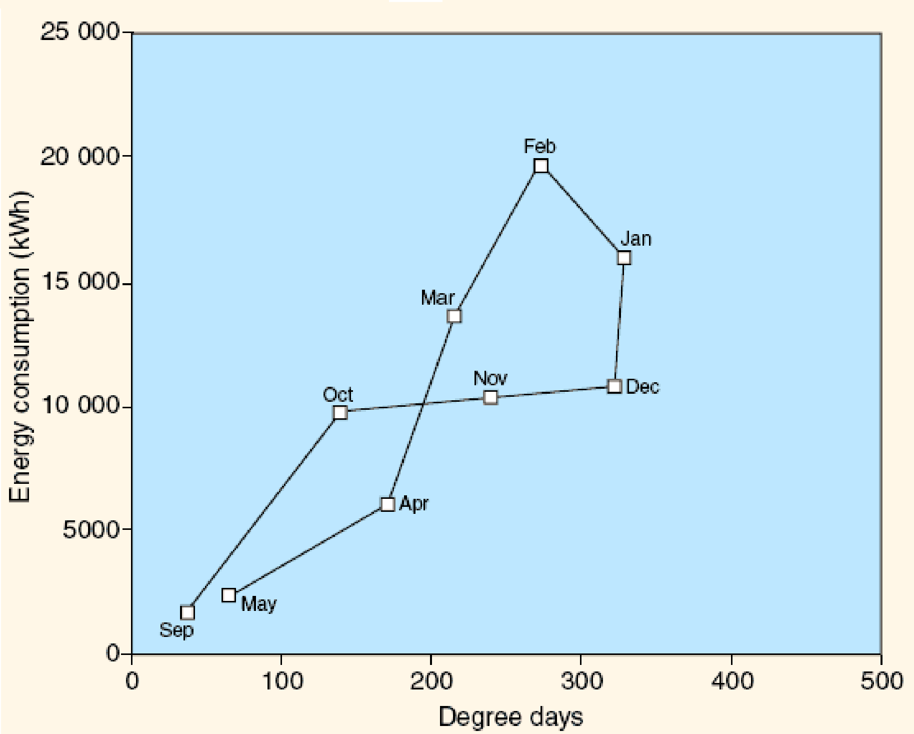
Practical Applications

- Data-based methods
  - Screening
  - Benchmarking
  - Building energy signatures
- Analysing energy signatures
  - Identify problems
  - Cumulative changes from signatures
  - Comparison from one year to another





Degree-days are commonly used for analysis of energy signatures

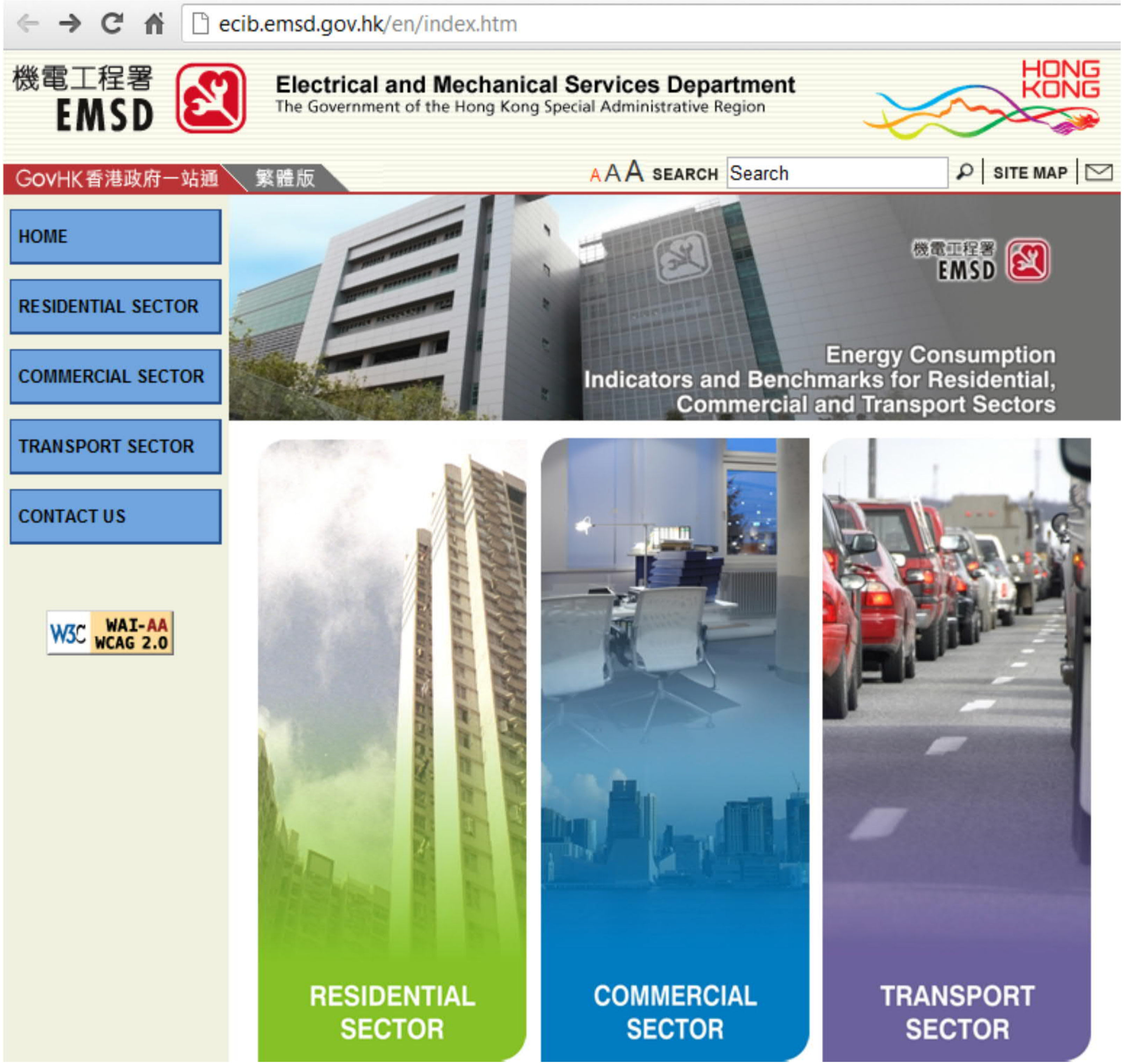


Practical Applications

- Intro to Energy Efficiency in Offices (UK)
  - Energy management
  - Measures to achieve energy savings
  - Comparing performance indices with benchmarks
    - Type 1 naturally ventilated cellular
    - Type 2 naturally ventilated open plan
    - Type 3 air conditioned, standard
    - Type 4 air conditioned, prestige

Practical Applications

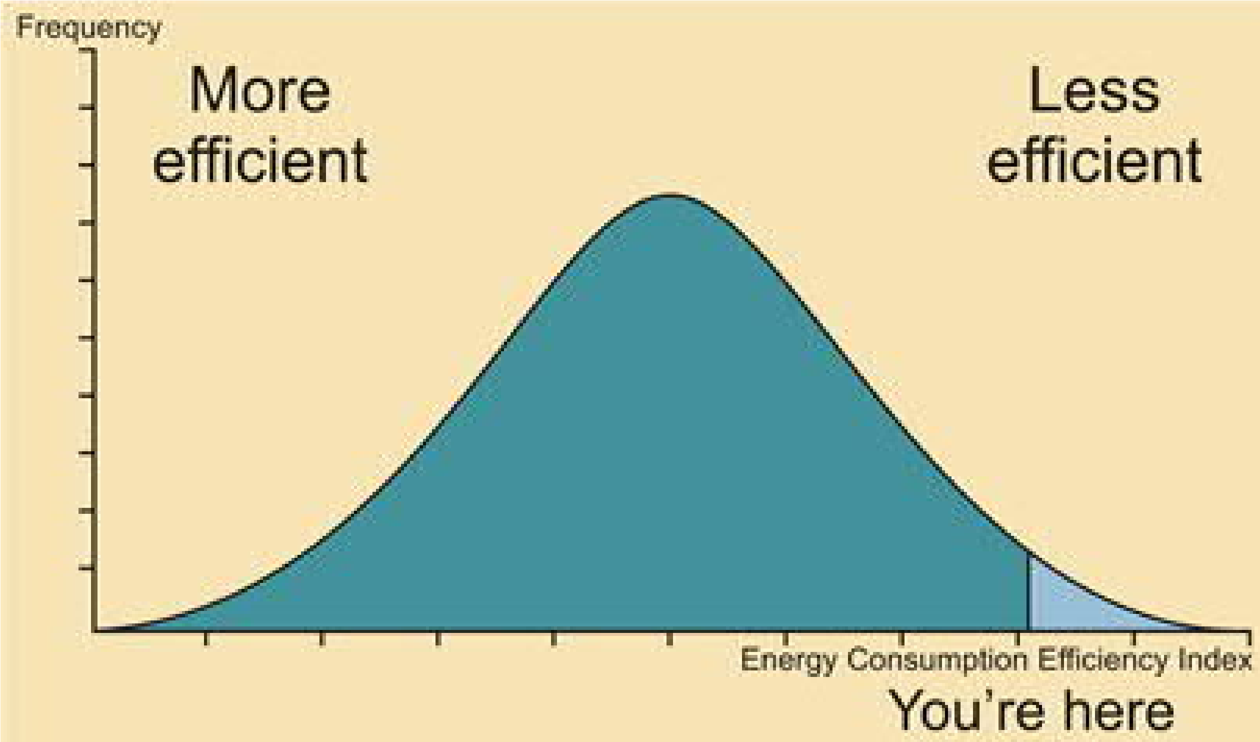
- Local building energy benchmarks in HK
  - EMSD Energy Consumption Indicators and Benchmarks
    - http://www.emsd.gov.hk/emsd/eng/pee/ecib.shtml
    - Residential sector
      - 1) Public Housing, 2) Private Housing, 3) Housing Authority Subsidized Sale Flat, 4) Other Housing
    - Commercial sector
      - 1) Restaurant and Retail, 2) Accommodation, 3) Hospital and Clinic, 4) Educational Services, 5) Warehouse, 6) Office Flatted Factory, 7) Central Services for Shopping Arcade, 8) Private Office, 9) Government Office
    - Transport sector
      - 1) Private Car and Motorcycle, 2) Bus and Light Bus, 3) Taxi, 4) Light Goods Vehicle (LGV), 5) Medium Goods Vehicle (MGV), 6) Heavy Goods Vehicle (HGV)



(Source: http://ecib.emsd.gov.hk)

Example of energy benchmarking result

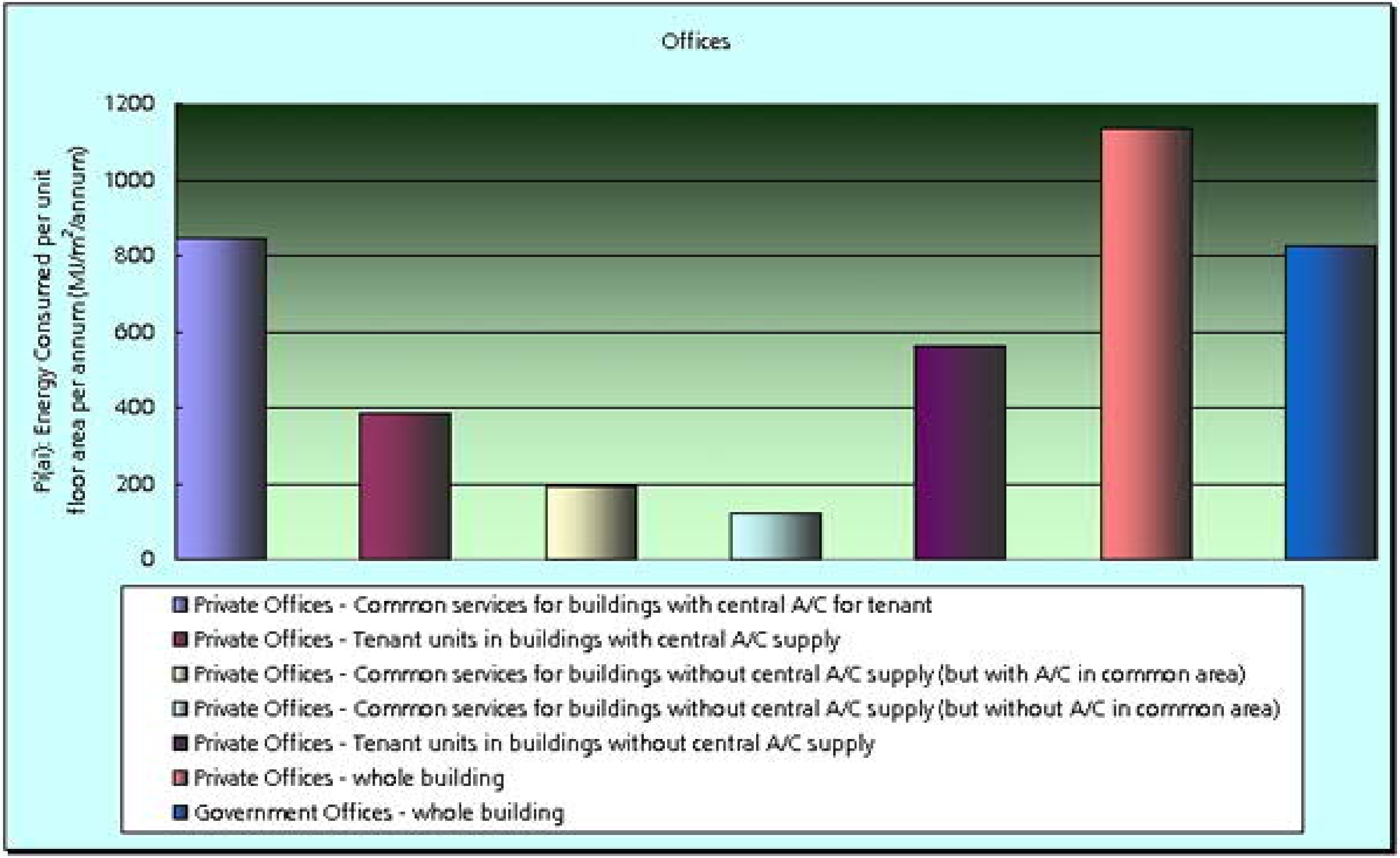
Commercial - Online Benchmarking Tools
Your benchmark result compared with the same group:
Your annual energy consumption per area is 3600.0 MJ/m^2/annum.



Your energy consumption performance is at the 90th percentile.
It means that 90% of the sampled subjects in the subgroup are better than your energy consumption performance.

(Source: http://ecib.emsd.gov.hk)

Energy Consumption Indicators for Offices



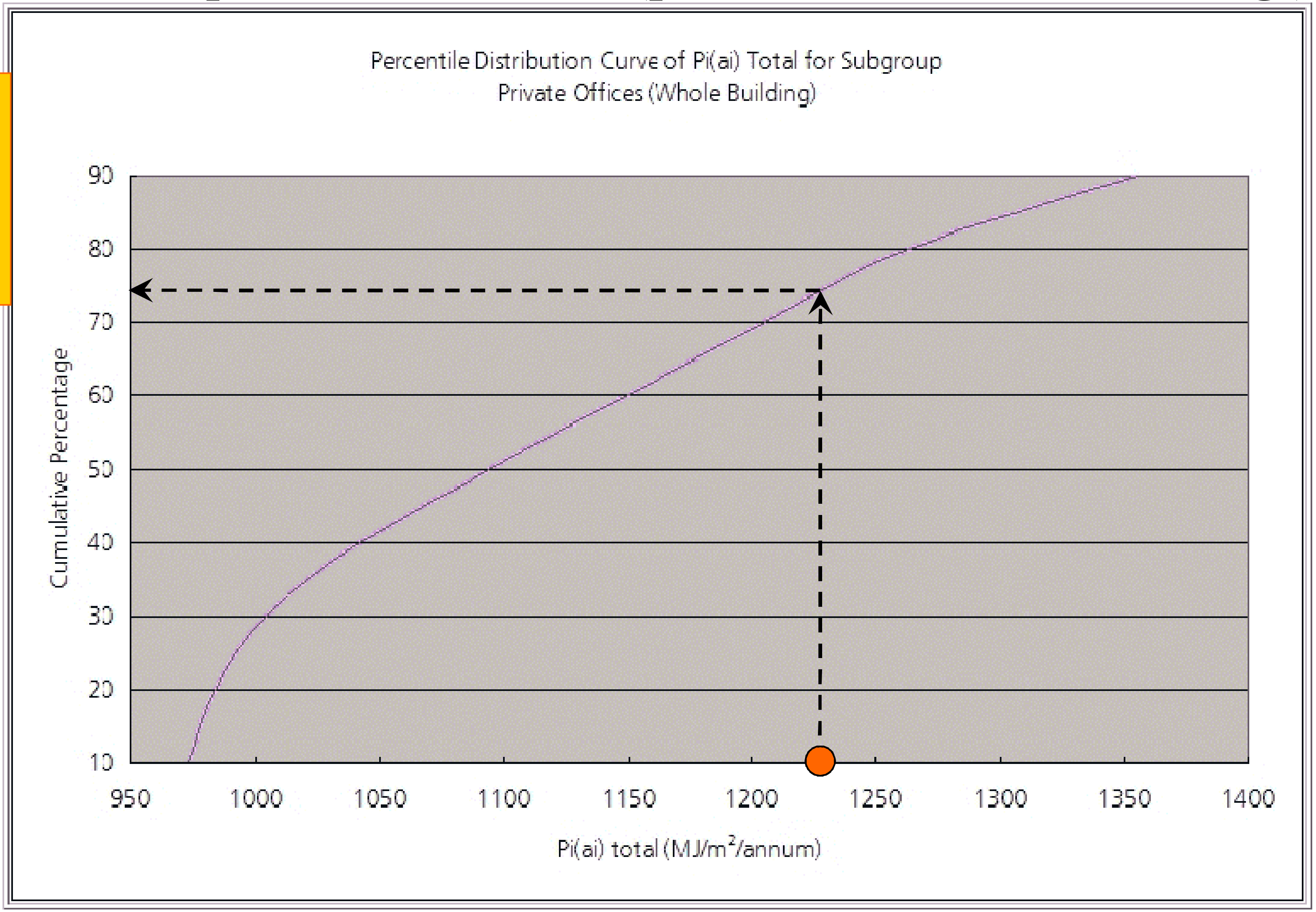
(Source: www.emsd.gov.hk)

Principal Group	Subgroups	Indicator PI(ai): Energy consumed per unit floor area per annum ($MJ/m^2/annum$)	Detail benchmarks
Private Offices	Common services for buildings with central A/C for tenant	848	Benchmarks
	Tenant units in buildings with central A/C supply	385	Benchmarks
	Common services for buildings without central A/C supply (but with A/C in common area)	192.3	Benchmarks
	Common services for buildings without central A/C supply (but without A/C in common area)	122.3	Benchmarks
	Tenant units in buildings without central A/C supply	561	Benchmarks
	Private Offices (whole building)	1132	Benchmarks
Government Offices	Government Offices (whole building)	826.5	Benchmarks

(Source: www.emsd.gov.hk)

Energy Consumption Benchmark (private offices: whole bldg.)

Do you know how to use this?

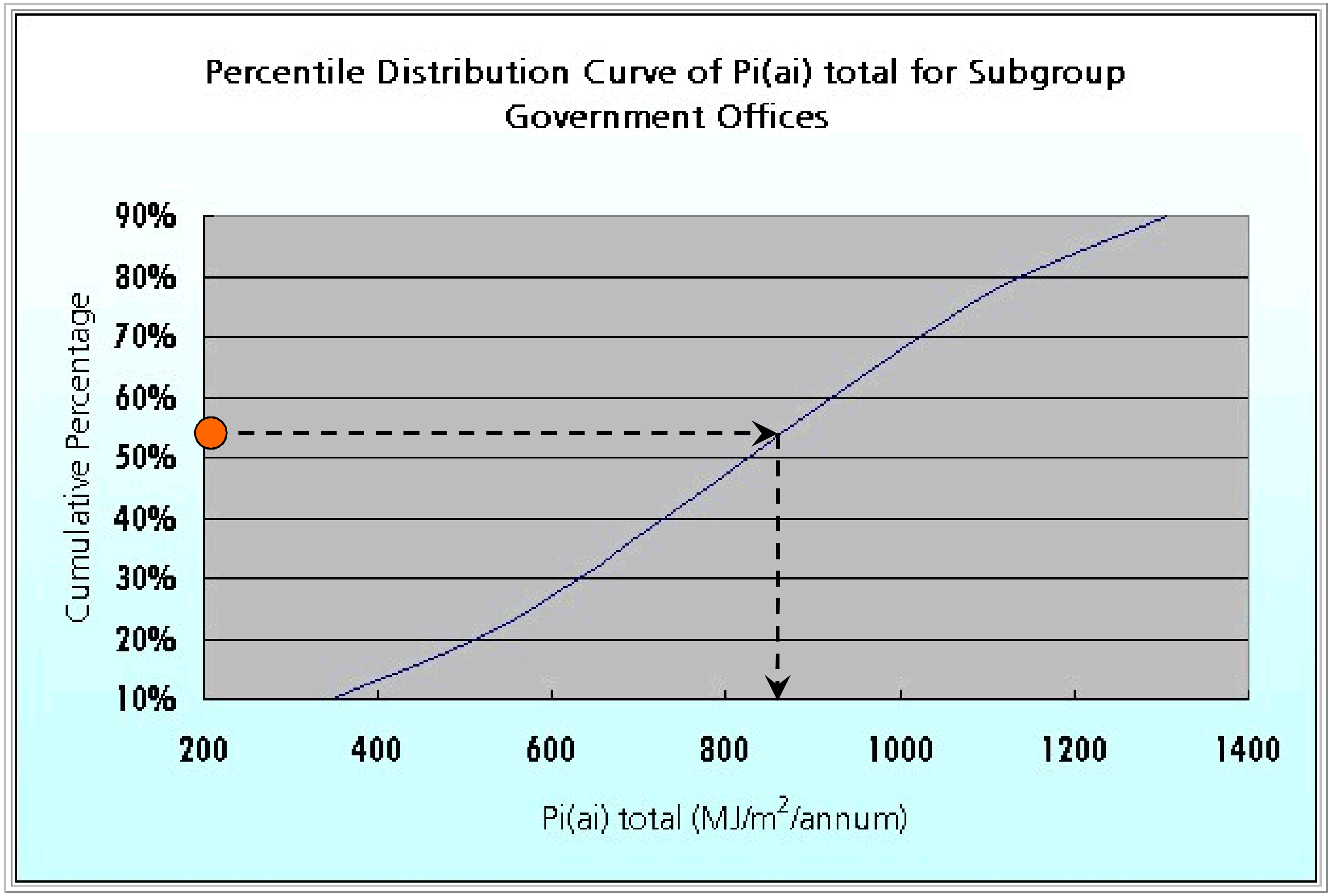


The 10th , 30th , 50th , 70th and 90th percentile benchmarks are :				
10th	30th	50th	70th	90th
973 MJ/m^2/annum	1004 MJ/m^2/annum	1094 MJ/m^2/annum	1205 MJ/m^2/annum	1355 MJ/m^2/annum

(Source: www.emsd.gov.hk)

Energy Consumption Benchmark (government offices)

Is this lower than private offices? Why?



The 10 th, 30 th, 50 th, 70 th, 90 th percentile benchmarks are				
10 th	30 th	50 th	70 th	90 th
346.56 MJ/m^2/annum	630.11 MJ/m^2/annum	826.50 MJ/m^2/annum	1022.89 MJ/m^2/annum	1306.44 MJ/m^2/annum

(Source: www.emsd.gov.hk)

Practical Applications

- Applications of energy benchmarking
  - Energy performance contracting (EPC)
    - Contract with an energy service company (ESCO)
    - ESCO will evaluate energy-saving opportunities and guarantee that savings to cover project costs
    - Energy codes are often used as a baseline level
  - Building environmental performance assessment
    - Energy is often the key component
    - Use building energy codes as reference since they are commonly known/agreed

Further Reading

- Guides from ETSU, UK (can be downloaded from course website)
  - Good Practice Guide No. 231: Introducing Information Systems for Energy Management
  - General Information Leaflet 50: Energy Saving in Buildings – Methods for Quickly Identifying Opportunities
  - Introduction to Energy Efficiency in Offices

Further Reading

- Articles on Energy Information System (EIS):
  - Motegi, N. and Piette, M. A., 2002. *Web-based Energy Information Systems for Large Commercial Buildings*, LBNL.
  - Motegi, N., Piette, M. A., Kinney, S. and Dewey, J., 2003. Case studies of energy information systems and related technology: operational practices, costs, and benefits
  - Ruffing, C. J. (Eastman Kodak Company), 2010. Energy information system a key to driving savings, *Environmental Leader (Energy & Environmental News for Business)*, August 3, 2010.