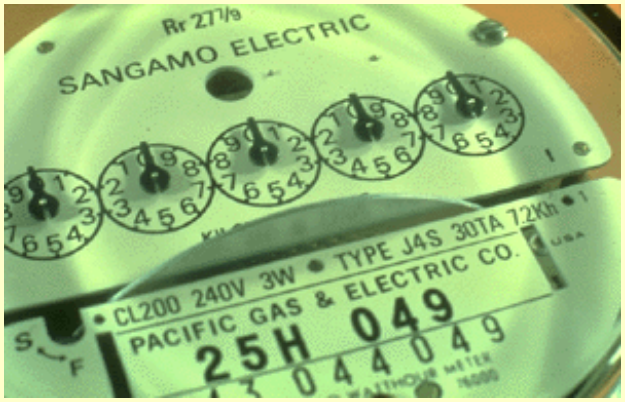
Young Members Group of CIBSE Hong Kong Branch

Technical Seminar (18 May 2007)



Basic Energy Management in Buildings

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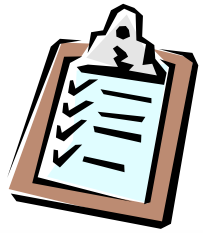
Contents



- Energy Basics
- Energy Use in Buildings
- Energy Policy and Codes
- Building Operation and Energy Management
- Financial Aspects

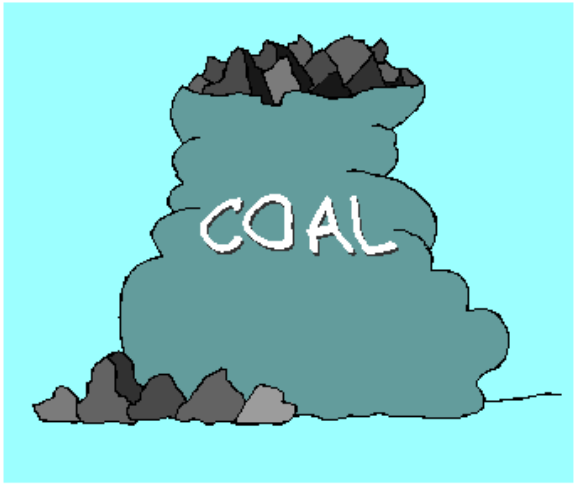
Energy Basics

Energy Basics

- Units of energy
  - Kilowatt-hour (kWh), 1 kWh = 3.6×10^6 joule
    - 1 kWh = 3.6 MJ = 860 kcal = 3412 Btu
  - British thermal unit (Btu), 1 Btu = 1.055×10^3 J
  - Therme (gas industry), 1 therme = 100 000 Btu
  - Tonne of oil equivalent (toe), 1 toe = 4.5×10^{10} J
    - From oil industry
  - Calorie, 1 calorie = 4.2×10^3 J
- Power unit:
  - 1 W = 1 J/s = 0.86 kcal/h = 3.41 Btu/h

Energy Basics

- Forms of energy:
  - Electricity
  - Natural gas, town gas, liquified petroleum gas (LPG)
  - Oil products
  - Coal
  - Renewable energy (e.g. solar, wind)
- Energy end-use:
  - Air-conditioning, ventilation, lighting, equipment, hot water, and industrial processes



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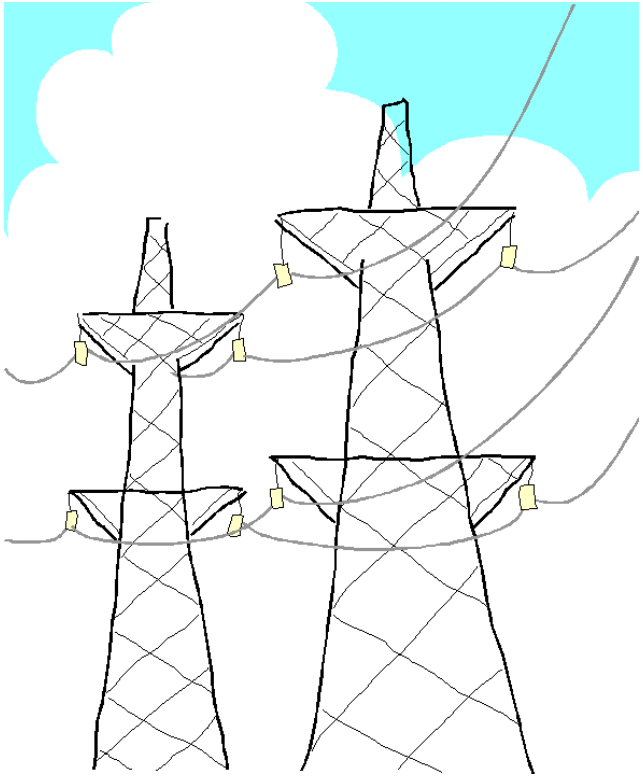
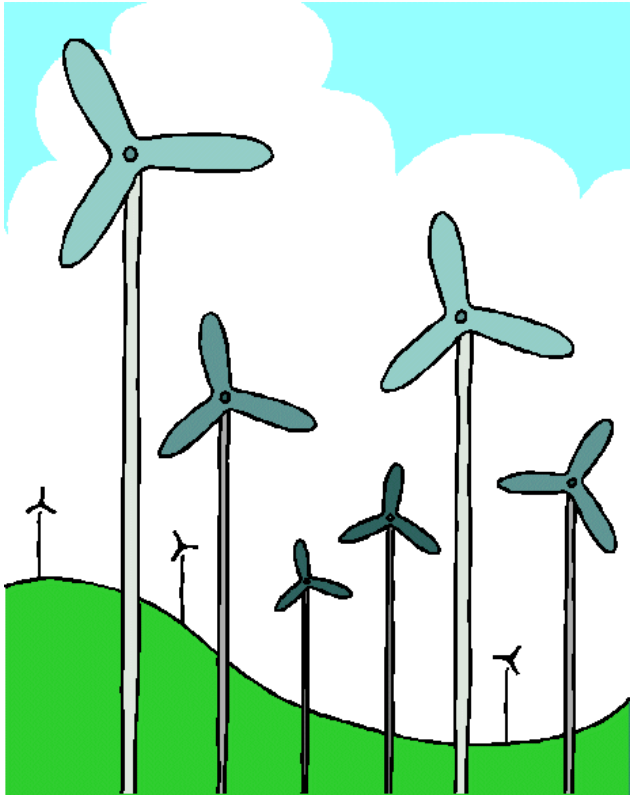
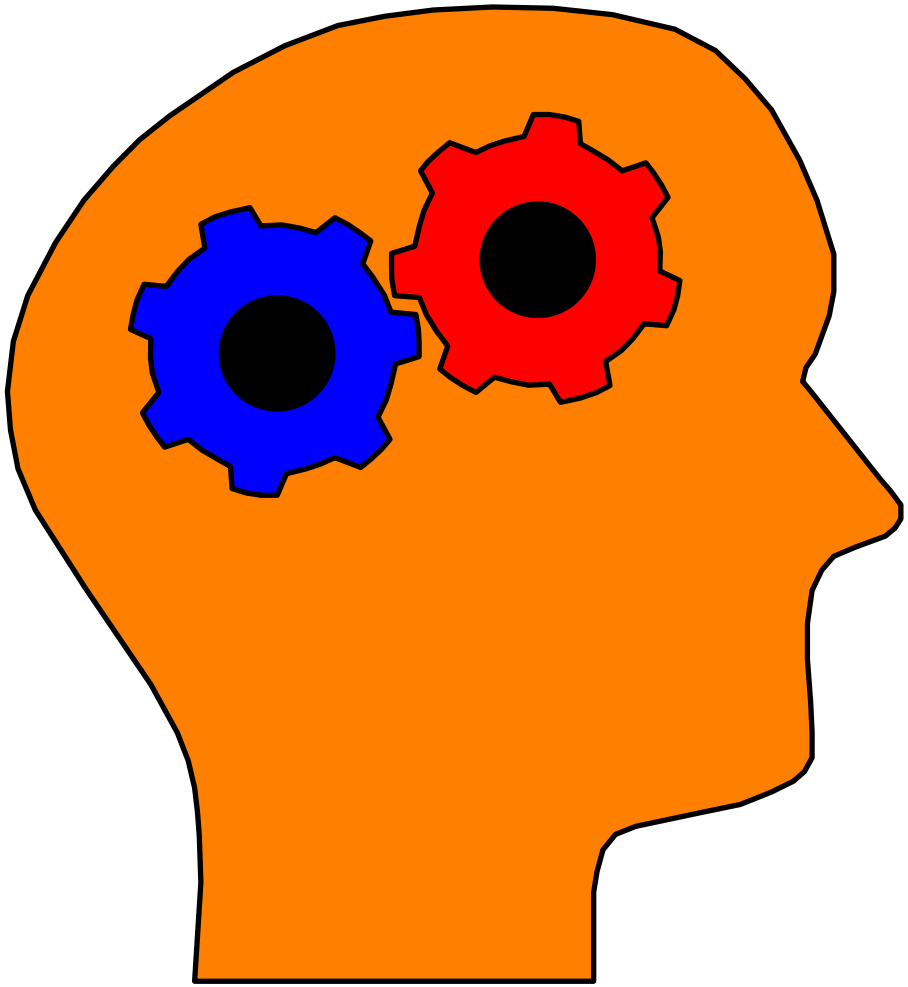




QUIZ



The average prices (HK$) of electricity and towngas in Hong Kong are (Year 2005):

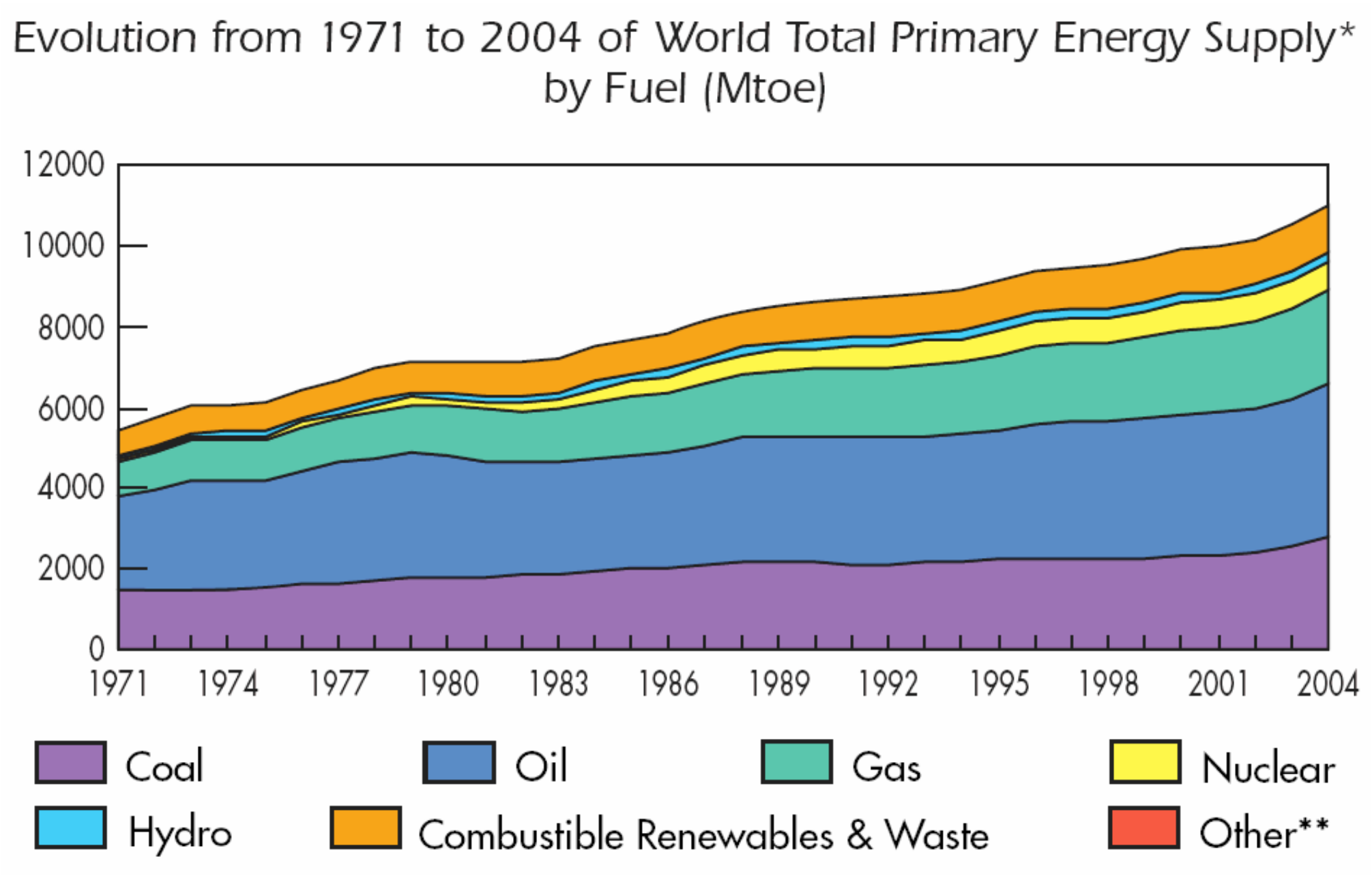
A. Elec. = $0.9/kWh (CLP) Towngas = $0.25/MJ	B. Elec. = $1.9/kWh (CLP) Towngas = $0.11/MJ
C. Elec. = $1.9/kWh (CLP) Towngas = $0.25/MJ	D. Elec. = $0.9/kWh (CLP) Towngas = $0.11/MJ

Energy Basics

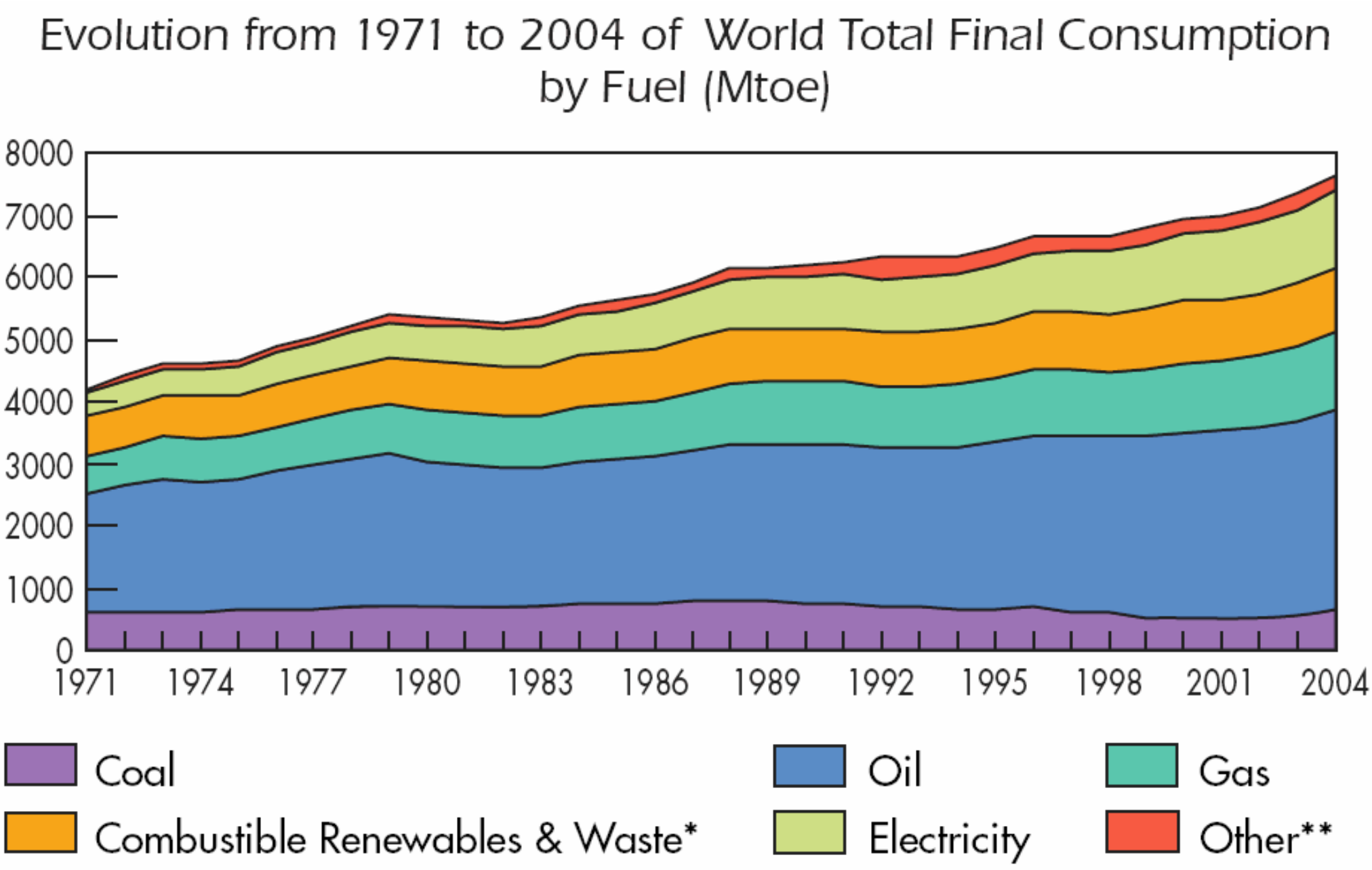
- **Energy** is important to every society
  - Economic, environmental & social impacts
  - It is also a key issue for ***sustainable development***
- Use energy …
  - Consume finite fossil fuels (oil, coal, natural gas)
  - Cause air pollution & environmental damage
  - Contribute to global warming
  - Cost money

Energy Basics

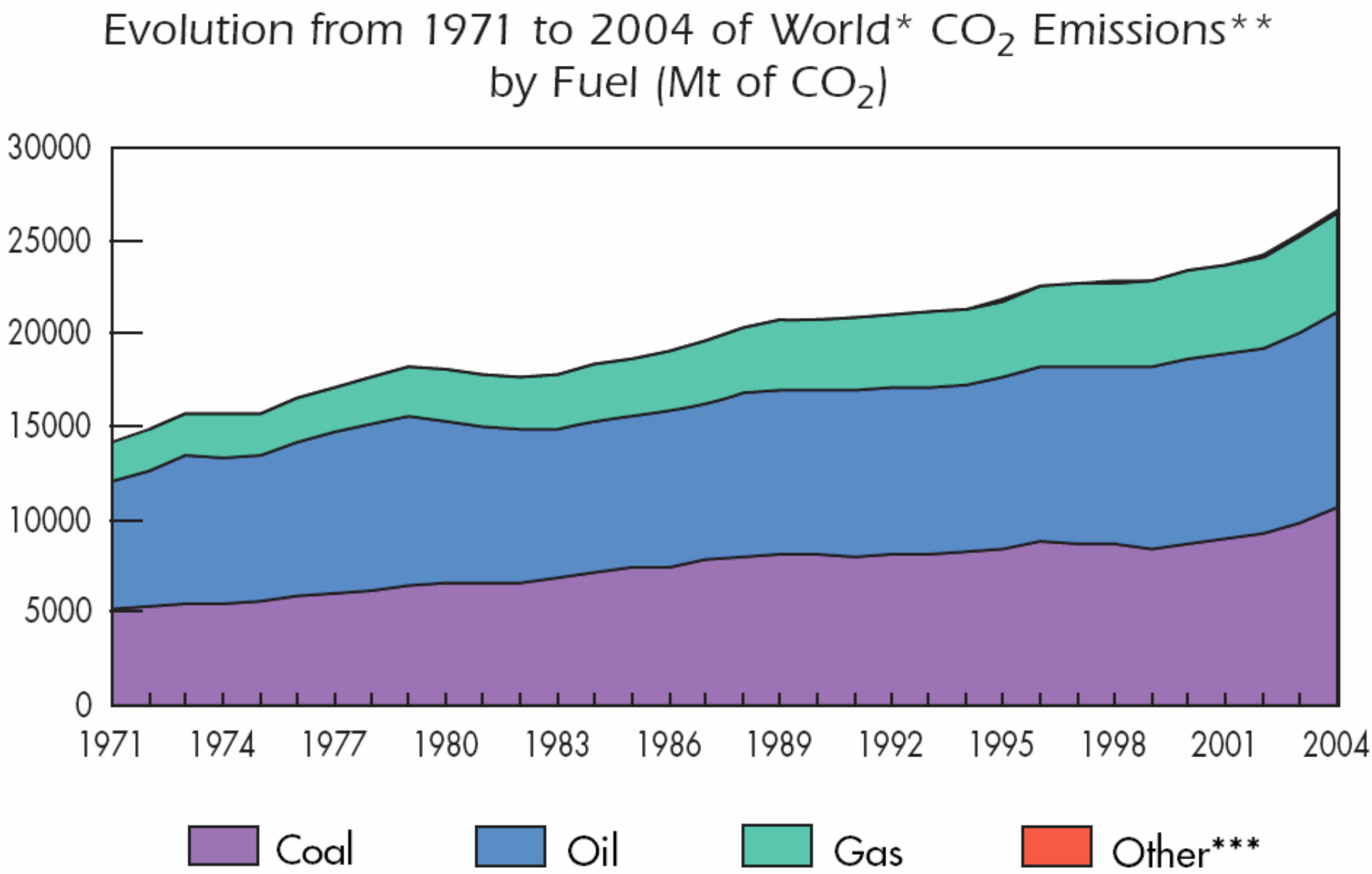
- History of energy issues in the modern world
  - **1970s** (oil crises): to preserve supplies of what were thought to be scarce fuels
  - **1980s**: emphasize on cost effectiveness of energy efficiency (drop in oil price)
  - **1990s**: to reduce the impact of energy use on the environment (esp. control greenhouse gases)
  - **2000s**: to achieve sustainable energy future



(* Source: IEA, 2006. *Key World Energy Statistics 2006*, International Energy Agency, Paris.)



(* Source: IEA, 2006. *Key World Energy Statistics 2006*, International Energy Agency, Paris.)



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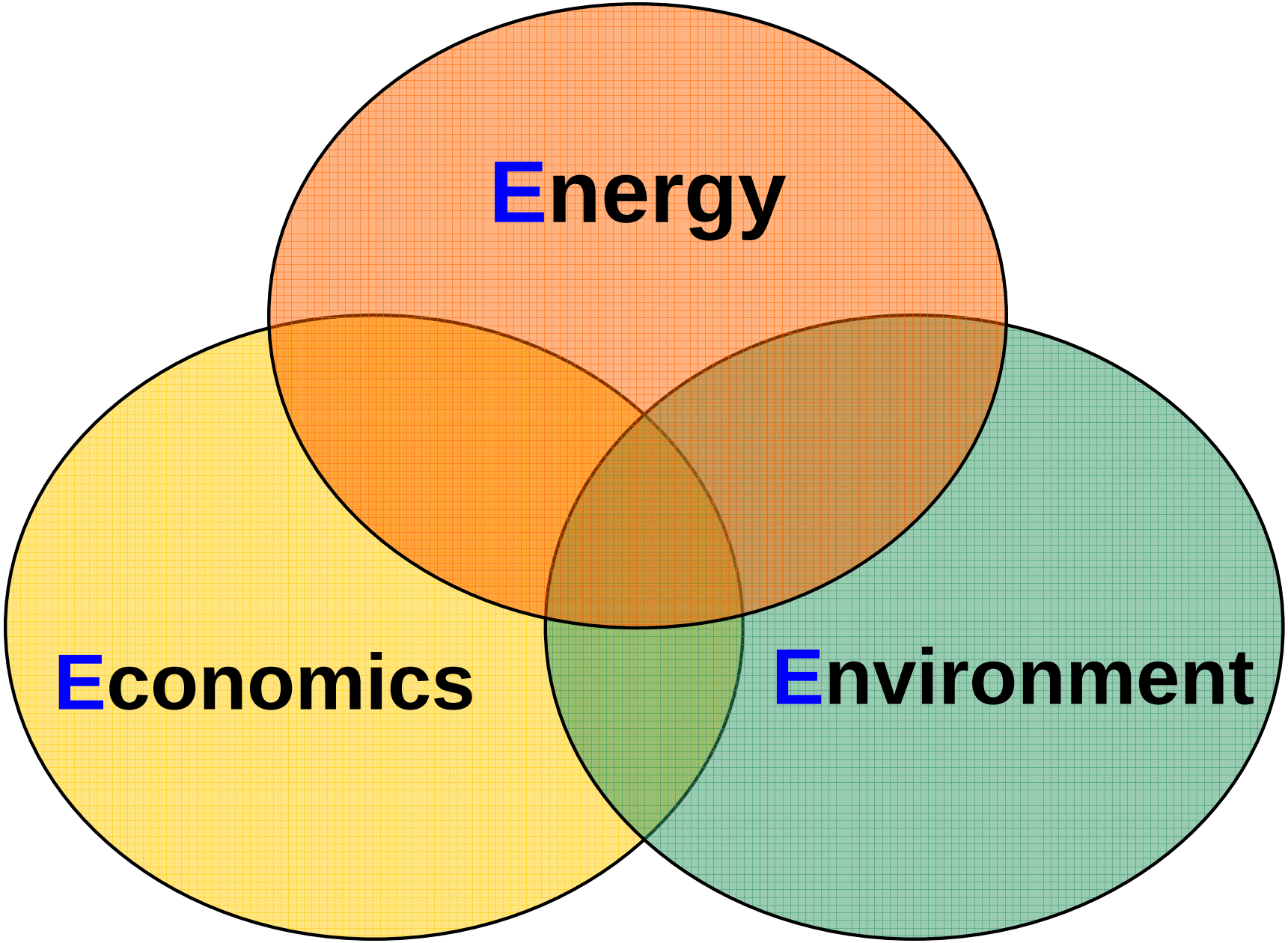
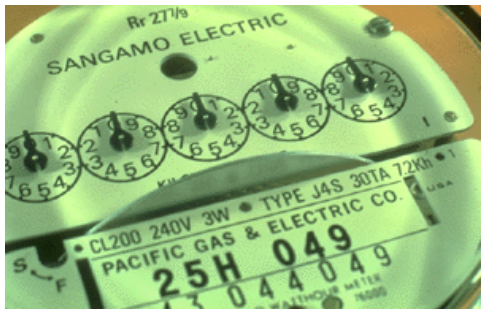


Energy Basics

- The need for energy management
  - Economics
    - Energy costs and operating costs
  - Environment
    - Climate change, global warming, air pollution
  - Energy security
    - Energy supply (political and economic reasons)
  - Resources depletion
    - Oil, gas and coal will be used up



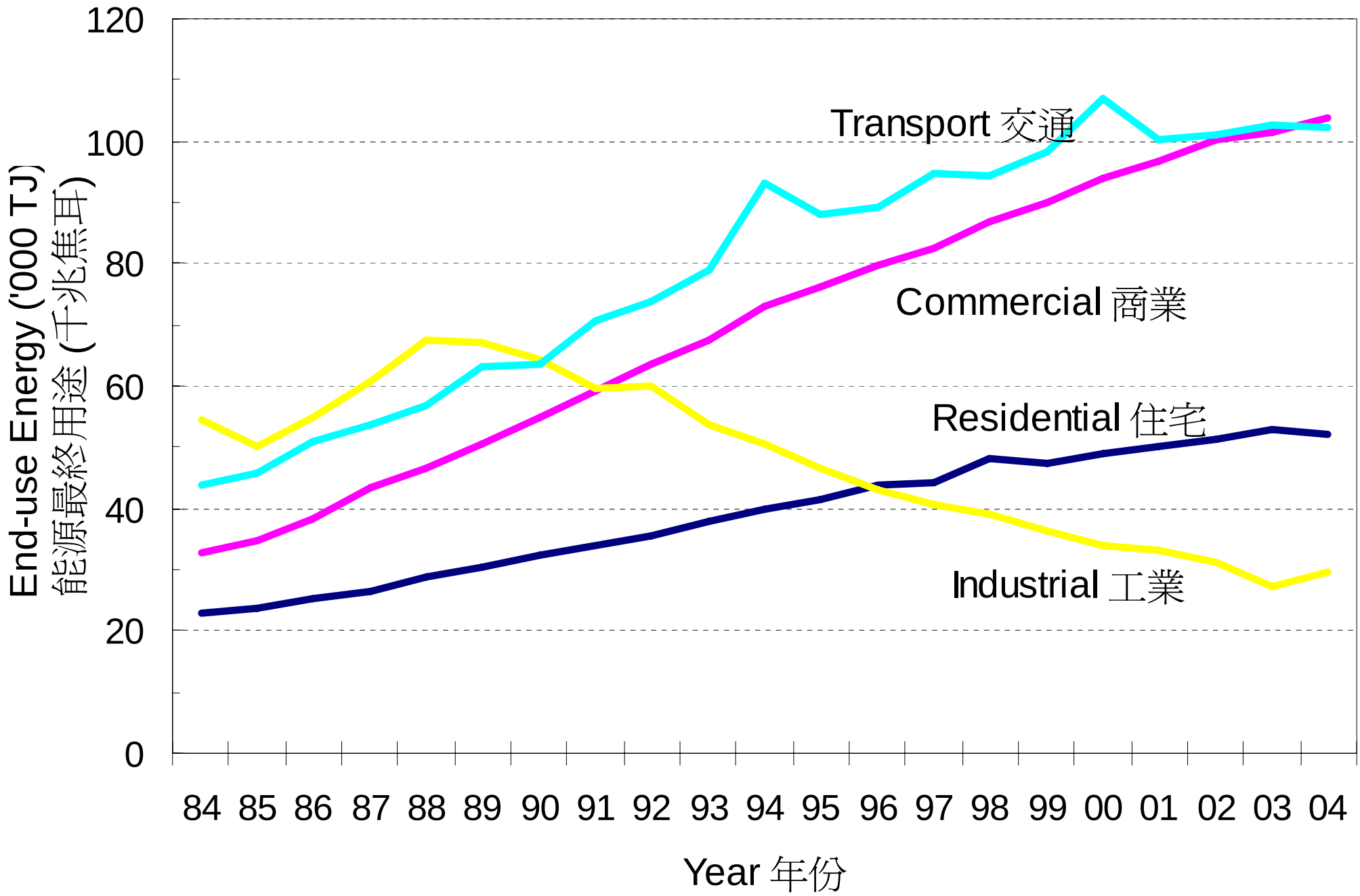
Energy Use in Buildings

Energy use in buildings

- Buildings constitute 30-50% of energy needs
  - Residential + commercial + industrial
  - The potential for energy saving is large
- The real cost of energy
  - Energy price
  - Environmental costs or externalities
    - e.g. $$ for pollution control & “repairing” of environmental damages
  - Need to internalise the externalities

Energy use in buildings

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

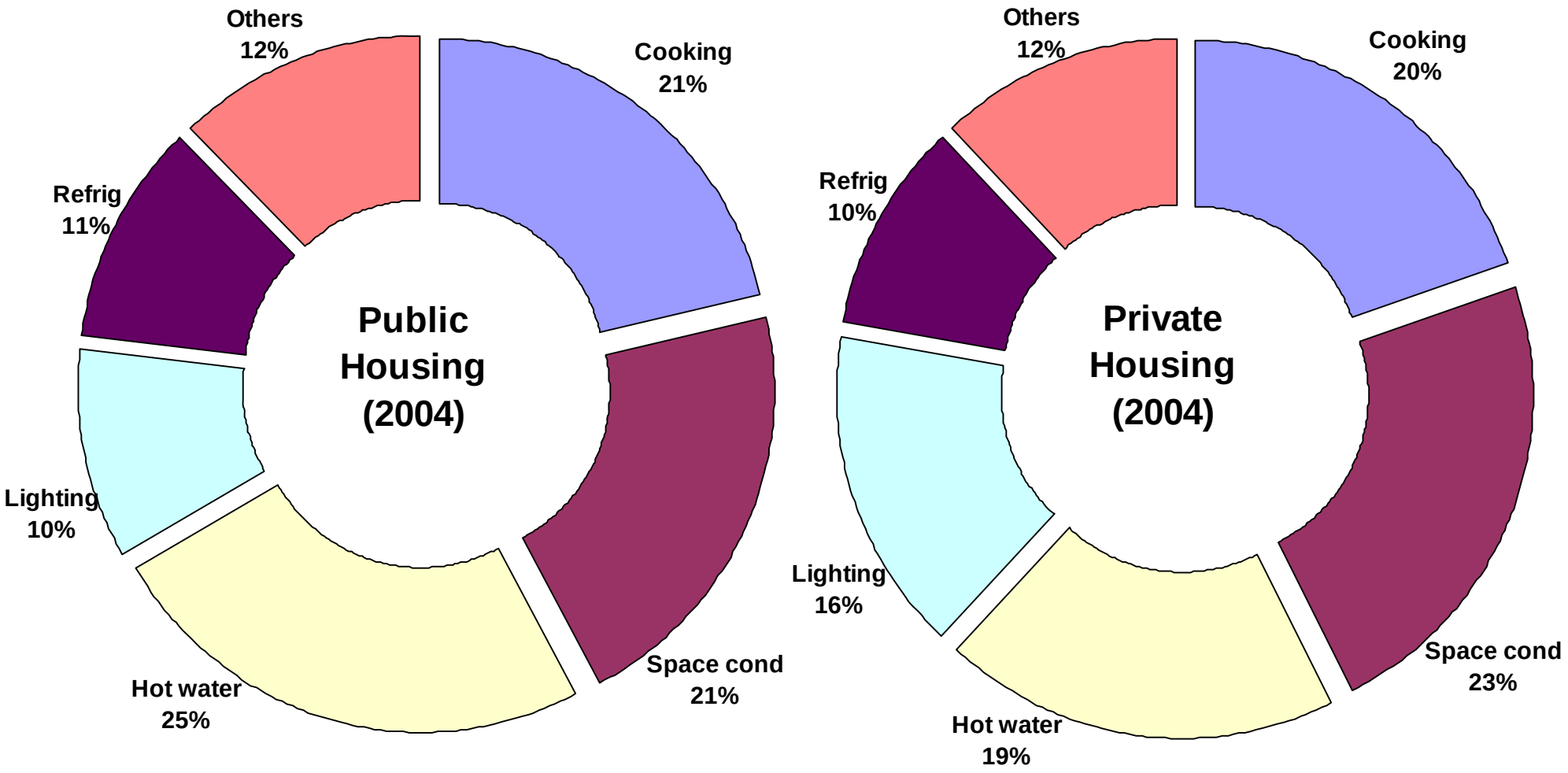


Energy end-use in Hong Kong by sectors, 1984-2004

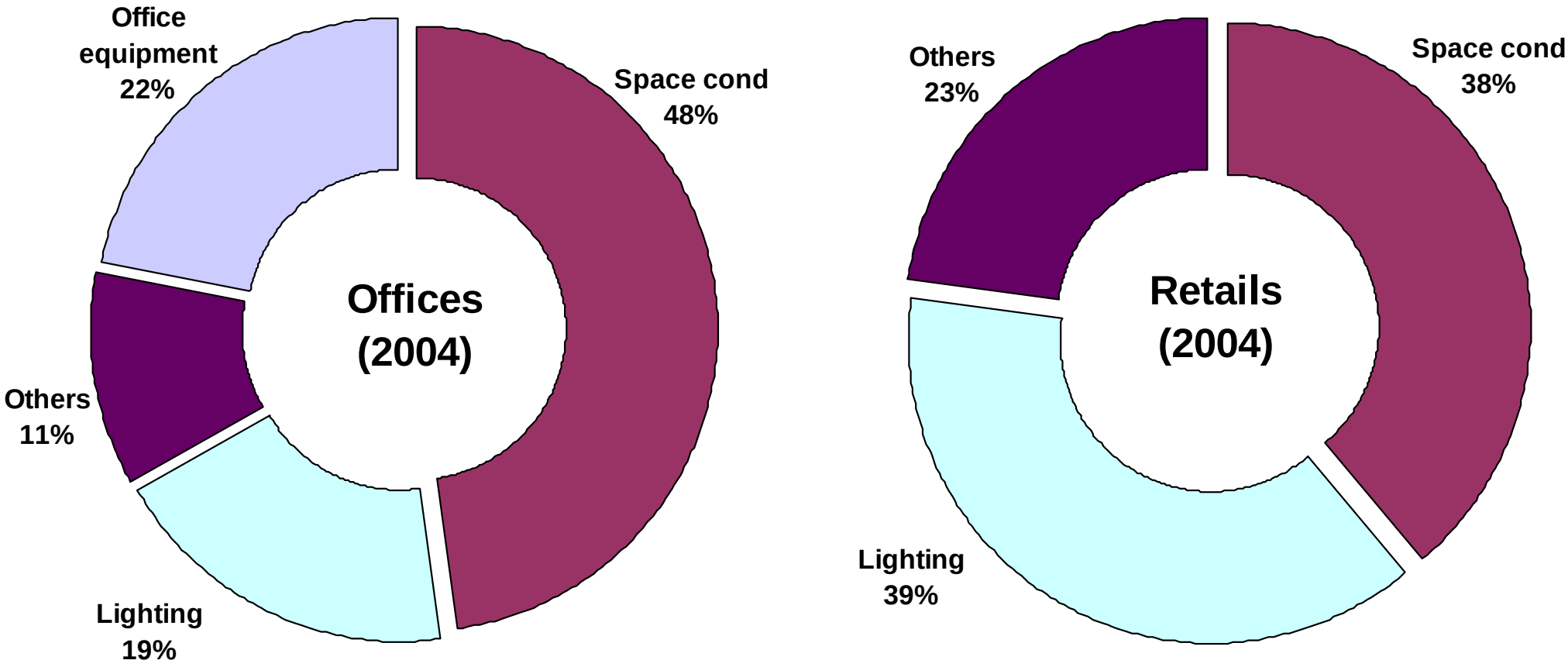
Table 1 - Final energy requirements (FER) in Hong Kong (year 2005)

Unit: MJ	**Commercial**	**Residential**	**Industrial**	**Total**
Electricity	93 724 (65%)	35 811 (25%)	14 636 (10%)	144 172 (100%)
Town gas	10 919 (40%)	15 444 (57%)	898 (3%)	27 261 (100%)
Elec. + town gas	104 643	51 255	15 534	171 433
% in total FER	31.5%	15.5%	4.7%	51.7%

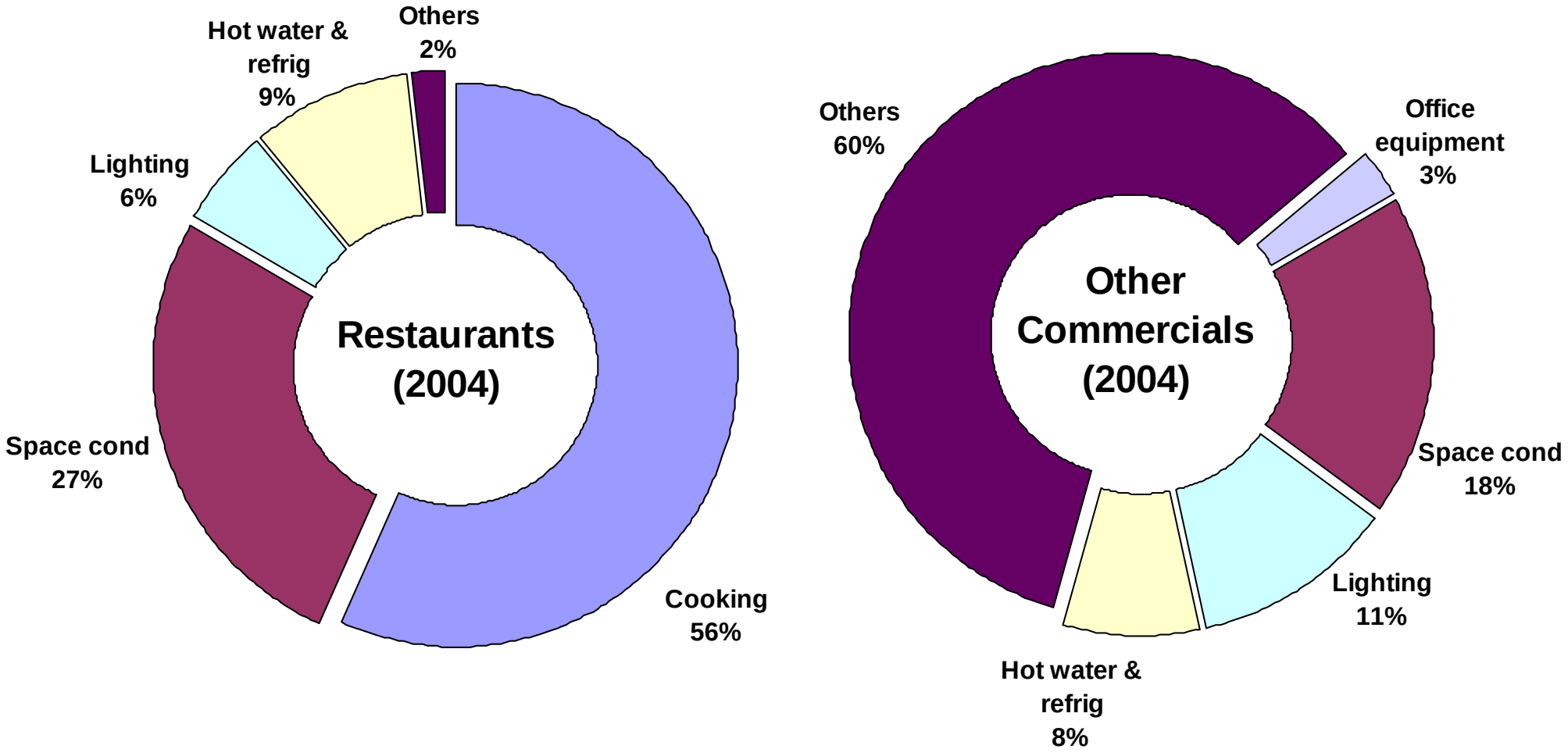
(* Source: *Hong Kong Energy Statistics 2005 Annual Report*)



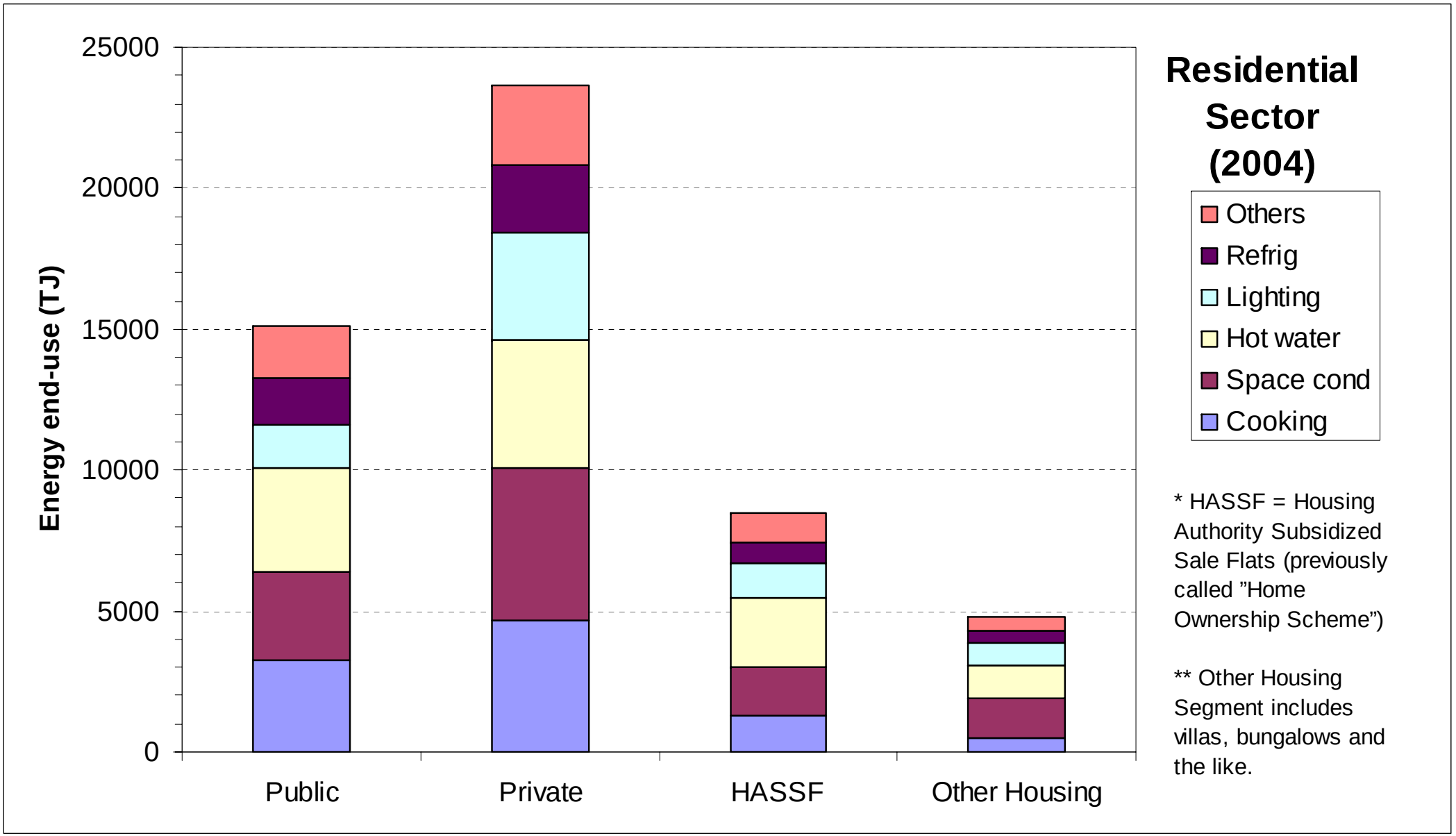
Energy consumption patterns in residential buildings
(Data source: Energy Efficiency Office, HK)



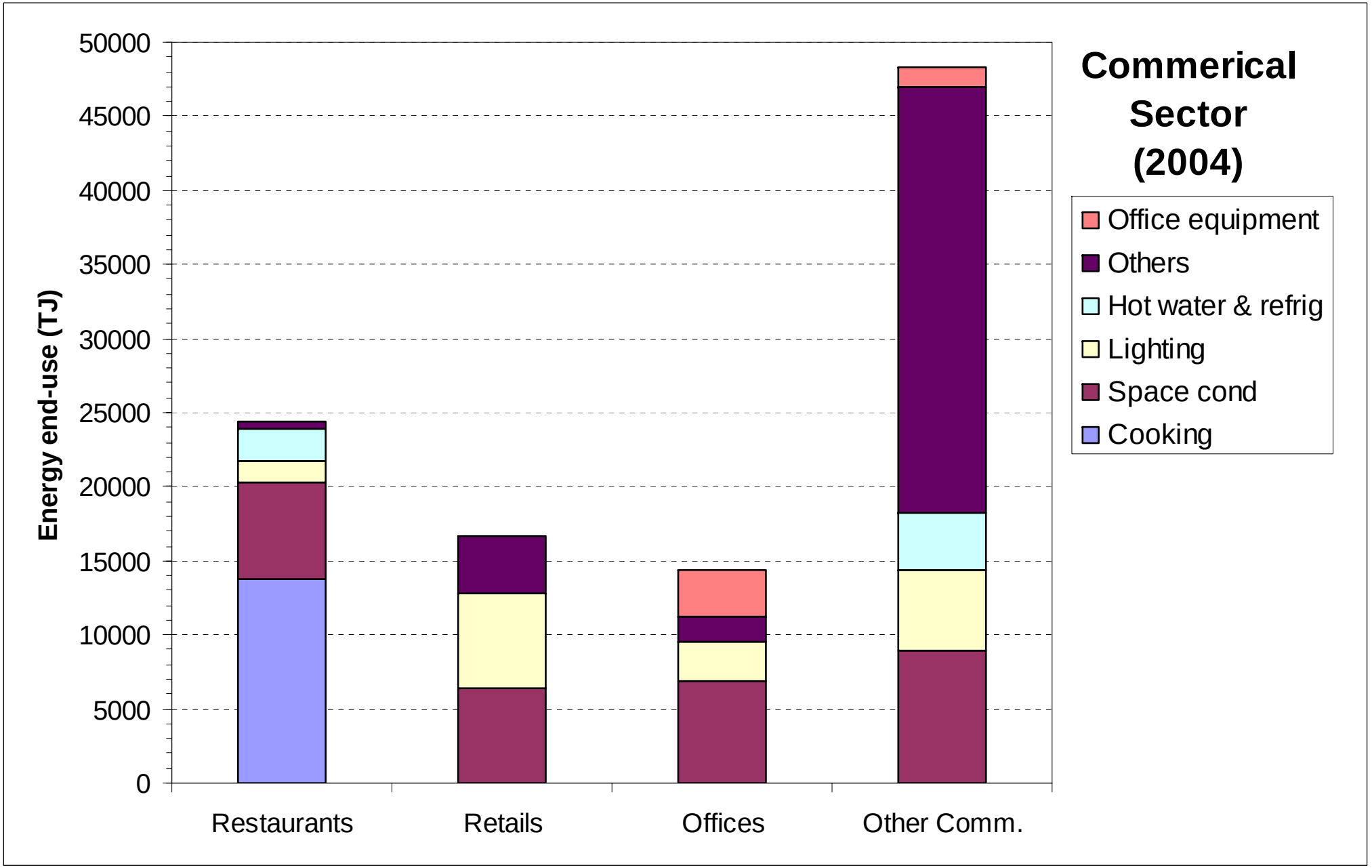
Energy consumption patterns in offices and retails
(Data source: Energy Efficiency Office, HK)



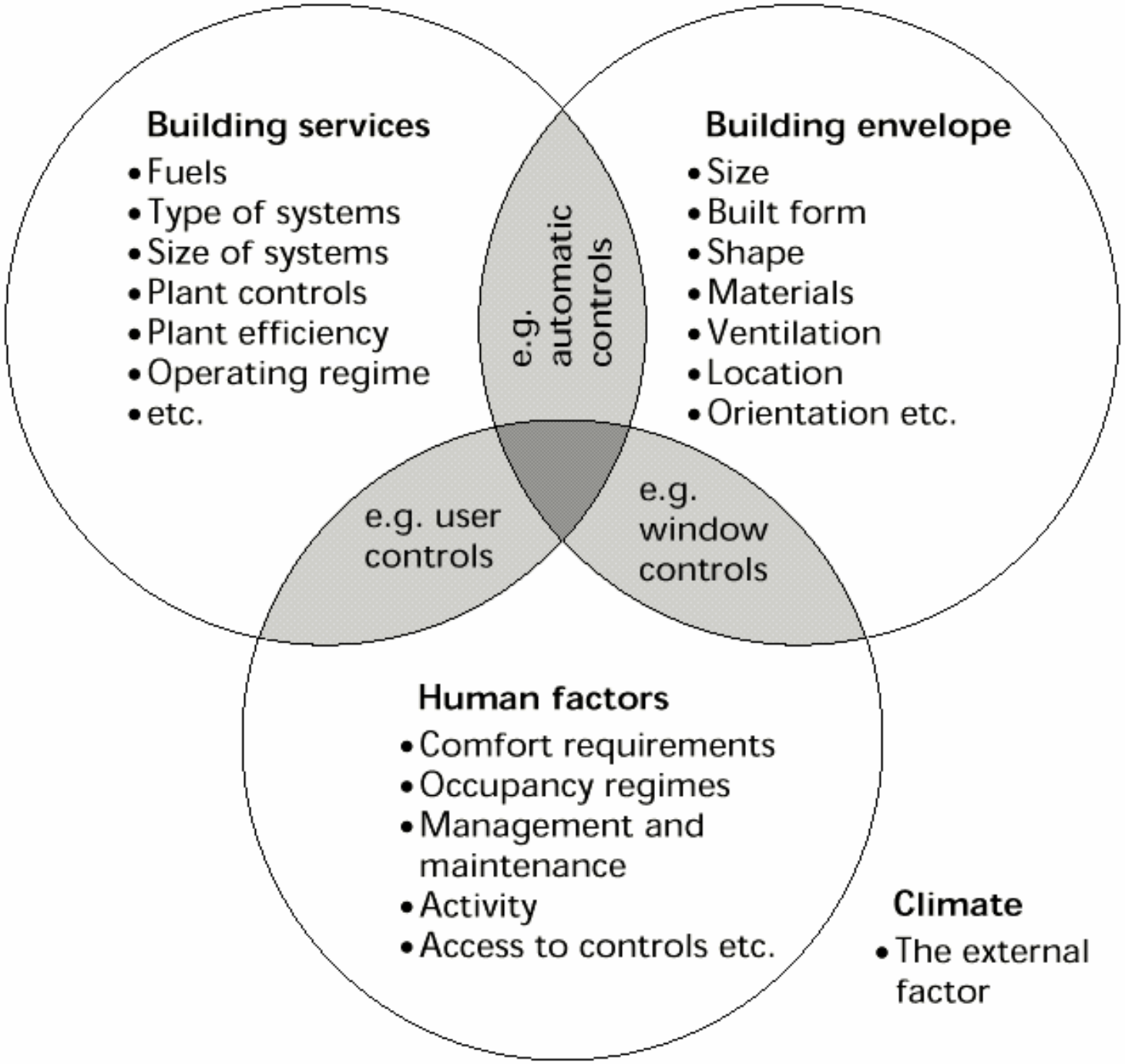
Energy consumption patterns in other commercial buildings
(Data source: Energy Efficiency Office, HK)



Energy end-use in residential sector, 2004
(Data source: Energy Efficiency Office, HK)

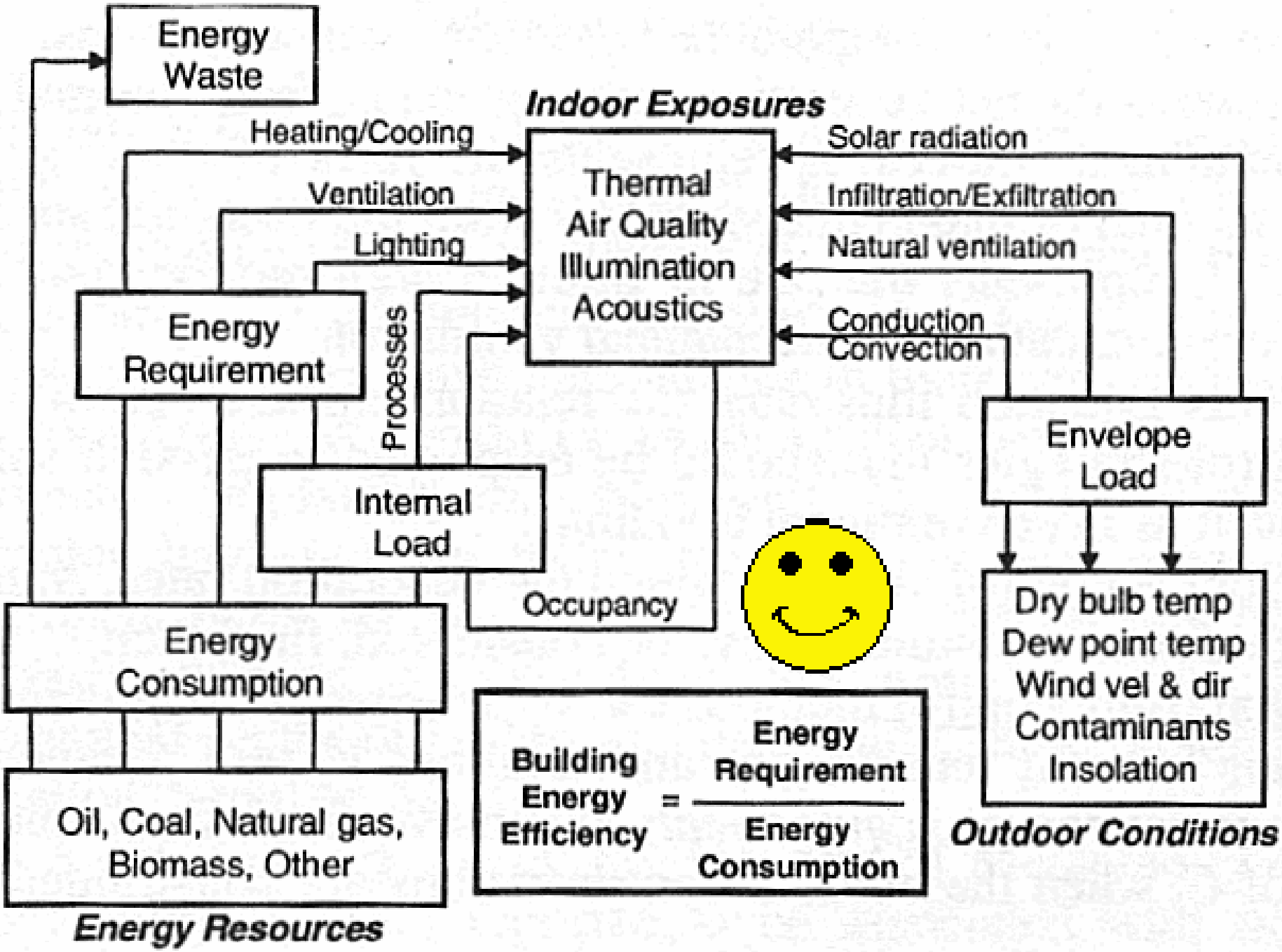


Energy end-use in commercial sector, 2004
(Data source: Energy Efficiency Office, HK)



Key factors influencing energy consumption

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



Energy flow and concept in buildings

Good design practices

Integrated & total energy approach

Efficient systems

Good house-keeping

User education & awareness

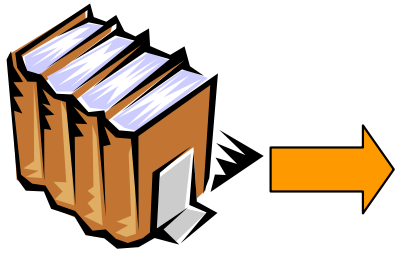
Efficient operation

Energy Policy and Codes

Energy Policy and Codes

- Energy efficiency matters is affected by policy and regulatory issues
  - Thus, we need to understand the social, economic and political context of them
- Government's role is important for stimulating the market and promoting long-term benefits
  - Legislative control (by codes) and guidance
  - Financial and tax incentives
  - Administrative measures and information

Important energy sector



Building Energy Codes

Energy Efficiency
- Buildings
- Industries
- Transport
- Appliance
- Utilities
- Energy management

Energy Supply
- Coal
- Oil
- Natural gas
- Nuclear
- Electricity
- Renewable energy

Energy Resources
- Coal
- Oil
- Natural gas
- Nuclear energy
- Renewable energy

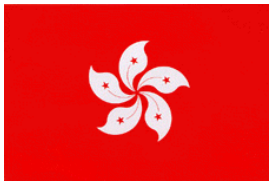
Other Issues
- Energy security
- Energy and environment
- Energy economics

Building sector in the overall energy policy

Energy Policy and Codes

- Building Energy Codes (*BEC*)
  - Set out energy consumption objectives
  - Form part of the energy policy
  - Control building design and/or operation
- Energy audit requirements (in some countries)
  - Essential for existing buildings
- Energy management programmes
  - Promote good practices in design and operation

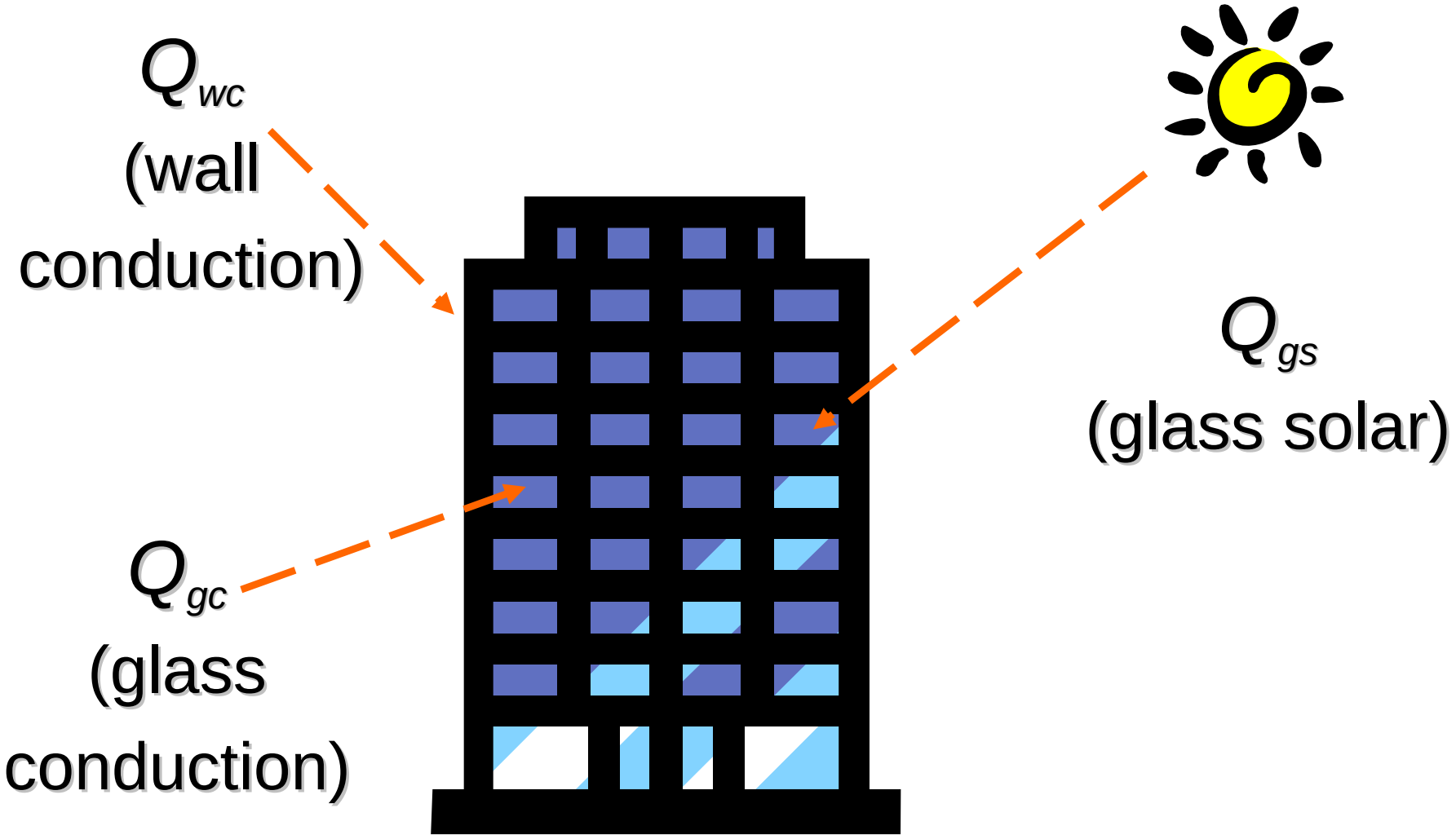
Energy Policy and Codes



- Energy policy of Hong Kong
  - Indicated by the Economic Services Bureau
  - Main objectives:
    - To ensure the *energy needs* of the community are met efficiently, safely and at reasonable prices;
    - To minimise the *environmental impact* of energy production and promote efficient use and conservation of energy
  - Free market philosophy is adopted
    - Proactive and non-intervening (積極不干預)

Energy Policy and Codes

- First energy efficiency regulation in HK
  - *Building (Energy Efficiency) Regulation*, Cap. 123 sub. Leg. M [implemented in July 1995]
    - http://arch.hku.hk/research/BEER/bee-reg.htm
  - Using Overall Thermal Transfer Value (OTTV) method for building envelope design control
    - http://www.info.gov.hk/bd/english/documents/code/e_ottv.htm
  - Applied mainly to commercial buildings and hotels; requirements revised in 2000
    - Building tower: OTTV $\leq$ 30 W/m^2; podium: OTTV $\leq$ 70 W/m^2



$$OTTV_i = \frac{Q_{wc} + Q_{gc} + Q_{gs}}{A_i}$$

$$= \frac{(A_w \cdot U_w \cdot TD_{eq}) + (A_f \cdot U_f \cdot DT) + (A_f \cdot SC \cdot SF)}{A_i}$$

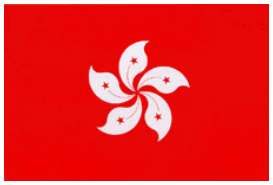
Energy Policy and Codes

- OTTV equation for Hong Kong:

$$OTTV_i = \frac{(A_w \cdot U_w \cdot \alpha \cdot TD_{eq}) + (A_f \cdot SC \cdot ESM \cdot SF)}{A_i}$$

- Two major differences from the general form:
  - Glass conduction term was omitted
  - Solar absorptivity and external shading multipler were introduced

Energy Policy and Codes



- HK building energy codes (voluntary)
  - Lighting
  - Air-conditioning
  - Electrical
  - Lifts & escalators
  - Performance-based code (using total-energy-budget approach)
- Put under the Hong Kong Energy Efficient Building Registration Scheme (HKEEBRS)

Building energy codes in Hong Kong

Energy Code	Date Implemented	Scope
OTTV	Jul 1995 (Mandatory)	Comm bldgs & hotels
Lighting	Jul 1998 (Voluntary)	All bldgs except domestic, indust. & medical
Air conditioning	Jul 1998 (Voluntary)	All bldgs except domestic, indust. & medical
Electrical	Feb 1999 (Voluntary)	All buildings
Lifts & escalators	Dec 1999 (Voluntary)	All buildings
Performance-based code	2004 (Voluntary)	Comm bldgs & hotels

Building Operation and Energy Management

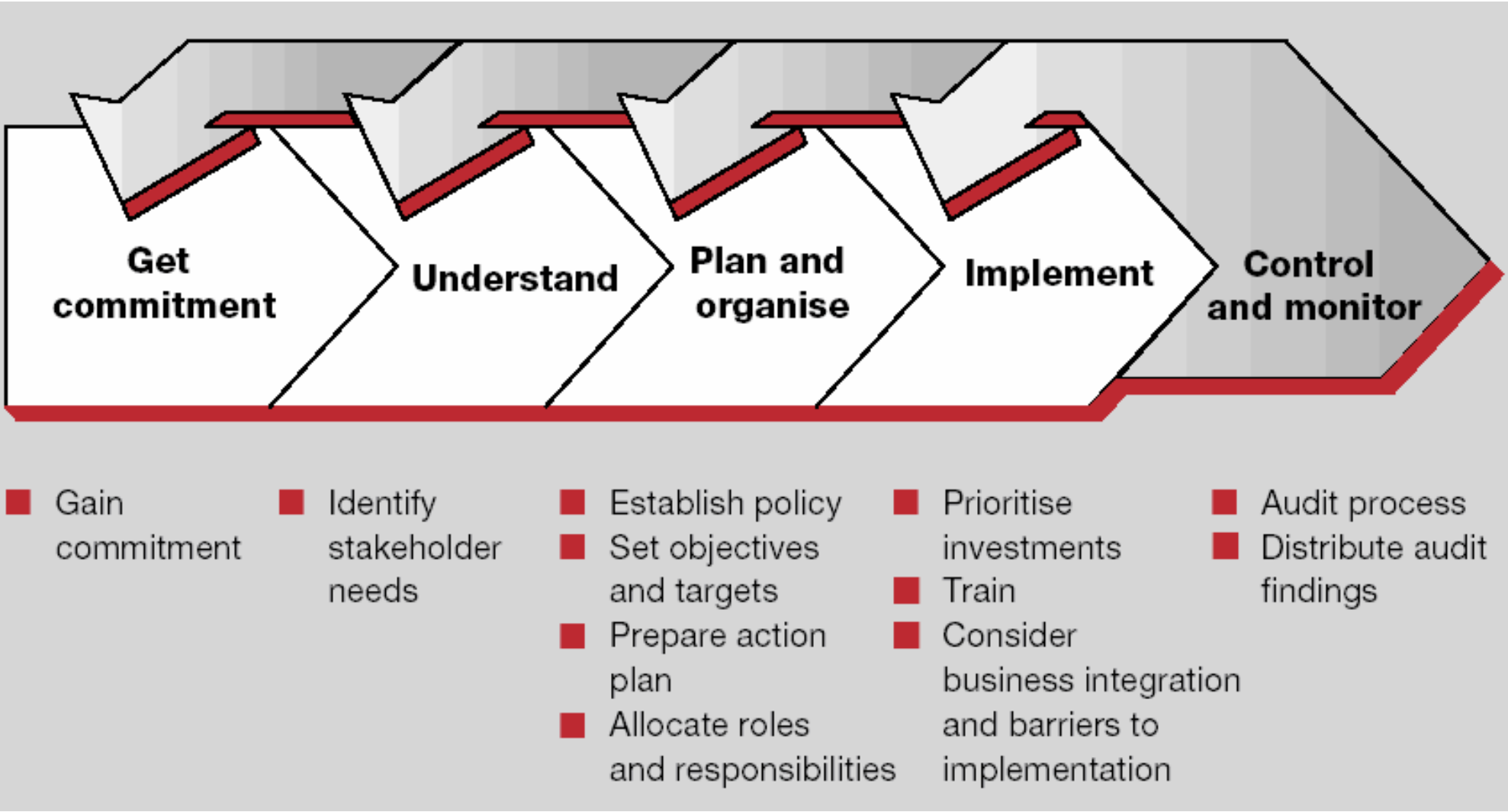
Energy Management

- Energy efficiency
  - It is greatly affected by building management, operation and maintenance
  - Key to energy efficient mgt. 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

Energy Management

- Energy management matrix (see Figure)
  - Energy policy
  - Organising
  - Motivation
  - Information systems
  - Marketing
  - Investment
- Performance levels: 0, 1, 2, 3, 4

A systematic approach to energy management



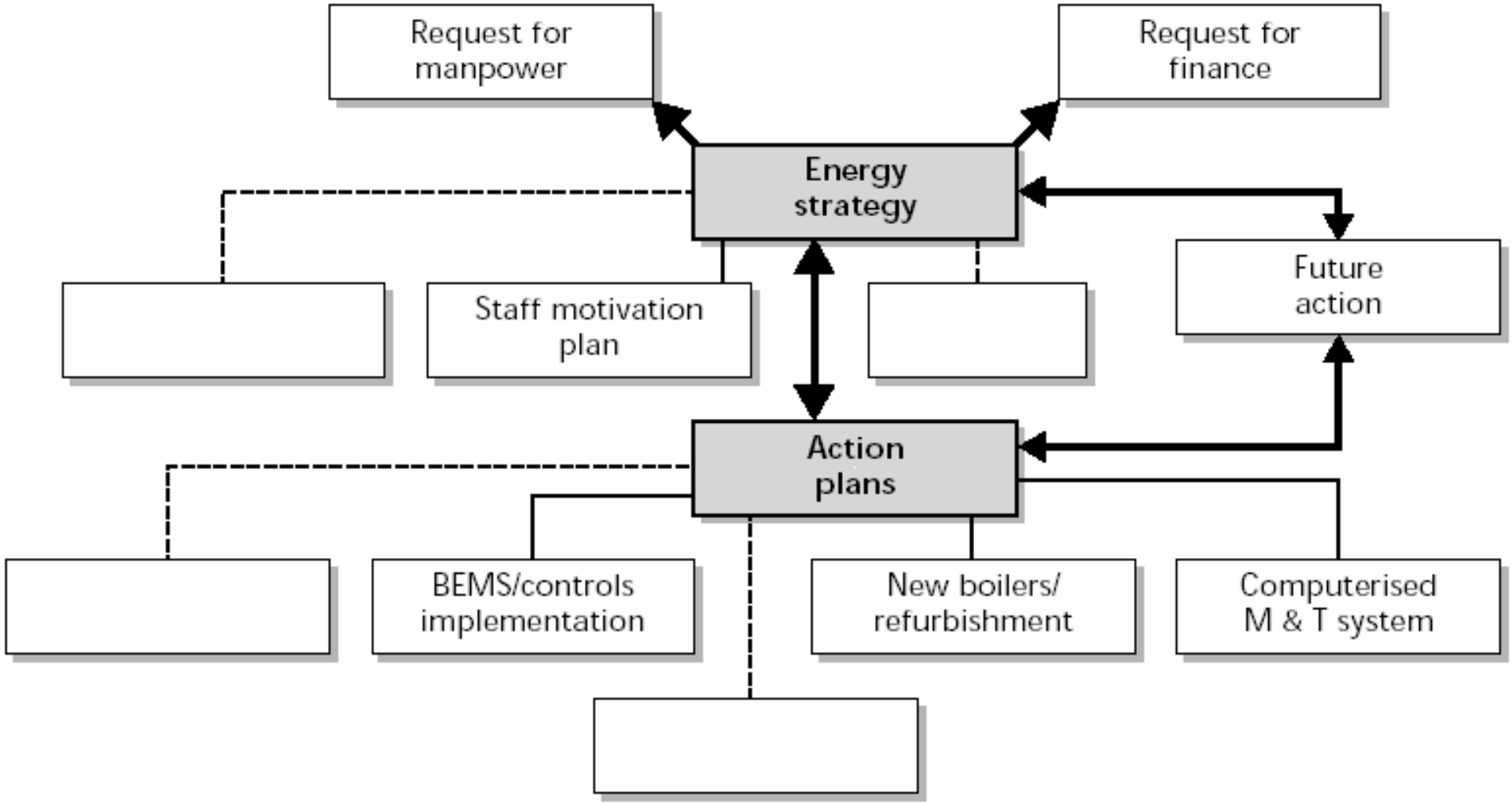
Energy Management

- Understand the building
  - Gain a strategic overview of the design intent
    - From O&M manuals, drawings, surveys & inspection
  - Ensure that the building is well documented
    - Such as the idea of "building log book"
  - Identify the current status of the building
    - Through overall & specific performance indicators
    - Detailed assessments, audits & surveys
  - Identify and address problem areas (e.g. controls)

Energy Management

- Set up energy policy to
  - Establish senior management commitment
  - Improve overall approach to energy management
  - Help to keep the main objectives in full view
  - Maximise the use of resources (time and money)
  - Provide goals against which to monitor
  - Provide a clear direction for the energy team
  - Give senior management a way forward

A framework for developing energy policy



Energy Management

- Management structures
  - Responsibility and reporting lines
    - Line managers accountable for their own energy use
  - Roles and activities
    - Senior management, energy manager, general staff
  - Obtaining resources
    - Financial investment
    - Manpower Investment

Energy Management

- Management structures (cont'd)
  - Sub-contracting energy management
    - Specialist consultants
    - Contract energy management (CEM) companies
      - Also called energy services companies (ESCO)
    - Contract facilities management
  - Purchasing policy
    - Energy
    - External contracts (out-sourcing)
    - Office equipment & high-efficiency motors

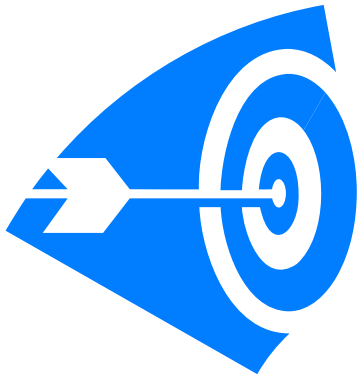
Energy Management

- Occupant involvement
  - Motivation and training
    - Managing PEOPLE
  - Occupant satisfaction
    - Comfort, health and safety of the occupants
    - Securing understanding and involvement of occupants

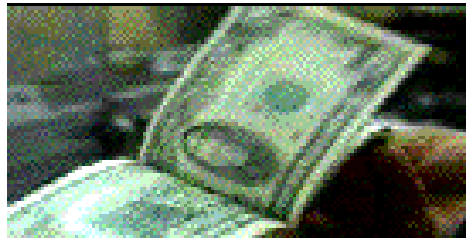
Financial Aspects

Financial Aspects

- Purpose of financial appraisal
  - To determine which investments, among all the possibilities, make the best use of the money
  - To ensure optimum benefits from each investment
  - To minimise risk to the enterprise
  - To provide a basis for subsequent analysis of performance of the investment



Financial Aspects



- Six key steps of financial appraisal of energy efficiency investment in buildings
  - Locate the buildings which have the potential
  - Identify the area where a saving can be made & identify the measures required to release it
  - Establish the costs & the savings for each measure & calculate the key financial indicators
  - Optimise the financial return
  - Establish how much investment capital is available & identify new sources of capital
  - Decide which projects make best use of the capital

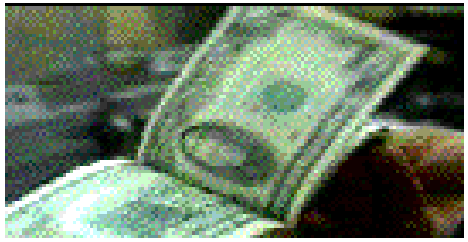
Financial Aspects

- Review using the financial energy management matrix (FEMM) (see diagram)
  - Identifying opportunities
  - Exploiting opportunities
  - Management information
  - Appraisal methods
  - Human resources
  - Project funding
- Mark on the levels & construct the profile

	Identifying Opportunities	Exploiting Opportunities	Management Information	Appraisal Methods	Human Resources	Project Funding
4	Detailed energy surveys are regularly updated. A list of high and low cost opportunities already fully costed and ready to proceed immediately.	Formal requirement to identify the most energy efficient option in all new build, refurbishment and plant replacement projects. Decisions made on basis of life-cycle costs.	Full management information system enabling identification of past savings and continuous opportunities for investment meeting organisation's financial parameters.	Full discounting methods using internal rates of return and ranking priority projects as part of an ongoing investment strategy.	Board take a proactive approach to a long-term investment programme as part of a detailed environmental strategy in full support of Energy Manager and team.	Projects compete equally for funding with other core business investment opportunities. Full account taken of benefits which do not have direct cost benefit, eg marketing opportunities, improved working conditions.
3	Energy surveys conducted by experienced staff or consultants in buildings likely to yield largest savings.	Energy staff are required to comment on all new build, refurbishment and plant replacement projects. Energy efficiency options often approved, but no account is taken of life-cycle costs.	Promising proposals get presented to decision makers, but insufficient information (eg for sensitivity analysis) results in delays and rejections.	Discounting methods using the organisation's specified discount rates.	Energy Manager working well with accounts/finance to present well argued cases to decision makers.	Projects compete for funding from capital budget along with other business opportunities, but have to meet more stringent requirements for return on investment.
2	Regular energy monitoring/analysis identifies possible areas for saving.	Energy staff are notified of project proposals which have obvious energy implications. Proposals for most energy efficient solutions vulnerable when capital costs need to be reduced.	Adequate management information available, but not in correct format or easily accessed in support of energy saving projects.	Undiscounted appraisal methods used, eg gross return on capital.	Occasional proposals to decision makers by Energy Manager with limited success and only marginal interest from decision makers.	Energy projects not normally considered for funding from capital budget, except when very short-term returns are evident.
1	Informal, ad hoc energy walkabouts conducted by staff with checklists in the hope of identifying energy saving measures.	Energy staff use informal contacts to identify projects where energy efficiency can be improved at marginal cost. Proposals routinely rejected to reduce capital cost.	Insufficient information to demonstrate whether previous investment in energy efficiency has been worthwhile.	Simple payback criteria is applied.	Responsibility unclear and those involved lack time, expertise and resources to identify projects and prepare proposals.	Funding only available from revenue on low risk projects with paybacks less than one year.
0	No mechanism/ resources to identify energy saving opportunities.	Energy efficiency not considered in new build, refurbishment and plant replacement decisions.	Little or no information available to develop a case for funding.	No method used irrespective of the attractiveness of project.	No one in organisation promoting investment in energy efficiency.	No funding available for energy projects. No funding in the past.

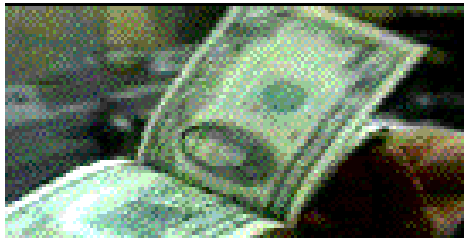
Financial Energy Management Matrix

Financial Aspects



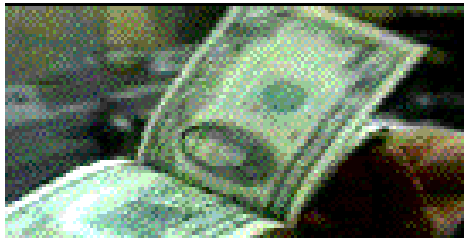
- From the profile of FEMM, assess how balanced your approach is
- Identify priority areas for action, such as
  - Least advanced
  - Easiest to implement
  - Cheapest to implement
  - Have most impact
  - Least contentious

Financial Aspects

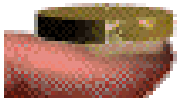


- Evaluate the strengths and weaknesses in managing energy efficiency investment
- Identify key opportunities for improving the performance
- Sensitivity analysis
  - Test how assumptions made in costs & benefits affect the cash flow & financial parameters

Financial Aspects



- Benefits likely to arise
  - Reducing cooling/heating energy use
  - Reduced electricity use
  - Lower maintenance requirements
  - Reduced plant supervision
  - Improved comfort
  - Enhanced property value
  - Longer service life of remaining plant



Financial Aspects

- Appraisal methods
  - Evaluate the cash flow (undiscounted)
  - Determine the payback period (initial screening) & other parameters, e.g.
    - Gross return on capital
    - Net return on capital
    - Gross average rate of return
    - Net average rate of return (internal rate of return, IRR)
  - Net present value (NPV)
    - Apply a discount factor to future costs & earnings

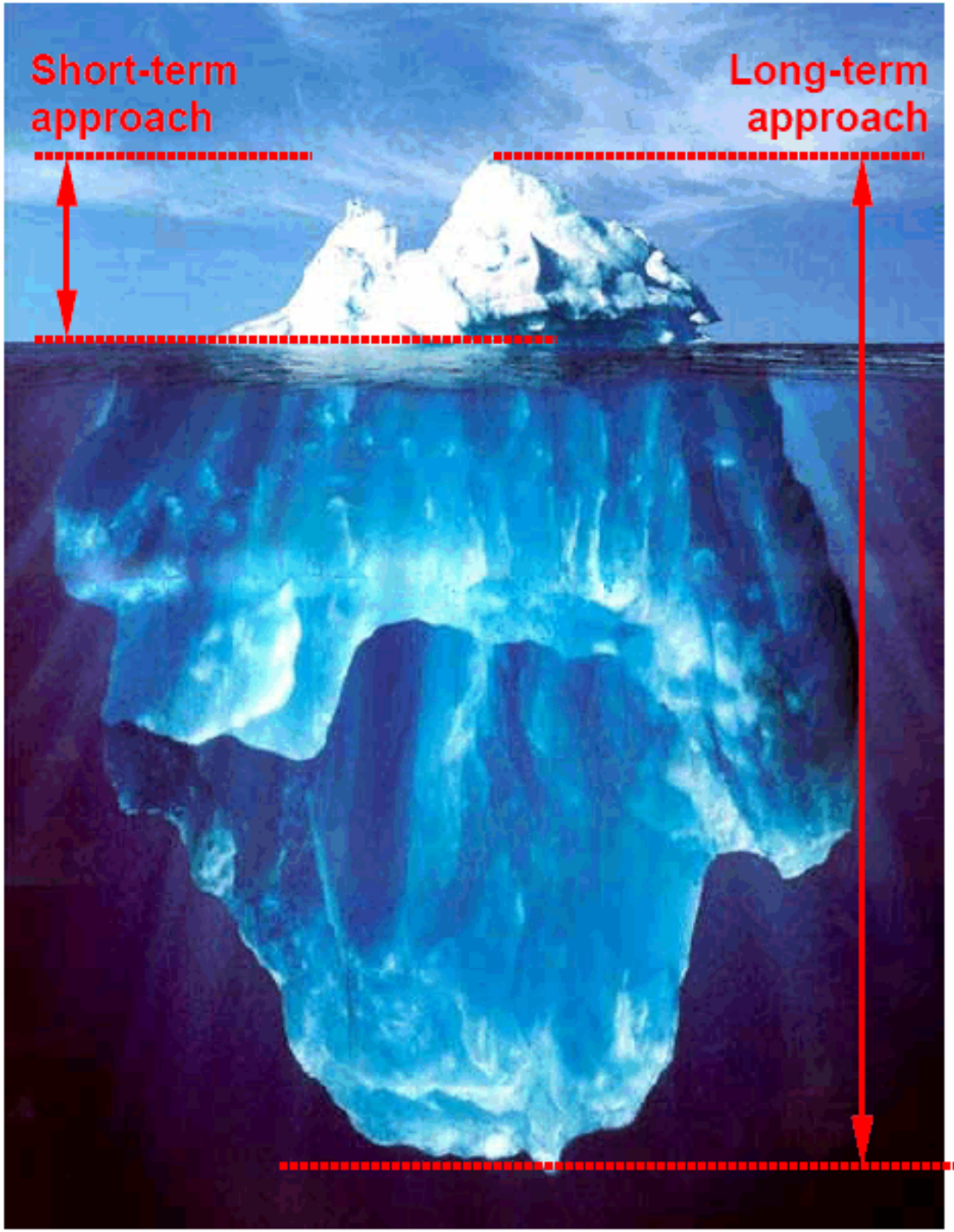
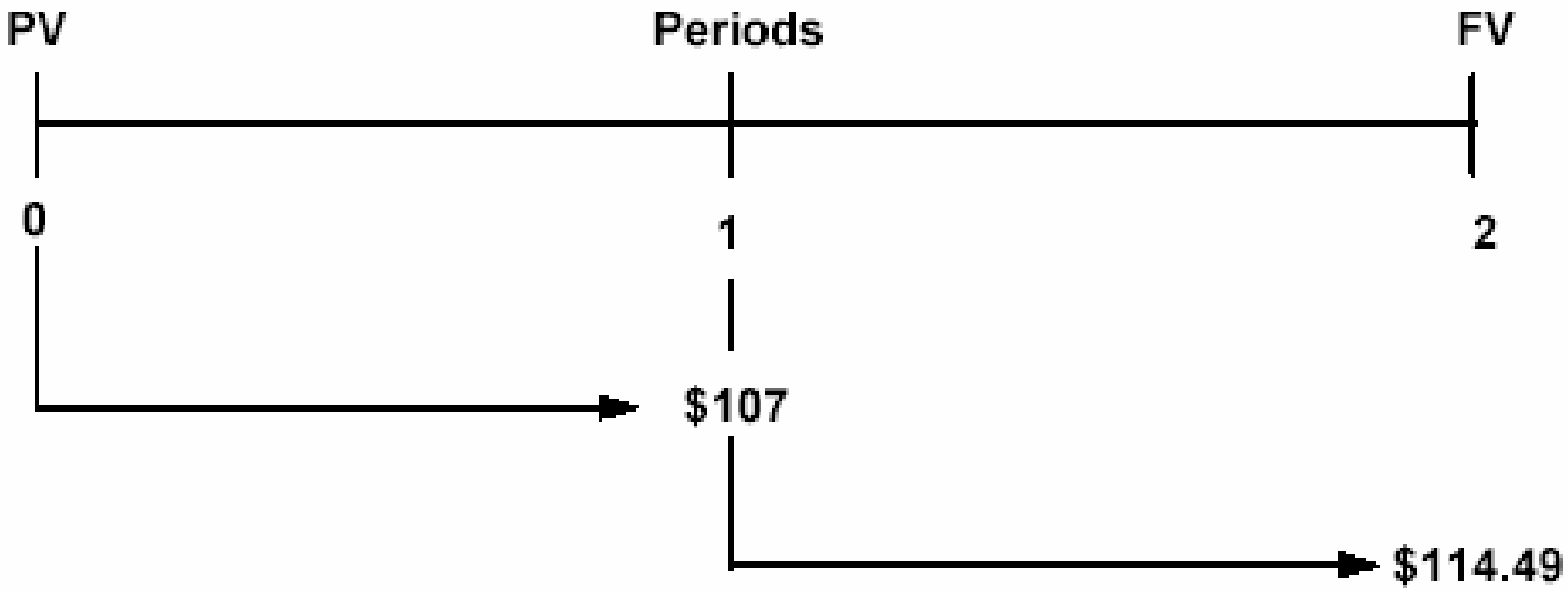
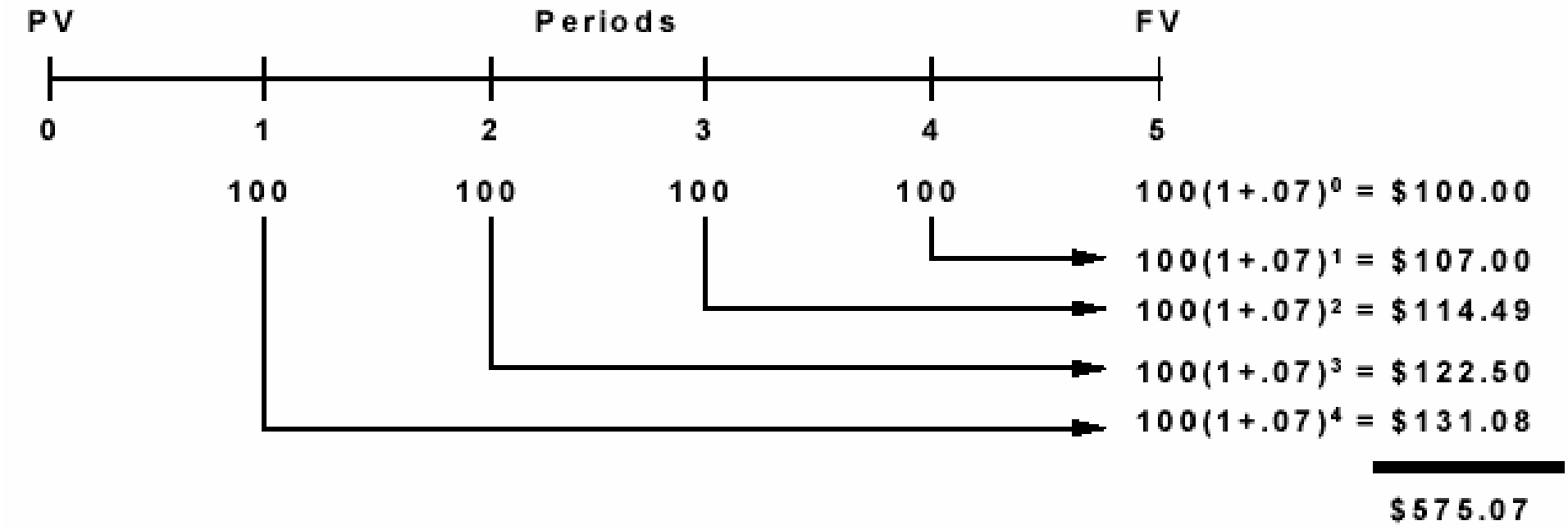


Figure 1.1.1: Two approaches to economic analysis



where: PV = Present Value; FV = Future Value

Figure 1. Future Value of a Single Payment



$$FV = D \times \left(1 + \frac{IR}{100}\right)^{n}$$

$$PV = S \times \left(1 + \frac{IR}{100}\right)^{-n} = S \times DF$$

FV = future value
D = initial investment
IR = interest rate (%)
PV = present value
S = value of cash flow in n years time
DF = discount factor

Table 1: Cash Flow Analysis For LED Exit Signs

Year	*Retrofit Cost*	*Energy & Demand Savings*	*Maintenance Savings*	*Omitted Savings*	*Risk Level*
0	$ 3,250	$ 0	$ 0	Neutral	Neutral
1	0	2,181	200		
2	0	2,181	200		
3	0	2,181	200		
4	0	2,181	200		
5	0	2,181	200		
6	0	2,181	200		
7	0	2,181	200		
8	0	2,181	200		
9	0	2,181	200		
10	0	2,181	200		

Key Assumptions:

1. Retrofit will be completed in 3 months.
2. LED exit signs have a 10-year life expectancy.
3. Energy savings are based on the current average energy rate of $0.078/kWh.
4. No changes in energy rates will occur during the 10-year period.
5. Maintenance savings are realized because lamps are changed less frequently.

(Source: EnergyStar Building Manual, available at www.energystar.gov)

Table 3: Comparing The Profitability Of Upgrade Options

Year	*Upgrade Option 1A Occupancy Sensors*		*Upgrade Option 1B Central Timeclock*	
	Initial Cost	*Savings Generated*	*Initial Cost*	*Savings Generated*
0	$ 42,000	$ 0	$ 9,000	$ 0
1	0	12,200	0	3,550
2	0	12,200	0	3,550
3	0	12,200	0	3,550
4	0	12,200	0	3,550
5	0	12,200	0	3,550
6	0	12,200	0	3,550
7	0	12,200	0	3,550
8	0	12,200	0	3,550
9	0	12,200	0	3,550
10	0	12,200	0	3,550
		Cumulative Savings		
Over Ten Years		$122,000		$ 35,500
Simple Payback		3.4 years		2.5 years
IRR		26%		38%
NPV		$ 7,623		$ 4,903

(Source: EnergyStar Building Manual, available at www.energystar.gov)

Table 4: Assemble A Profitable Package

Stage Two Lighting Options		NPV	First IRR	Annual Net Cost	Cash Flow	Omitted Savings	Risk
1a	Install Occupancy Sensors	$7,623	26%	$42,000	$12,200	Neutral	Neutral
1b	Install Central Timeclock	4,902	38%	9,000	3,550	Neutral	Neutral
2	Install LED Exit Signs	5,606	73%	3,250	2,380	Neutral	Neutral
3	Improve Corridor Lighting	5,106	38%	9,490	3,725	Neutral	Neutral
4	Improve Office Lighting	4,751	23%	57,605	15,100	Neutral	Neutral
5	Upgrade Task Lighting	(929)	16%	9,500	2,000	Neutral	Neutral
6	Install Daylighting Controls	(26,524)	2%	59,080	6,500	Neutral	Neutral

Package Results				
Options 1a-4	$23,091	27%	$112,345	$33,405
Options 1a-5	$22,161	26%	$121,845	$35,405
Options 1a-6	$(4,363)	19%	$180,925	$39,905

(Source: EnergyStar Building Manual, available at www.energystar.gov)

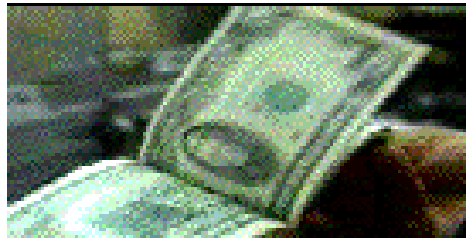
Table 2: Performance Comparison of Fluorescent Retrofit Options

	Base case: T12 Lamps w/magnetic ballasts **Case 1**	*"Energy saving" T12 lamps* **Case 2**	*T8 lamps, electronic ballasts* **Case 3**	*T8 lamps, electronic ballasts, reflector lens, + 50% delamping* **Case 4**	*Same as Case 4 + occupancy sensors* **Case 5**	*Same as Case 5 + maintenance* **Case 6**
Avg. maintained footcandles (fc)	28	25	30	27	27	27
Input watts per fixture	184	156.4	120	60	60	50
Total kW	2.208	1.877	1.440	0.720	0.720	0.600
Annual energy use (kWh)	8,832	7,507	5,760	2,880	1,800	1,500
Costs						
Energy savings (%)	N/A	15%	35%	67%	80%	83%
Annual operating cost for energy ($)	883.70	750.74	576.00	288.00	212.40	177.00
Upgrade cost ($)	N/A	312	1,440	1,620	1,970	1,970
Savings						
Energy savings (%)	N/A	15%	35%	67%	80%	83%
Operating cost savings (%)	N/A	15%	35%	67%	76%	80%
Simple payback (years)	N/A	2.4	4.7	2.7	2.9	2.8
Internal Rate of Return (10-year)	N/A	41%	17%	35%	32%	34%

Source: Adapted from E SOURCE, *Lighting Technology Atlas*, Table 3.1.

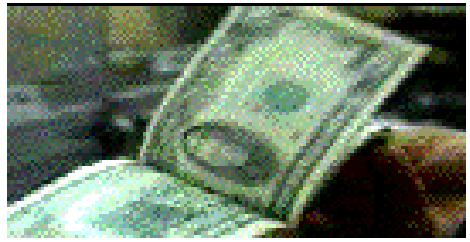
(Source: EnergyStar Building Manual, available at www.energystar.gov)

Financial Aspects



- Human resources
  - People's commitment to energy efficiency
  - Promote the culture of energy efficiency
  - Supportive senior management (board of directors)
  - Clear lines of responsibility
  - Joint forces with account/finance department

Financial Aspects

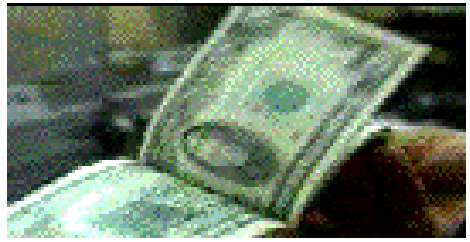


- Project funding
  - Well prepared proposals
  - Energy or environmental policy with board level backing
  - Take account of potential risks
  - Keep track of investment & accrued year-on-year savings, e.g. using a capital return budget

Financial Aspects

- Project financing
  - Typical financing options
    - Cash (your own)
    - Bonds
    - Municipal lease
    - Performance contracts
  - See the comparison table from EnergyStar Building Manual (interest rates, financing term, approval process, flexibility)
  - How to obtain financing at a min. cost and risk

Financial Aspects

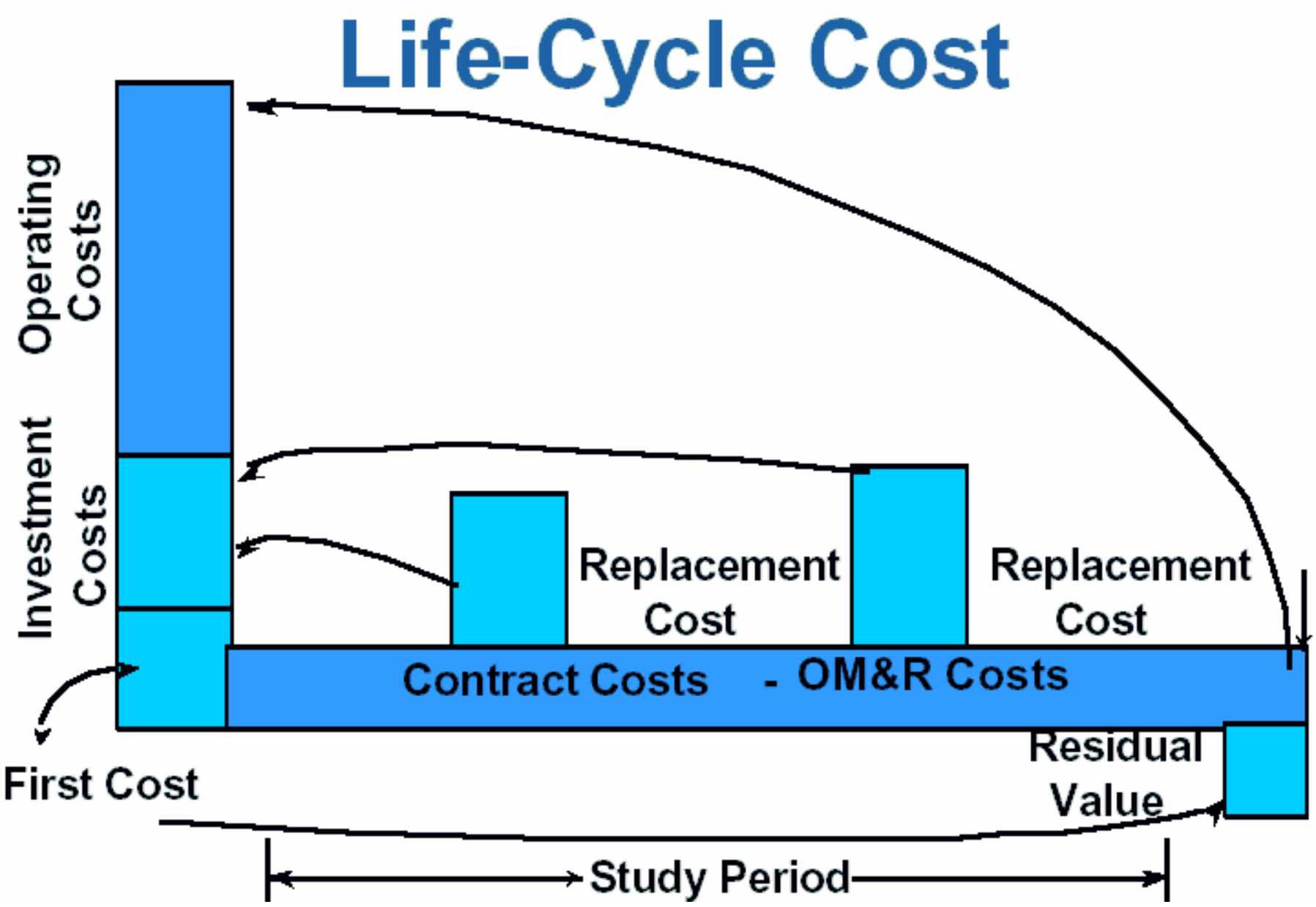


- Project financing (cont'd)
  - Evaluation factors
    - Balance sheet (e.g. debt level)
    - Initial payment (initial capital outlay)
    - Payments (to receive financial benefits)
    - Ownership (equipment depreciation & performance risk)
    - Tax deductions (e.g. deductions for loan interest)
    - Performance risk (who bears the risk of failure)

Table 2: Summary Of Options

Evaluation Factor	*Cash Purchase*	*Loan*	*Capital Lease*	*Operating Lease*	*Performance Contract*
Balance sheet	on	on	on	off	off
Initial payment	100%	downpayment	none	none	none
Payments	none	fixed	fixed	fixed	variable or fixed
Ownership	owner	owner	owner	lessor	contractor
Tax deductions	depreciation	depreciation, interest	depreciation, interest	lessor	contractor
Performance risk	owner	owner	owner	lessor	contractor

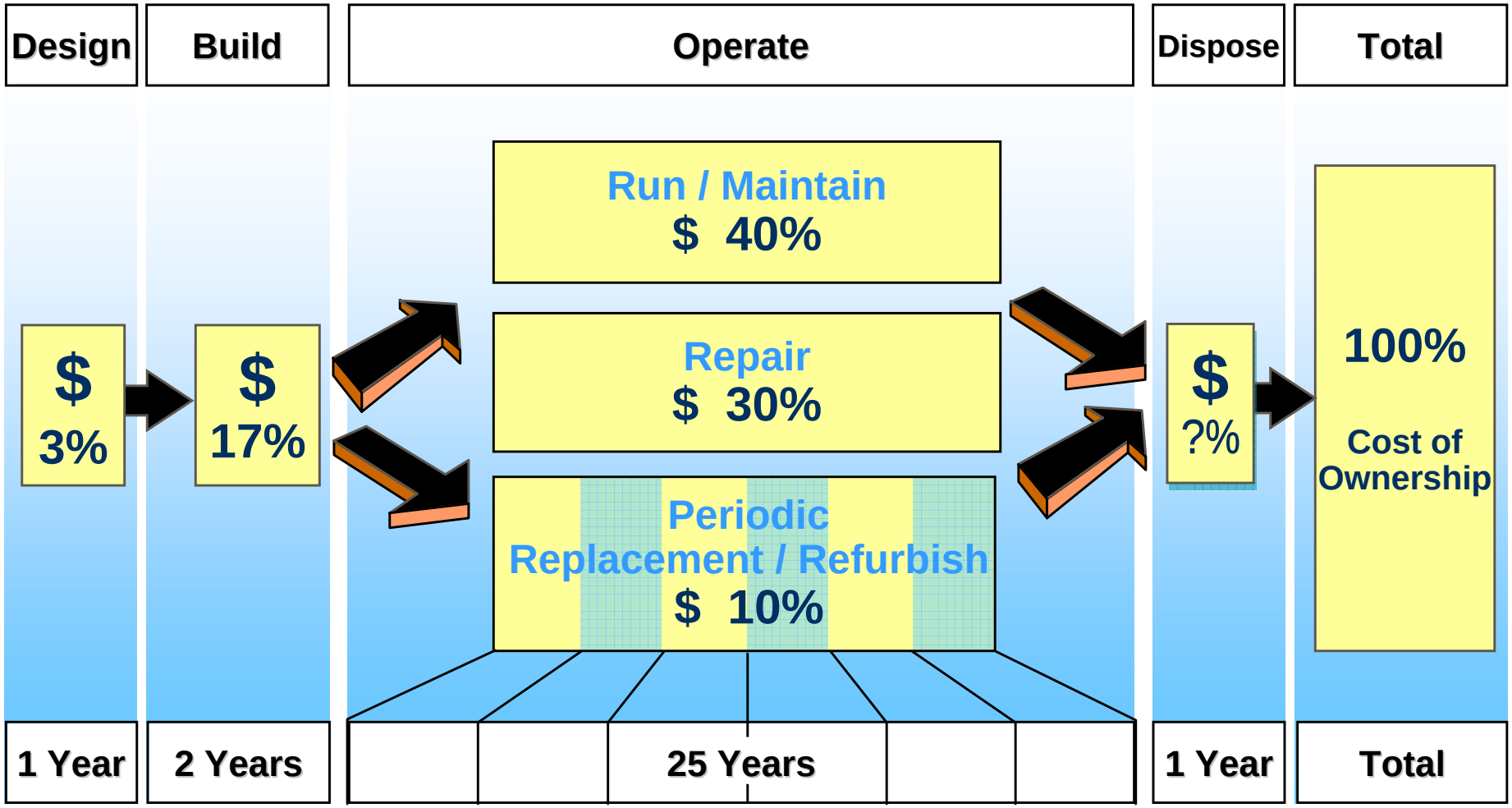
(Source: EnergyStar Building Manual, available at www.energystar.gov)


Life-Cycle Cost
Operating Costs
Investment Costs
Replacement Cost
Replacement Cost
Contract Costs - OM&R Costs
First Cost
Residual Value
Study Period

Whole Life Costing

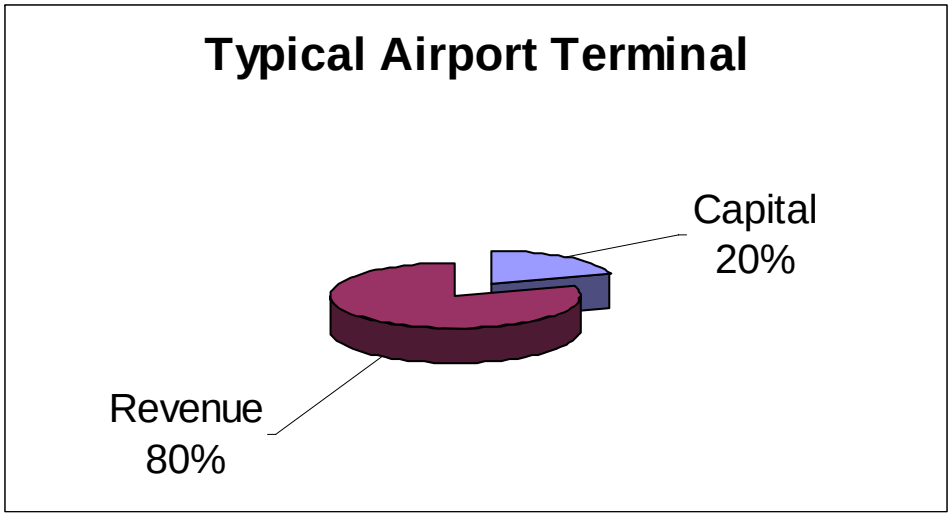
- Whole life cost ratios (typical)
  - Capital Cost : Cost in Use : Business Costs
  - = 1 : 5 : 200
  - Source.: "The long term costs of owning and using buildings" – published by The Royal Academy of Engineering (November 1998).

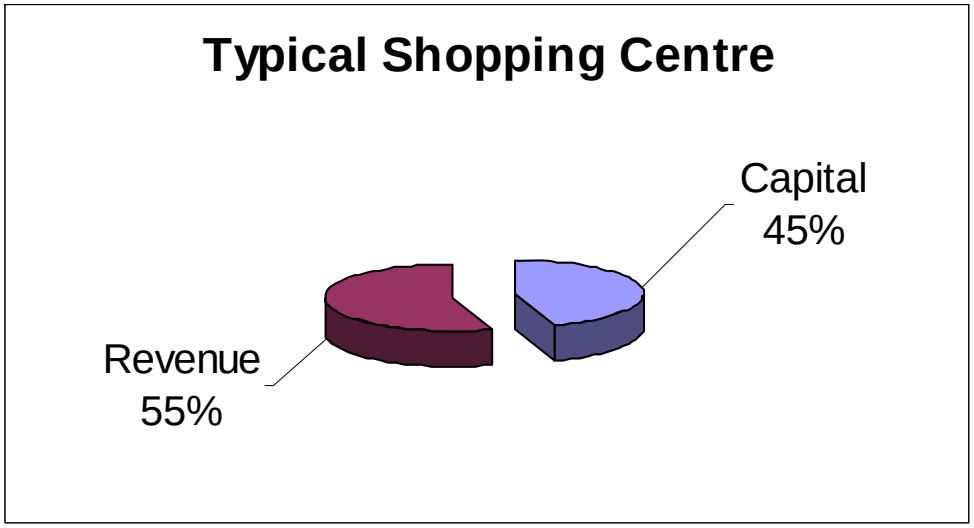
Whole life cost – the Big Picture

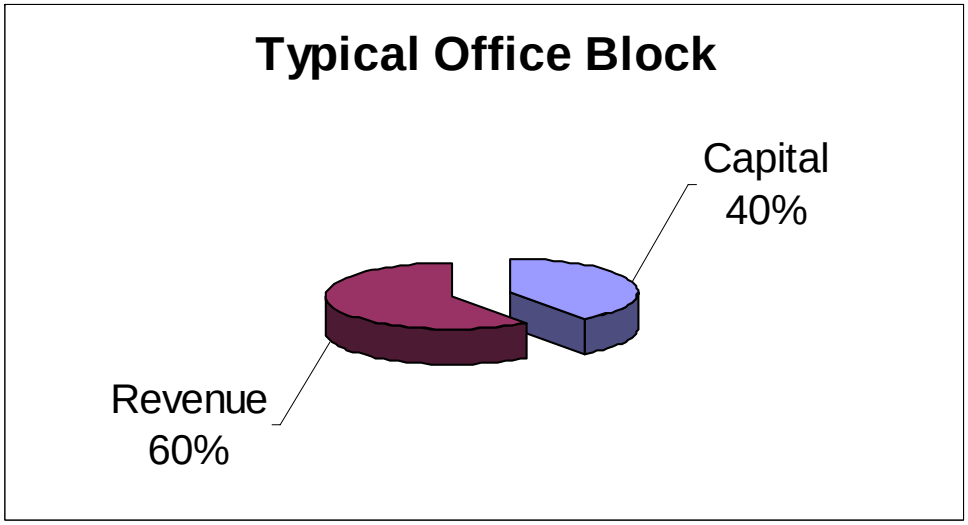


(Source: www.wlcf.org.uk)

Whole life cost – Rules of Thumb

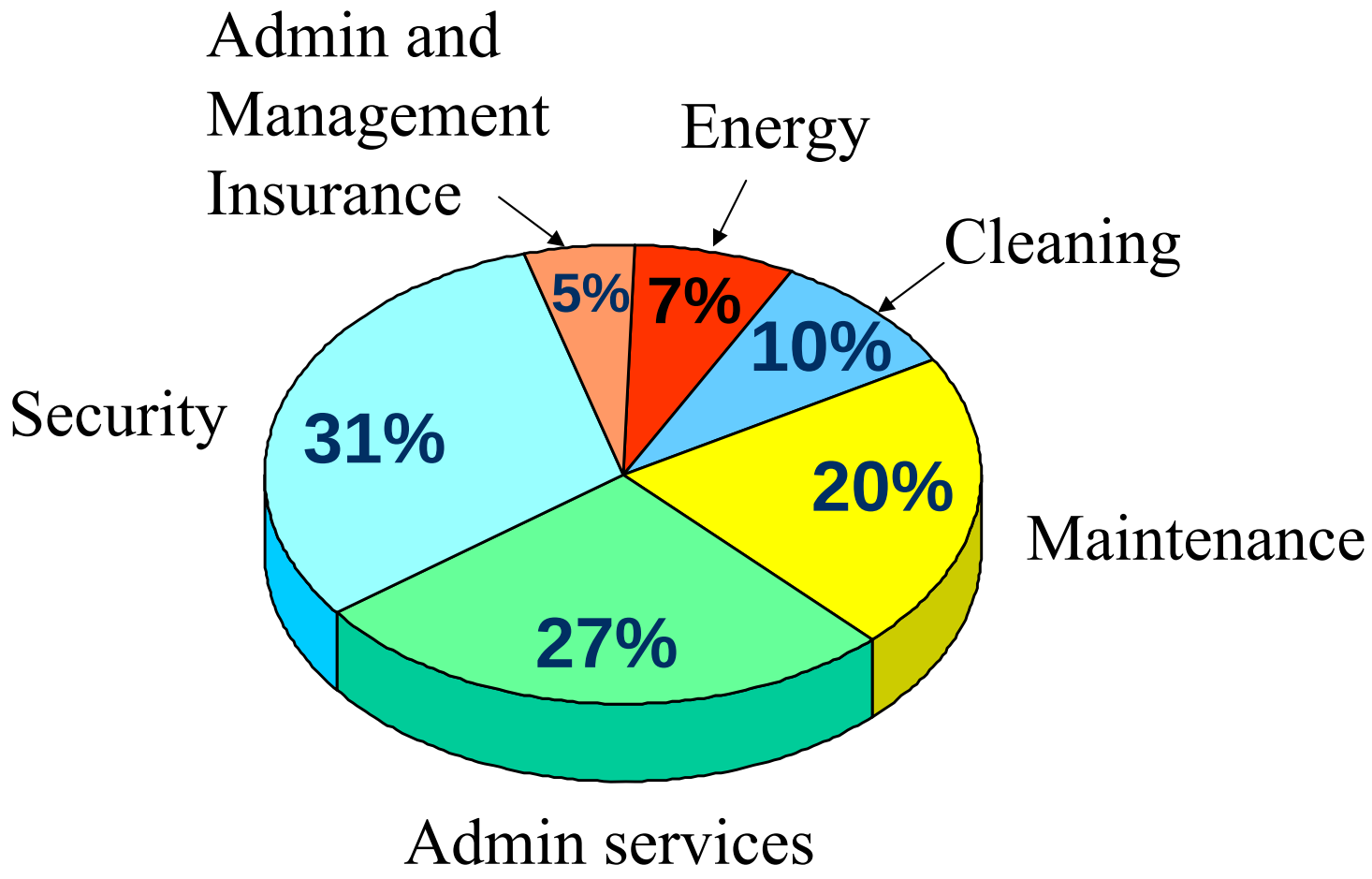






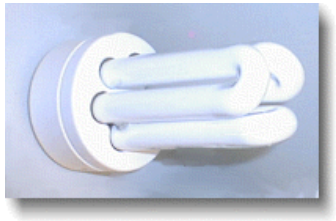
(Source: www.wlcf.org.uk)

Revenue Cost Breakdown



(Source: www.wlcf.org.uk)

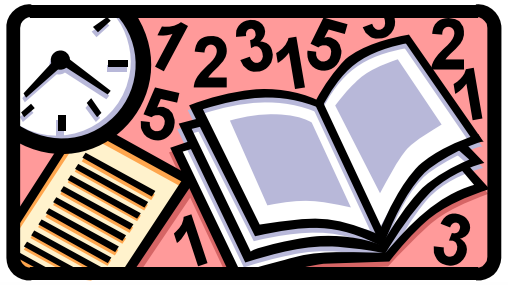
Energy Efficiency



- Video: The Story of Lang [16 min.]
  - Energy efficiency and conservation in Hong Kong
- Website: EnergyLand
  - http://www.energyland.emsd.gov.hk/
  - Interesting website on related info and issues

Energy saving in lift system

Useful References



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  - http://www.emsd.gov.hk/emsd/e_download/pee/emsd100dpi.pdf
- Beggs, C., 2002. *Energy: Management, Supply and Conservation*, Butterworth-Heinemann, Oxford. [696 B41]
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