MEBS6016 Energy Performance of Buildings

http://www.hku.hk/bse/MEBS6016/

Energy Efficiency in Buildings (II)

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Jan 2012

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- Building Operation and Energy Management
- Energy Performance Contracting

Basic Principles

- "An energy efficient building provides the required internal environment and services with minimum energy use in a cost effective and environmentally sensitive manner." – *CIBSE Guide F: Energy Efficiency in Building*
  - Design energy efficient new buildings and refurbishment of existing buildings
  - Manage and operate buildings in an energy efficient way; Upgrade buildings to improve ongoing energy efficiency

Basic Principles

- Principles of energy efficiency (1)
  - Integrated building design
    - Design the most energy efficient buildings and services possible. Provide holistic designs which are responsive to the external climate whilst still meeting the needs of the occupants
  - The energy efficient brief
    - Ensure the client's brief includes energy efficient criteria and targets for all buildings, new or refurbished. Review the project in relation to these targets and criteria as the design progresses

Basic Principles

- Principles of energy efficiency (2)
  - Benchmarking
    - Compare designs and in-use performance of buildings with appropriate benchmarks to ensure that best practice energy efficiency is being achieved
  - The integrated design team
    - Work with other members of the design team in order to optimise building energy performance

Basic Principles

- Principles of energy efficiency (3)
  - Reduce demand
    - Keep energy demand to a minimum through careful design of built form and services using renewable energy sources, ambient energy and passive solutions. Make every effort to avoid the need for air conditioning
  - Design for operation
    - Design for commissionability, maintainability and manageability by keeping solutions simple and eliminating potential failure pathways

Basic Principles

- Principles of energy efficiency (4)
  - Optimise plant
    - Select the most efficient plant, using certified or otherwise independently verified product performance data, and ensure that plant and equipment are not oversized
  - Use effective controls
    - Introduce energy efficient controls which operate systems efficiently, safely and economically, whilst still allowing individual occupants to alter their own comfort levels, but avoiding systems defaulting to ‘on’

Basic Principles

- Principles of energy efficiency (5)
  - Ensure complete handover
    - Ensure that building services are properly commissioned and handed over to managers, operators and occupants
  - Improve operation
    - Encourage energy efficient operation of buildings through management, policy, maintenance, monitoring and control

Basic Principles

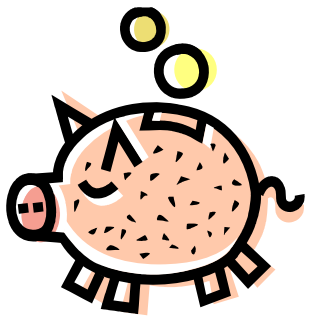
- Principles of energy efficiency (6)
  - Understanding the building
    - Provide managers, engineers, operators and occupants with suitable documentation to ensure they understand the design intention and how the buildings are meant to function
  - Monitoring and feedback
    - Develop a strong element of feedback to improve understanding from previous good and bad experience related to these principles. Introduce appropriate metering to improve info. and to detect faults rapidly

Basic Principles

- Principles of energy efficiency (7)
  - Build-in energy efficiency
    - Always consider introducing energy efficient technologies throughout the design and upgrade processes but avoid unnecessary complications. Seek opportunities for improving existing buildings during operation, maintenance, alteration and refurbishment
  - Environmental impact
    - Minimise adverse effects on the external environment. Minimise emissions and select environmentally friendly materials and fuels, utilising renewable sources as much as possible

Basic Principles

- Investing in energy efficiency
  - Improve the overall environmental performance
    - In response to an overall environmental policy laid down by senior management or as a result of government initiatives in the public sector
    - Can significantly enhance corporate image which may influence future investors



  - Cost savings and savings in operating costs
  - May also be justified for environmental reasons e.g. emissions trading

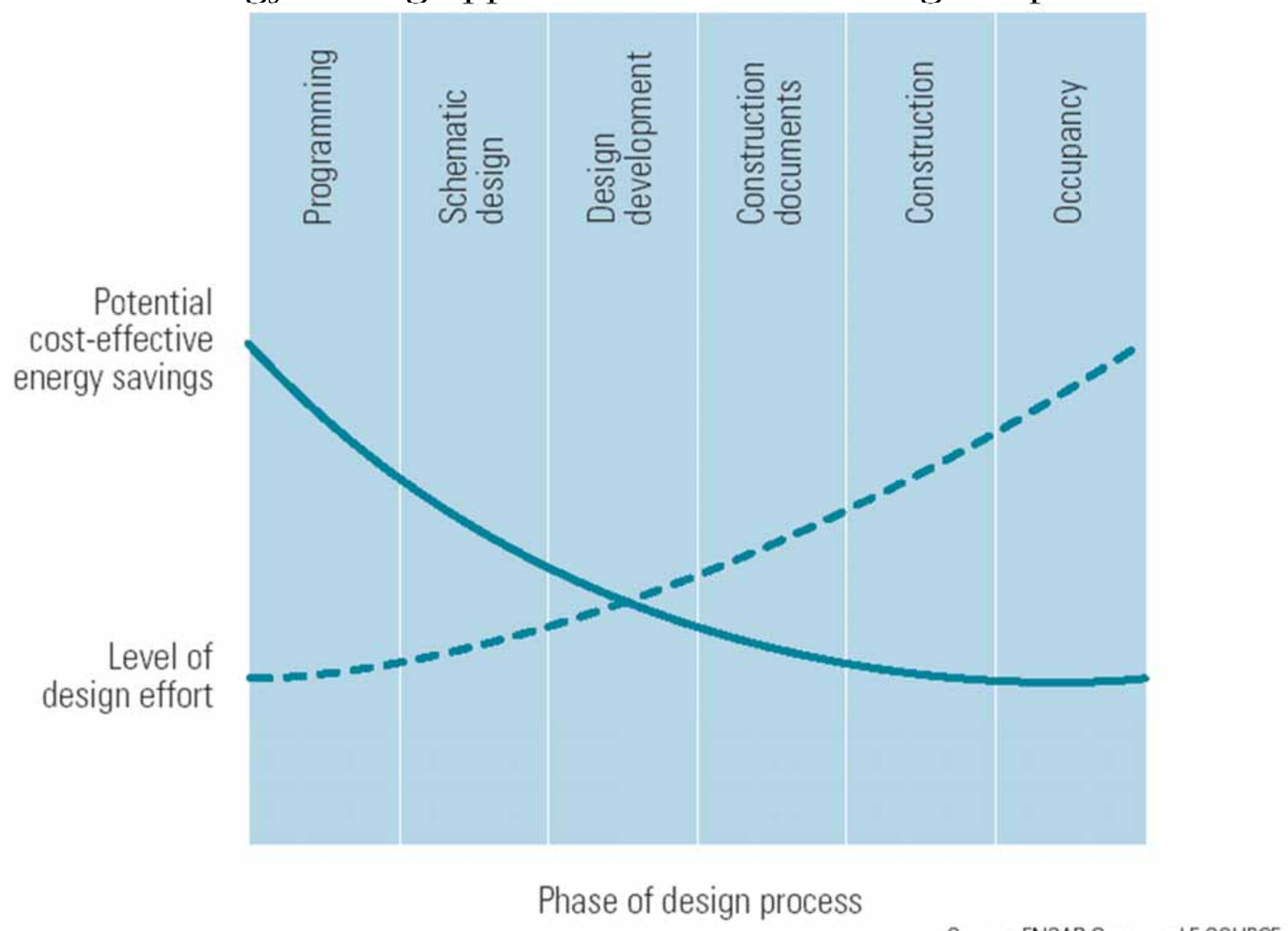
Basic Principles

- Three types of energy efficiency measures
  - No-cost/low-cost: require no investment appraisal
  - Medium cost: require only a simple payback calculation
  - High capital cost: require detailed design and a full investment appraisal
- Financial decision to consider economic payback, complexity and ease of application
  - Wider benefits such as improvements in comfort and the environment

Building Energy Design

- Process of energy efficient design
  - 1. Identify user requirements
  - 2. Design to meet them with minimal energy use
  - 3. Establish an integrated design team with a brief and contract that promotes energy efficiency
  - 4. Set energy targets at early stage & design for them
  - 5. Design for manageability, maintainability, operability & flexibility
  - 6. Check that the final design meets the targets

Energy-saving opportunities and the design sequence



(Source: www.energydesignresources.com)

Building Energy Design

- Building design stages (e.g. RIBA plan)
  - A. Inception
  - B. Feasibility
  - C. Outline proposals
  - D. Scheme design
  - E. Detail design
  - F. Production information

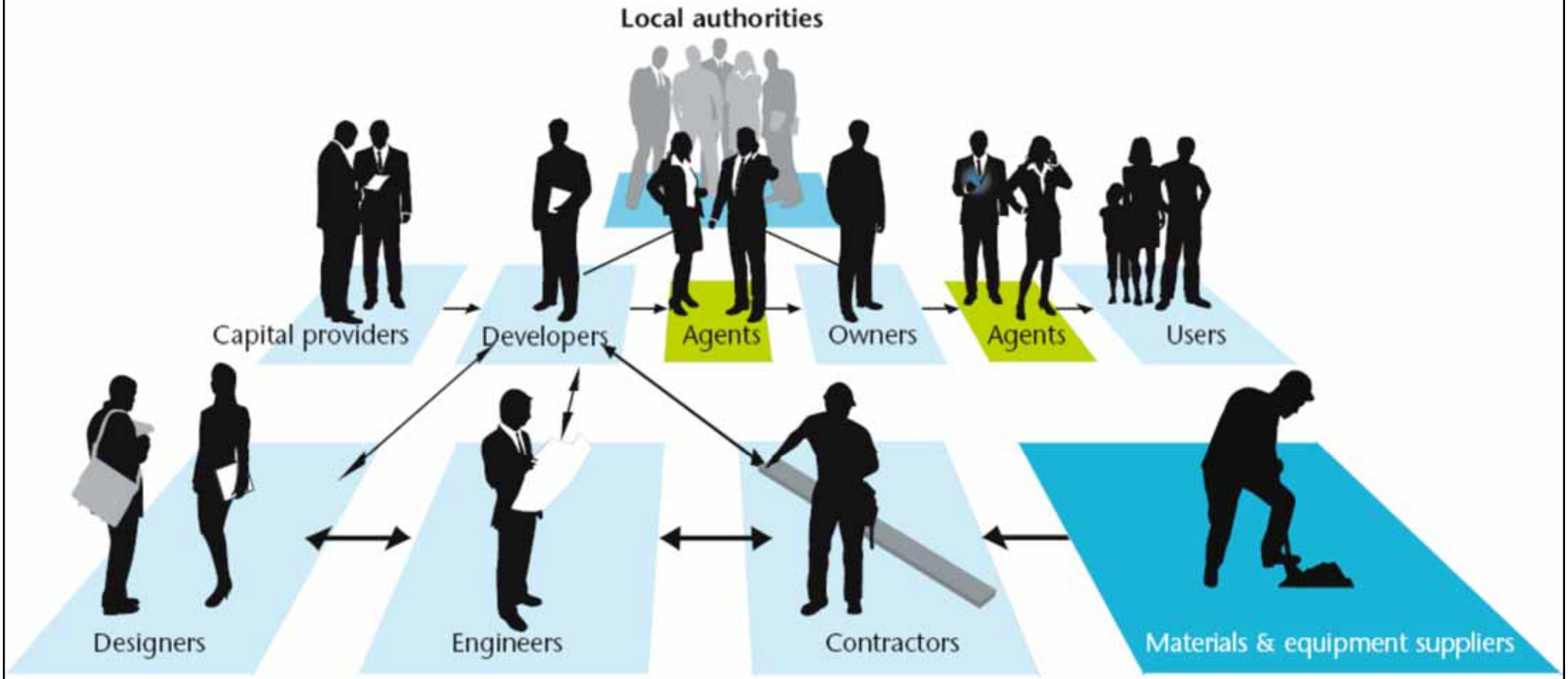
(RIBA = Royal Institute of British Architects)

- What are the energy efficiency considerations at each stage?

(See handout Table 2.1 & Figure 2.3)

Integrated energy design process

Project phase	Action items
Preliminary design	Define energy problems and opportunities Identify candidate solutions Perform preliminary economic analysis
Design development	Perform detailed lighting and daylighting studies Integrate load-avoidance techniques into mechanical design Coordinate architectural, lighting, and interior designs Simulate energy performance of the integrated design Refine economic analysis Prepare commissioning plan
Construction documents	Review building plans and specifications Review equipment selections Review construction details Finalize energy-performance and economic analyses
Construction	Review change orders Review product substitutions Inspect quality of materials and correctness of installations
Commissioning and occupancy	Implement a commissioning plan Verify energy savings Solicit feedback from occupants



The complex value chain in the building sector

(Source: World Business Council for Sustainable Development, www.wcbsd.org)

Building Energy Design

- Success depends on
  - Understanding the interactions between people, building fabric and services (See Table 3.1)
  - Collaboration of client, project manager, architect, engineer and quantity surveyor at the early conceptual stage of the project
- Generally, owner-occupiers will be more interested in low running costs than will speculative developers

Building Energy Design

- The design team (multi-disciplinary)
  - Should be appointed early at inception stage

    - Make the client aware of the implications that decisions have on life cycle costs
    - Provide an energy efficient design that takes account of energy management, maintenance needs and occupant comfort/control
    - Predict energy performance and running costs; Propose further options for energy efficiency, highlighting the potential benefits
    - Produce good documentation which makes the design intent clear

Building Energy Design

- The energy efficient brief should include:
  - The client's intentions, requirements and investment criteria
  - Energy & environmental targets
  - Life cycle costs
  - Intentions to include energy efficient equipment
  - A requirement to undertake integrated design

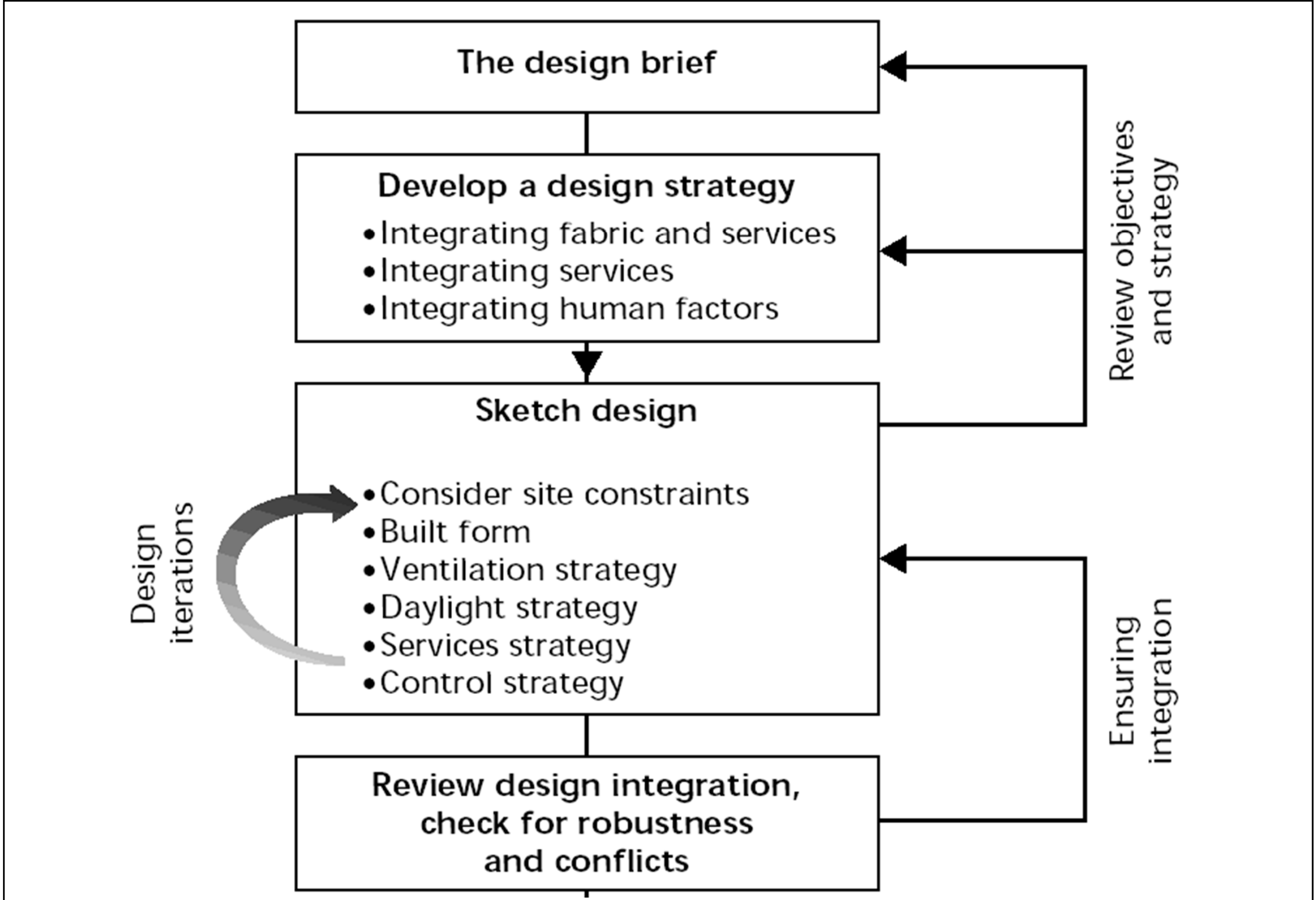
- Good use of natural light & ventilation often can provide greater energy efficiency

Building Energy Design

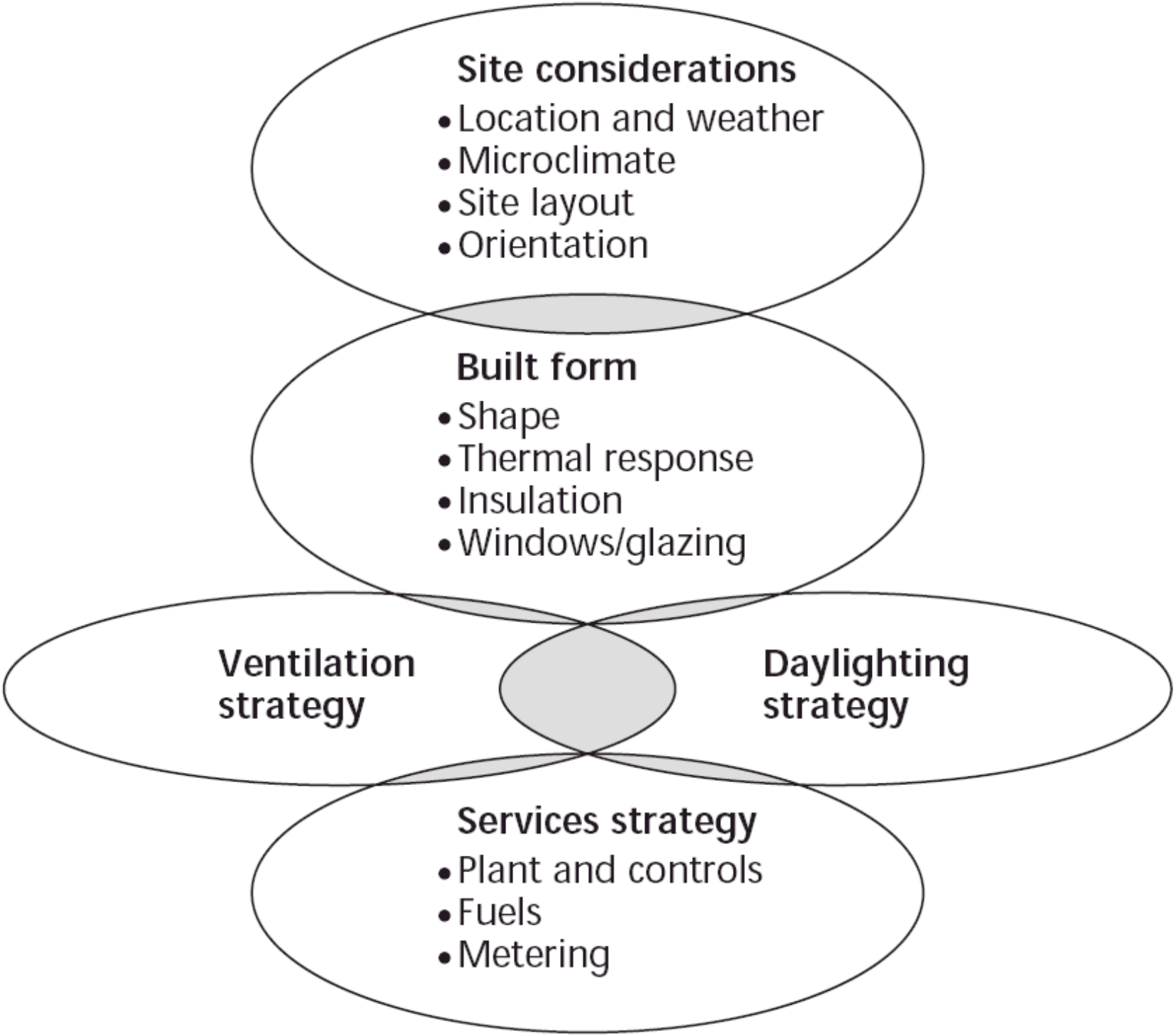
- The contract issue
  - Energy efficient buildings often require greater professional skill and design input
  - Must have enough time at an early stage
  - Fee component for energy design on a contract
    - Fee structures based entirely on capital cost may not encourage energy efficiency
    - Lump sum fees based on the estimated time spent
  - Any other suggestions for a better fee structure?

Building Energy Design

- Building design as an iterative process
  - Review objectives, strategy & design criteria
  - Re-think fundamental aspects of the design
- Integrated approach to energy efficient design
  - Integrate fabric (Arch/Struct) and services (BSE)
  - Integrate building services
  - Integrate human factors
- The integration can present opportunities to reduce capital cost, e.g. reduce HVAC plant



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



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

Building Energy Design

- Integrate fabric and services
  - Function of the building envelope
    - Climatic modifier
  - Good design can minimise the need for services
    - Respond to weather & occupancy
    - Make good use of natural light, ventilation, solar gains and shading
  - Performance criteria
    - Cost, indoor environment quality, space requirements, energy use, robustness, ease of operation

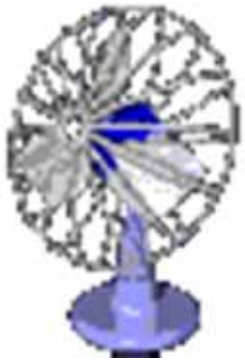
Building Energy Design

- Fabric issues
  - Deep/swallow floor plan
  - Orientation
  - Percentage glazing
  - Lightwells/atria
  - Air tightness
  - Thermal response
- Services issues
  - Cooling
  - Heating
  - Electric light & daylight
  - Natural ventilation
  - Mechanical ventilation & air conditioning

(See handout Figure 3.2)

Building Energy Design

- Integrate services
  - Minimise conflict between building services
    - Such as electric light & the need for cooling
    - Simultaneous heating and cooling
  - Zoning services & proper controls
  - Natural ventilation, free cooling, heat recovery



(See handout Figure 3.3)

Building Energy Design

- Minimise requirements for services
  - Avoid over-specification & excessive design margins
  - Optimise internal heat gains
  - Optimise natural ventilation
  - Optimise daylighting
  - Utilise thermal storage, heat recovery, free cooling
  - Minimise distribution losses

Building Energy Design

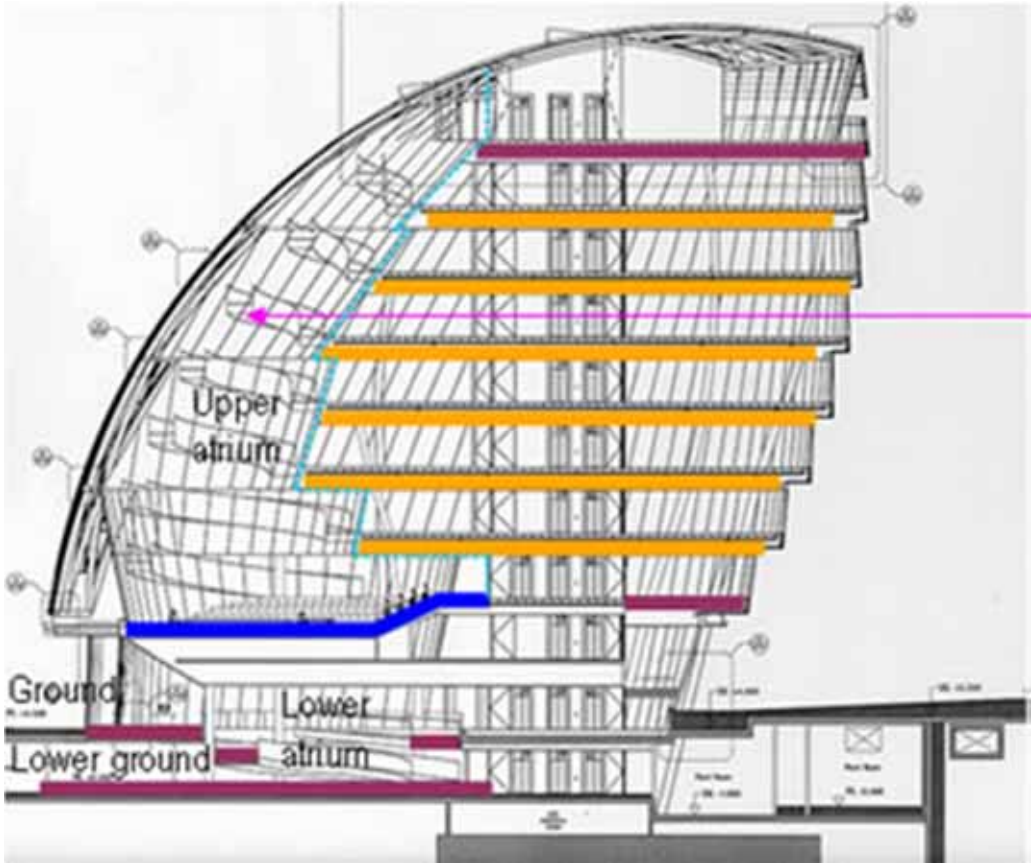
- Integrate human factors
  - Manageability (avoid over complex design)
  - Maintainability (adequate access & monitoring)
  - Flexibility (adaptation & space allowance)
  - Controllability (allow users to adjust)

Building Energy Design

- Video: “A Democratic Building” (17 min.)

  - GLA Building in London
    - Client: Greater London Authority (GLA)
    - Architects: Foster and Partners
    - Engineers: Ove Arup
  - Review questions:
    - How the project team reduce building’s energy needs?
    - What are the integrated features?
    - What is the energy code requirement in UK?

London City Hall GLA Building



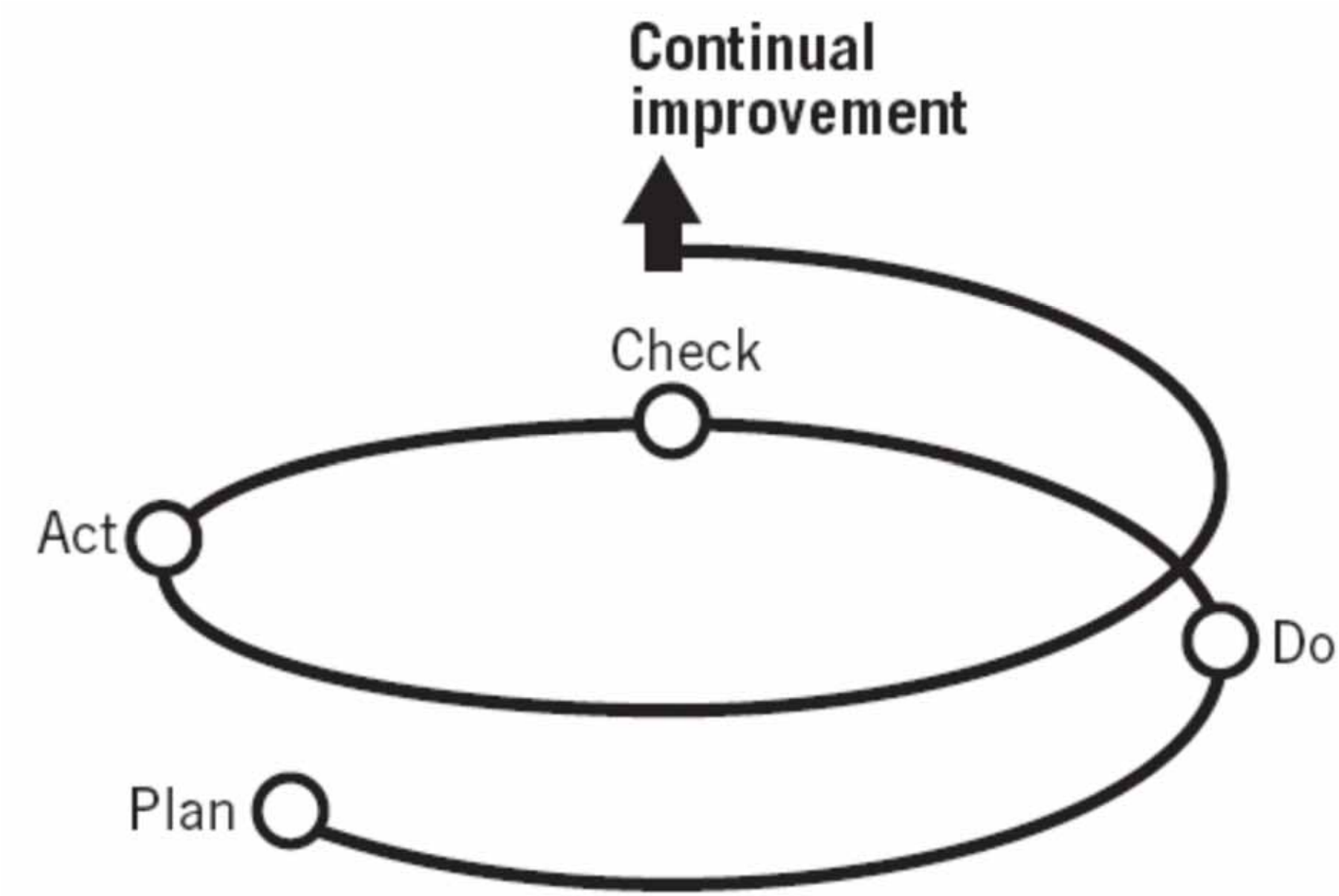
(Source: www.london.gov.uk/gla/)

Bldg Energy Management

- The Deming System of Profound Knowledge
  - Appreciation of a system: understand the overall processes involving suppliers, producers, and customers of goods and services
  - Knowledge of variation: the range and causes of variation in quality, and use of statistical sampling in measurements
  - Theory of knowledge: the concepts explaining knowledge and the limits of what can be known
  - Knowledge of psychology: concepts of human nature

(Source: The New Economics, by Dr. W. Edwards Deming)

Four steps of the management process (for continual improvement)



(Source: The New Economics, by Dr. W. Edwards Deming)

Bldg Energy Management

- **Plan**
  - Obtain insight (energy audit)
  - Get management commitment
  - Nominate energy champion
  - Policy, objectives, structure
  - Assign responsibilities
  - Develop programme(s)
  - Set targets and measures
  - Set priorities, develop action plans

Bldg Energy Management

- **Do**
  - Create awareness
  - Train key resources
  - Implement projects
  - Monitor progress
  - Lock in the gains – Set new targets
  - Communicate results
  - Celebrate success

Bldg Energy Management

- **Check**
  - Review results
  - Verify effectiveness
  - Examine opportunities for continual improvement

Bldg Energy Management

- **Act**
  - Correct deficiencies
  - Review original energy policy
  - Review objectives and targets
  - Review energy program
  - Update action plans
  - Start the cycle anew

Bldg Energy Management

- Energy Management Opportunities (EMOs)
  - Housekeeping: an energy management action that is repeated on a regular basis and never less than once per year
  - Low cost: this type of energy management action is done once and for which the cost is not considered great.
  - Retrofit: this energy management action is done once, but the cost is significant

Bldg 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

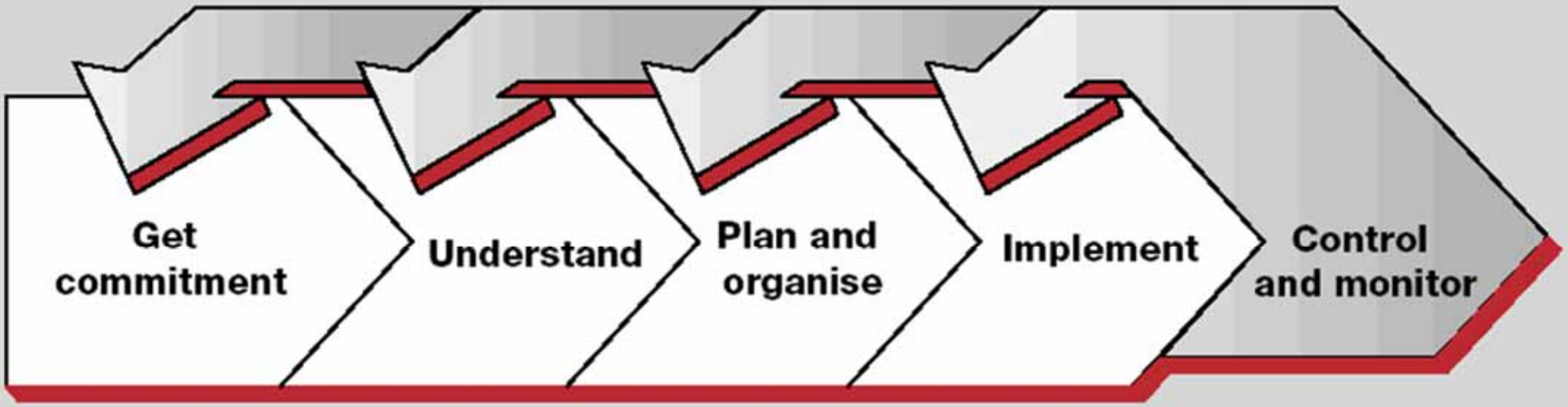
Bldg Energy Management

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

Level	Energy policy	Organising	Motivation	Information systems	Marketing	Investment
4	Energy policy, action plan and regular review have commitment of top management as part of an environmental strategy	Energy management fully integrated into management structure. Clear delegation of responsibility for energy consumption	Formal and informal channels of communication regularly exploited by energy manager and energy staff at all levels	Comprehensive system sets targets, monitors consumption, identifies faults, quantifies savings and provides budget tracking	Marketing the value of energy efficiency and the performance of energy management both within the organisation and outside it	Positive discrimination in favour of 'green' schemes with detailed investment appraisal of all new-build and refurbishment opportunities
3	Formal energy policy but no active commitment from top management	Energy manager accountable to energy committee representing all users, chaired by a member of the managing board	Energy committee used as main channel together with direct contact with major users	M&T reports for individual premises based on sub-metering, but savings not reported effectively to users	Programme of staff awareness and regular publicity campaigns	Same pay back criteria employed as for all other investment
2	Unadopted energy policy set by energy manager or senior departmental manager	Energy manager in post, reporting to ad-hoc committee, but line management and authority are unclear	Contact with major users through ad-hoc committee chaired by senior departmental manager	Monitoring and targeting reports based on supply meter data. Energy unit has ad-hoc involvement in budget setting	Some ad-hoc staff awareness training	Investment using short term pay back criteria only
1	An unwritten set of guidelines	Energy management the part-time responsibility of someone with only limited authority or influence	Informal contacts between engineer and a few users	Cost reporting based on invoice data. Engineer compiles reports for internal use within technical department	Informal contacts used to promote energy efficiency	Only low cost measures taken
0	No explicit policy	No energy management or any formal delegation of responsibility for energy consumption	No contact with users	No information system. No accounting for energy consumption	No promotion of energy efficiency	No investment in increasing energy efficiency in premises

Energy Management Matrix (see handout)

A systematic approach to energy management



- Gain commitment
- Identify stakeholder needs
- Establish policy
- Set objectives and targets
- Prepare action plan
- Allocate roles and responsibilities
- Prioritise investments
- Train
- Consider business integration and barriers to implementation
- Audit process
- Distribute audit findings

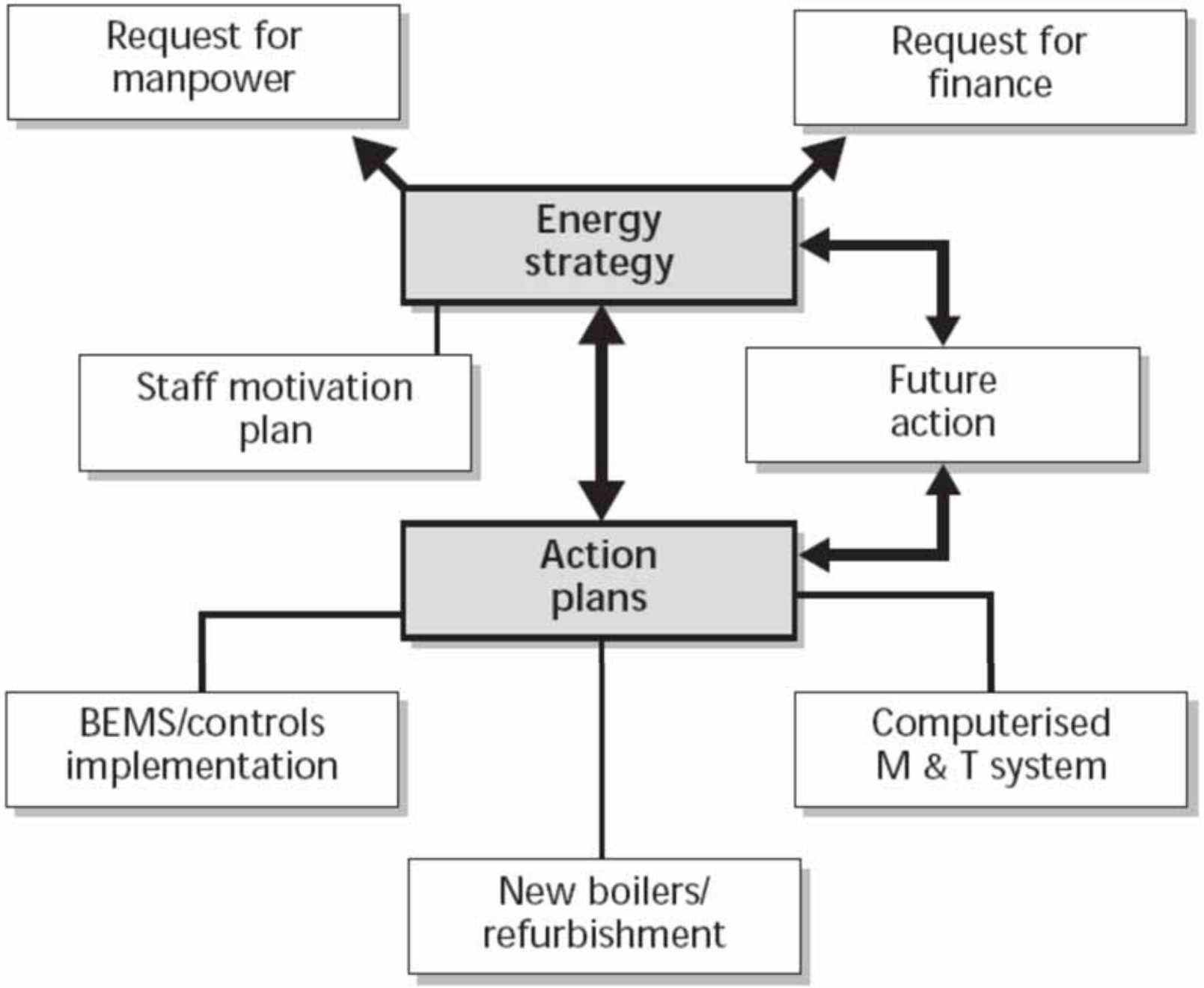
Bldg Energy Management

- 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)

Bldg 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



* M & T = monitoring & targeting

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

Bldg 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

Bldg 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

Bldg Energy Management

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

Bldg Energy Management

- Planning maintenance
  - Maintenance policy
  - Types of maintenance
    - Reactive or breakdown maintenance
    - Planned preventative maintenance
- Maintenance contracts
  - Performance specification
  - Use of maintenance contractors

Table 16.2 Advantages and disadvantages of contract and direct labour

Contract	Direct labour
More competitive price	More difficult to assess costs
More flexible workforce wit wide skills	Fixed workforce and fixed skills
May not be able to respond to all emergencies	Always available to respond to emergencies
Contract needs to be monitored	In-house supervision required
Specialist training and tools included	Need to provide specialist tools and training

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

Bldg Energy Management

- Monitoring maintenance
  - Maintenance records
    - Installation records: e.g. O&M manuals, plant details
    - Service records: include log sheets, job records, etc.
  - Checking maintenance standards
    - Such as breakdown frequency
    - Annual spend on building services maintenance

Bldg Energy Management

- Good housekeeping
  - Such as switch off lights when not needed
- Maintaining for energy efficiency
  - Building fabric
  - Controls
  - Heating ventilation & air conditioning systems
  - Refrigeration systems
  - Lighting systems
  - Motors and drives

Bldg Energy Management

- Refurbishing existing buildings
  - Complete refurbishment
    - Total replacement of plant & major changes to fabric
  - Major refurbishment
    - Replacement of major plant & some changes to fabric
  - Minor refurbishment
    - Refitting the interior & making minor alterations to space layout and plant
  - Passive refurbishment
    - Passive methods: daylighting & natural ventilation

Bldg Energy Management

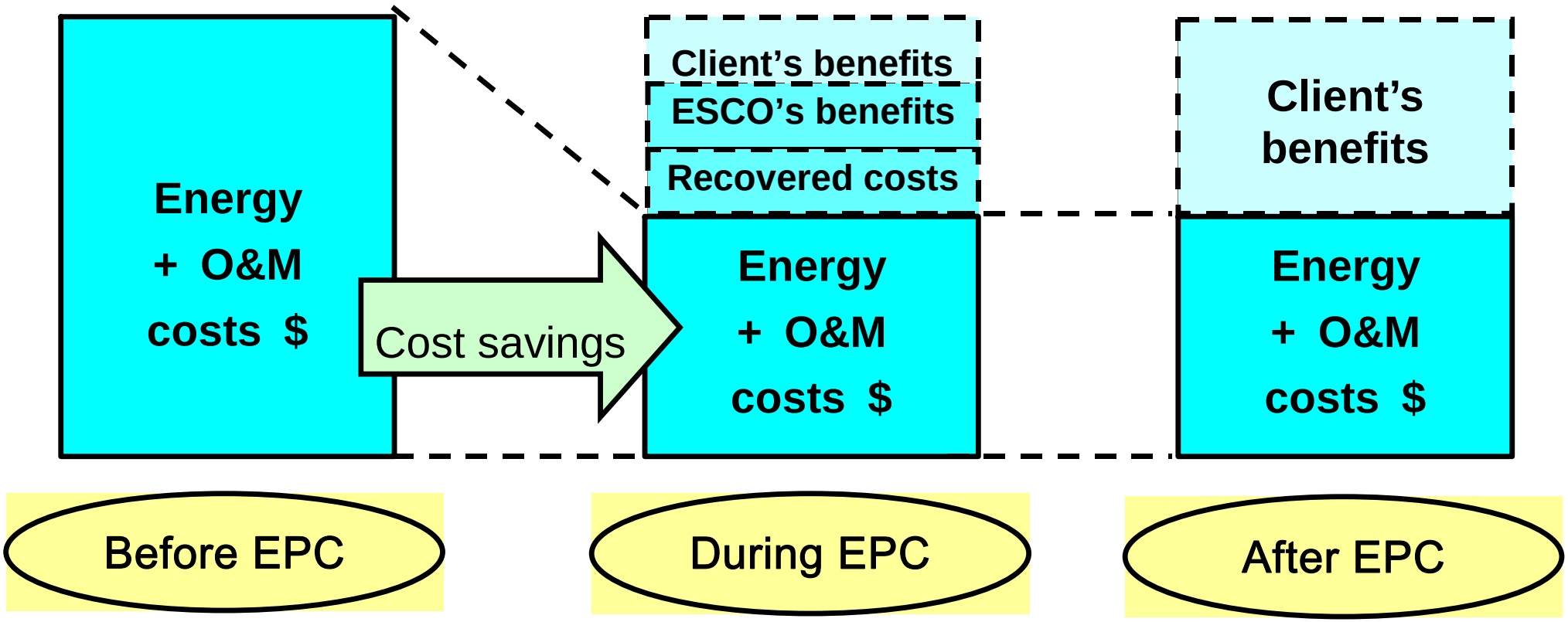
- Retrofitting energy saving measures
  - Identify high energy users
  - Establish the potential for energy saving through measurement, audits etc.
  - Identify practicable measures to achieve savings
  - Establish the financial case for introducing these measures, as well as other benefits
  - Implement the savings in a planned way
  - Monitor the savings to confirm

Bldg Energy Management

- Typical process
  - Programme development & planning
  - Identify measures
    - Energy surveys and audits
    - Integrating the measures
    - Reporting the results
  - Assessing energy saving measures
    - Option appraisal
    - Investment criteria
    - Life cycle costing

Energy Performance Contracting

- Energy performance contracting (EPC)
  - = energy savings performance contracting
  - A financing technique to raise money for energy efficiency investments based on future savings
- Energy services companies (ESCO)
  - Offer EPC services, without upfront capital on building owners
  - Becoming an important trend in many countries like USA and Japan



Basic concept of energy performance contracting (EPC)

Energy Performance Contracting

- Performance contract
  - Contract with payments based in performance
  - Can be used for energy conservation projects, to mitigate indoor air quality concerns, to reduce water & sewage usage, or to implement renewable energy systems
- ESCO guarantees and takes the risk of not achieving savings; it is paid back out of the savings (in around 4-10 years)

Energy Performance Contracting

- Benefits of a performance contract for a business
  - Reduced risk (contractor guarantees)
  - Turnkey services (contractor provides all services)
  - The business needs less internal expertise
  - Project financing can be ‘off balance sheet’
  - Advanced products & services can be used
  - Savings can be much higher than done by itself
  - Additional improvements to built environment

Energy Performance Contracting

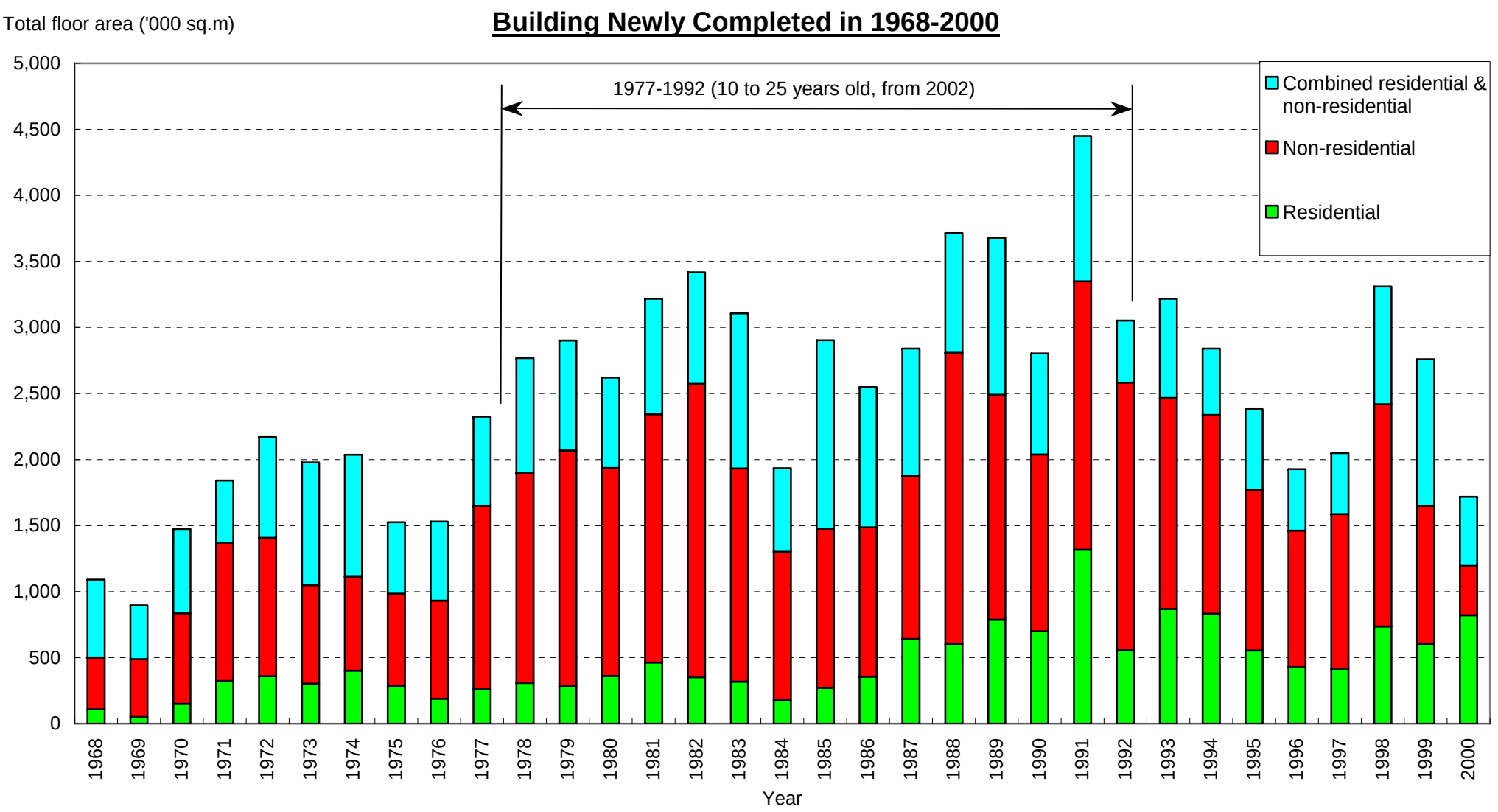
- Typical measures include
  - Energy reduction via equipment retrofitting
    - Such as replace lighting equipment, chillers & boilers
  - Fuel saving measures
    - Such as add wall insulation or pool cover
  - Water efficiency measures
  - Load shifting
    - Such as by energy management control systems
  - Modification of operating procedures

Energy Performance Contracting

- Different ways of structuring such a contract
  - ‘Guaranteed savings’
    - Most common; length 4-8 years
    - Allow extra measures to be added
  - ‘Shared savings’
    - The Client & ESCO share the savings; up to 10 years
    - Actual cost not included in contract
  - ‘Pay from savings’
    - Variation from shared savings; operates like a loan
  - ‘Chauffage’ or full services (ESCO takes over)

Energy Performance Contracting

- Potential ESCO market in HK
  - Energy cost is a concern for developers/owners
  - Vast stock of existing buildings (esp. commercial)
  - Potential market around US$100 million
  - ESCO prefer owner-occupied or single-tenant
  - Air-conditioning & lighting are major areas
  - Savings not difficult to obtain from equipment optimisation, retrofitting or retrocommissioning



Building completed in 1968-2000 in Hong Kong

Energy Performance Contracting

- Current EPC active players
  - Automatic control companies
  - Building services consultants/contractors
  - Hong Kong Productivity Council
  - Power companies (for demand side management)
- Government energy projects
  - Electrical & Mechanical Services Dept. (EMSD)
  - EMSD acts as an ESCO via trading fund

Energy Performance Contracting

- Prospects
  - Growing concern about energy & environment
    - Achieving sustainable performance!
    - Saving energy & operating costs
  - Policy tools & programmes by government
    - Such as building energy codes, energy labels, pilot renewable energy projects
    - Water-cooled air-conditioning systems (converting of air-cooled systems)
  - Need to upgrade existing buildings

Energy Performance Contracting

- Major barriers
  - Weak awareness & experience
  - Complex legal & contractual issues
  - Problems with conventional procurement process
  - Problems with measurement & verification
- Factors for successful EPC
  - ESCO has the technical, financial & mgt. skills
  - Customer & ESCO have a partnership
  - Good understanding of project goals

Energy Performance Contracting

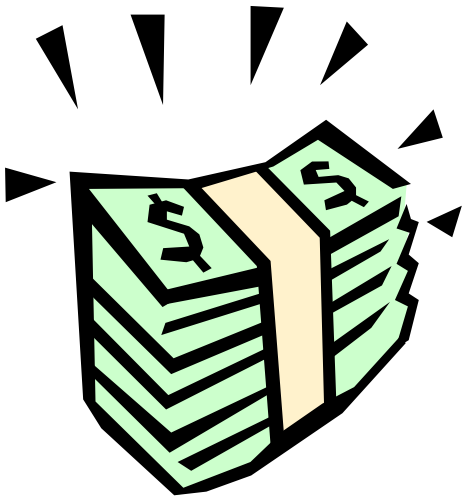
- Typical EPC project stages
  - Stage 1: The opportunity assessment
  - Stage 2: Preliminary energy services
  - Stage 3: Develop detailed proposal
  - Stage 4: Project implementation
  - Stage 5: Performance assurance + M&V services
- Technical knowledge, risk management skills & understanding of local practices
- Outsourcing strategies (why not in-house?)

Energy Performance Contracting

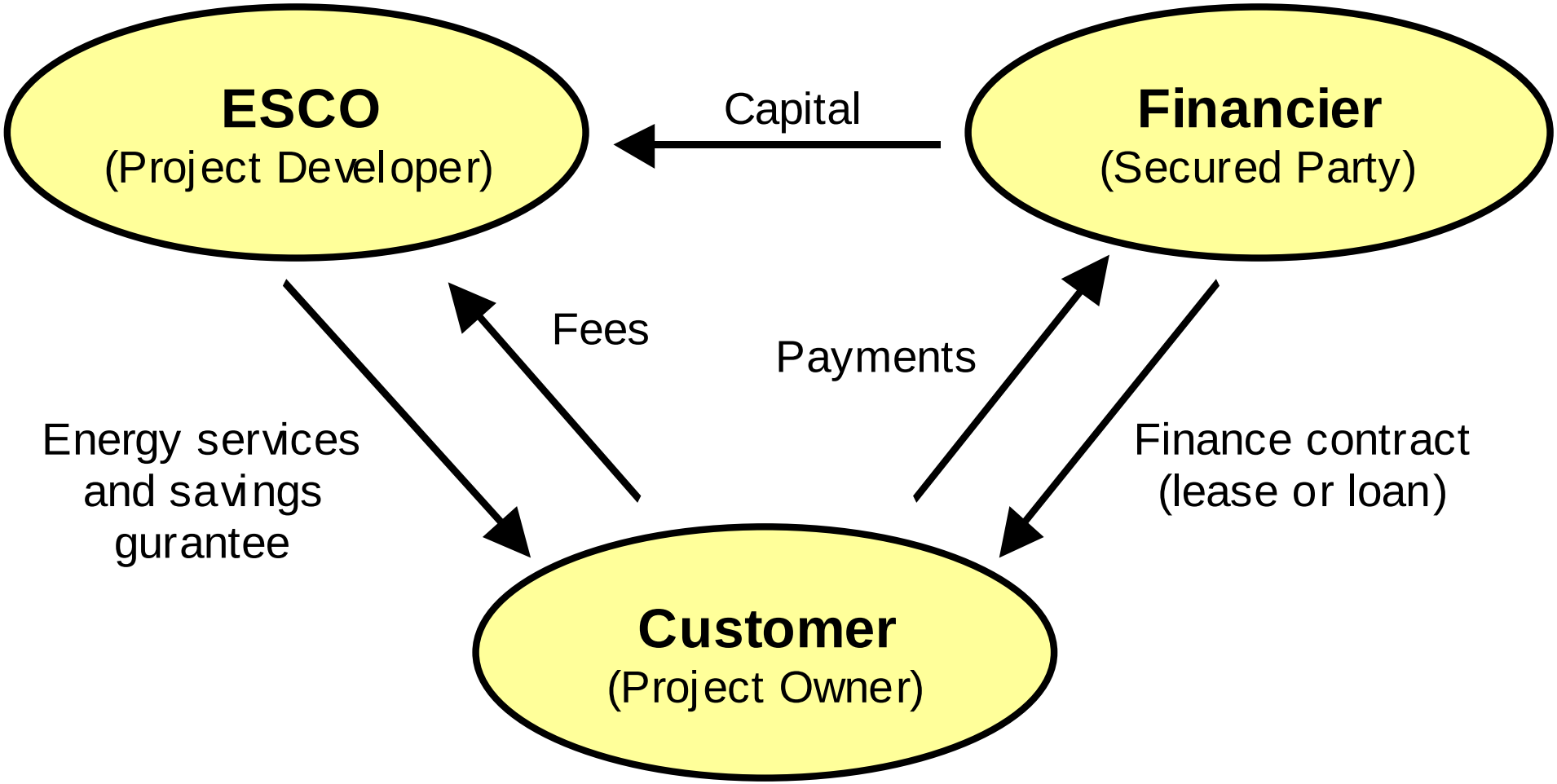
- Choosing a contractor
  - Equipment suppliers
    - Best if their technologies are the main measures
  - Fee-based ESCO
    - Best for a wide range of measures or long-term facilities management
  - Utility-based ESCO
    - Best if focus on electricity or gas technologies
  - International energy companies
    - Best for international connection & overseas technology transfer

Energy Performance Contracting

- Project financing
  - By the ESCO itself
  - As a loan from financial institution
  - By working together with the client



- Under adverse economy
  - The client may not have the project capital
  - ESCO need to negotiate with bankers to explore creative financial tools



Financial structure used by ESCO

Energy Performance Contracting

- Measurement & verification (M&V) methods
  - Deemed or stipulated savings
    - Payments based on savings estimates, using measurements or audit + equipment characteristics
  - Savings based on utility bills
    - Past energy bills determine baseline consumption
  - Measured savings
    - Compare ‘before’ & ‘after’ measurements
- M&V options & techniques have matured
  - Guidelines e.g. IPMVP and ASHRAE 14-P

M&V options and analysis techniques

M&V option	Analysis techniques
Partially measured retrofit isolation	Engineering calculations using short term or continuous measurements
Retrofit isolation	Engineering calculations using short term or continuous measurements
Whole facility	Analysis of whole facility utility meter or sub-meter data using techniques from simple comparison to regression analysis.
Calibrated simulation	Energy use simulation, calibrated with hourly or monthly utility billing data and/or endues metering.