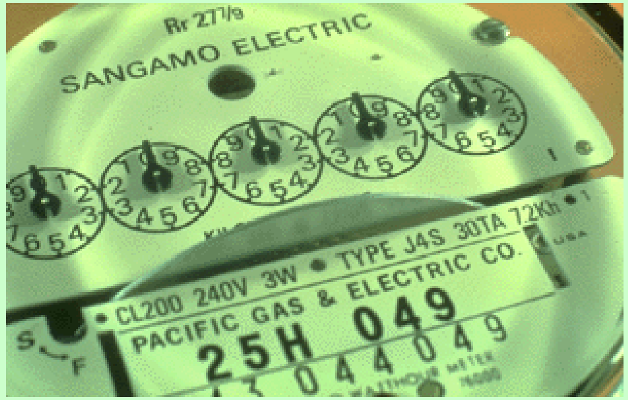

Building energy design and management

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- Basic Principles
- Building Energy Design
- Building 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

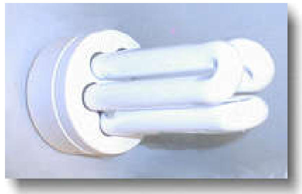
Basic Principles

- Principles of energy efficiency (1)
  - 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
  - 2. 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)
  - 3. Benchmarking
    - Compare designs and in-use performance of buildings with appropriate benchmarks to ensure that best practice energy efficiency is being achieved
  - 4. The integrated design team
    - Work with other members of the design team in order to optimise building energy performance (to avoid fragmented efforts)

Basic Principles



- Principles of energy efficiency (3)
  - 5. 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
  - 6. 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)
  - 7. 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
  - 8. 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)
  - 9. Ensure complete handover
    - Ensure that building services systems are properly commissioned and handed over to managers, operators and occupants
  - 10. Improve operation
    - Encourage energy efficient operation of buildings through management, policy, maintenance, monitoring and control

Basic Principles

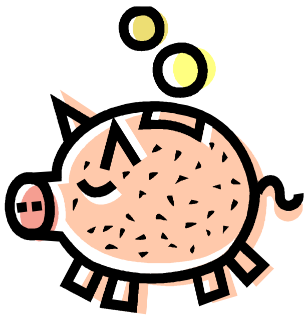
- Principles of energy efficiency (6)
  - 11. Understanding the building
    - Provide managers, engineers, operators and occupants with suitable documentation to ensure they understand the design intention and how the buildings are meant to function
  - 12. Monitoring and feedback
    - Develop a strong 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)
  - 13. 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
  - 14. 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. green building design & emissions trading

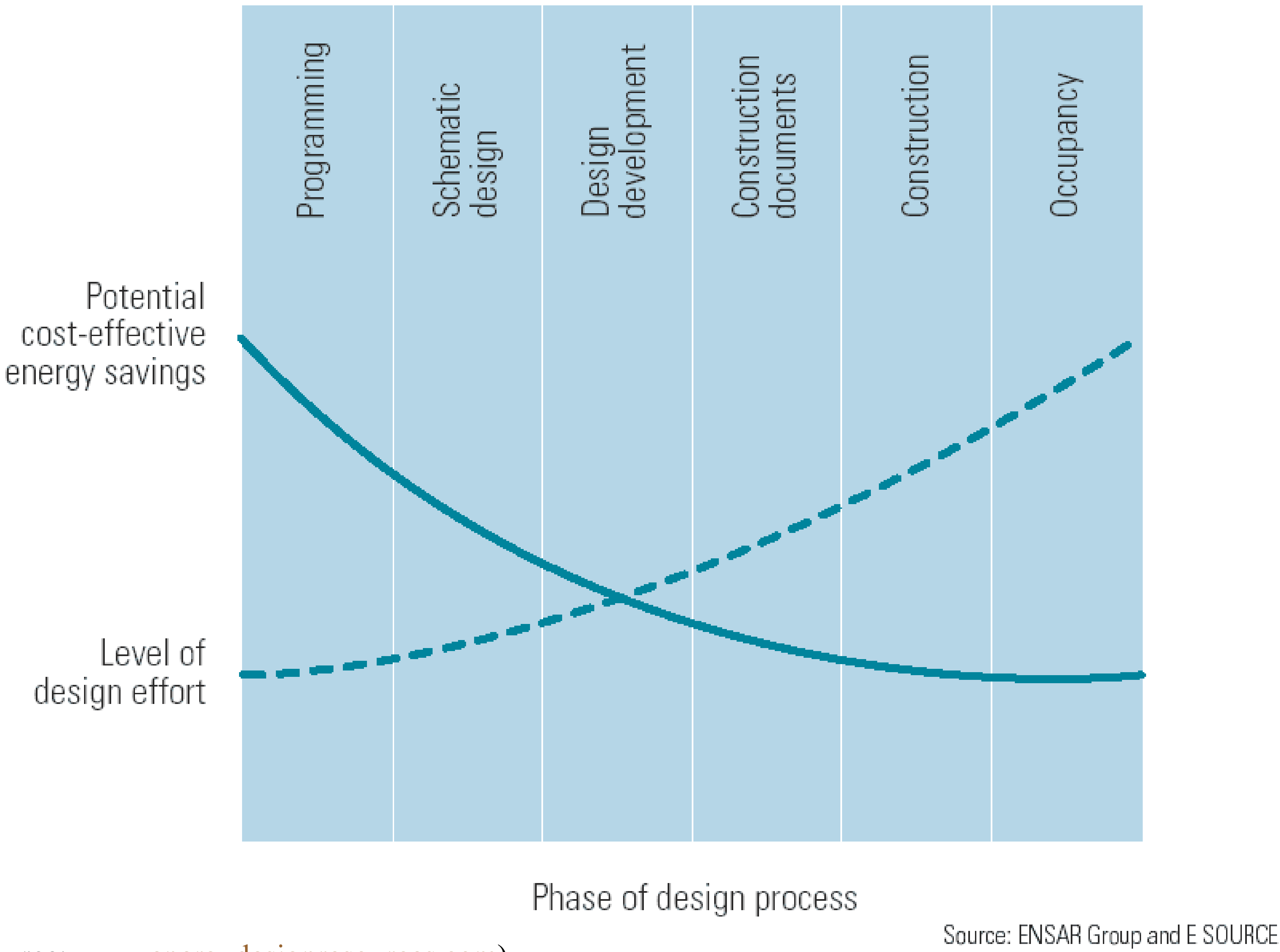
Basic Principles

- 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)

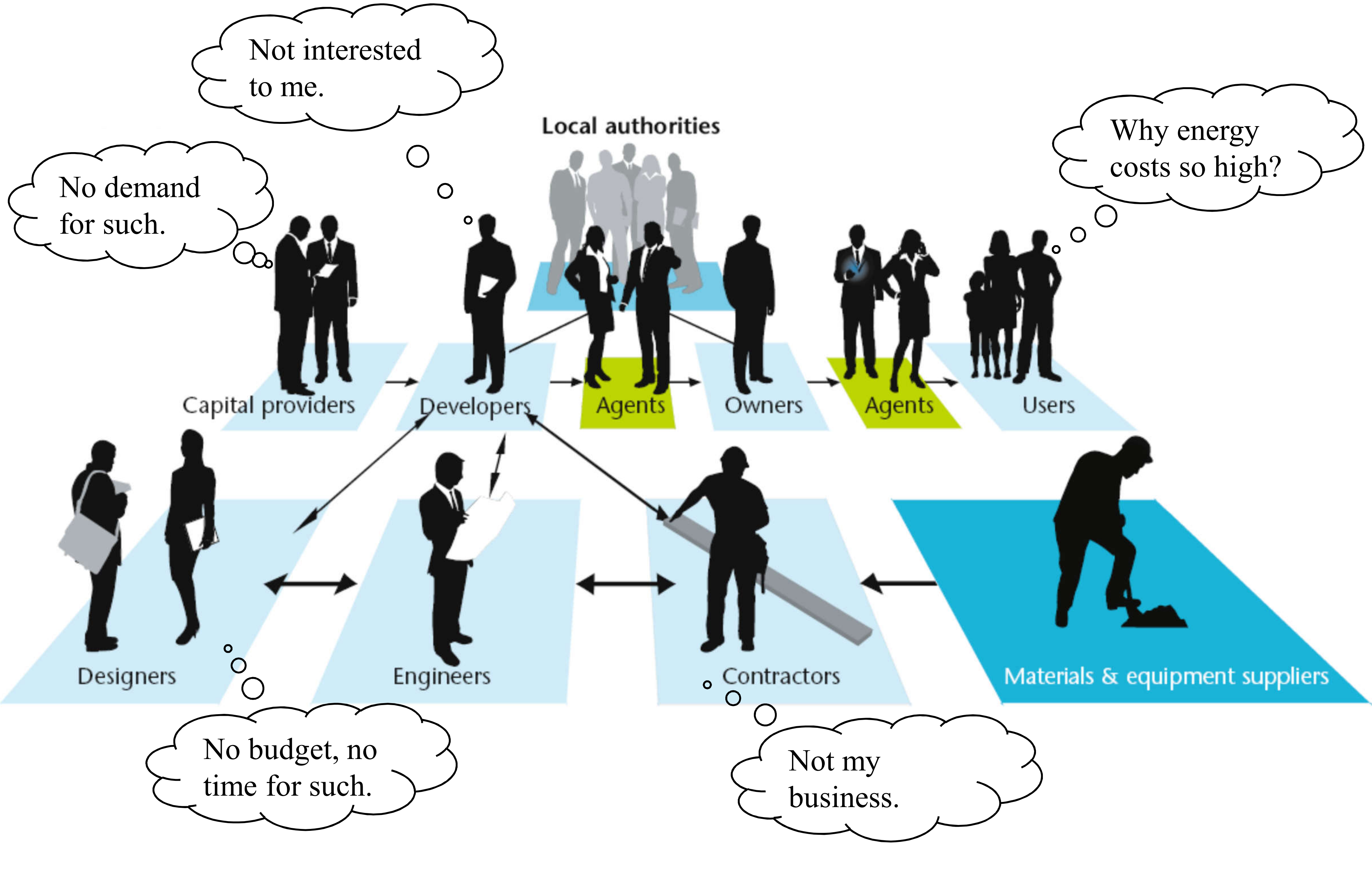
Integrated energy design process

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

Building Energy Design

- Major challenges:
  - To overcome barriers to energy efficiency in discussions with clients and other members of the design and construction team
  - To demonstrate the value of energy efficiency to clients, developers and tenants
- Main barriers:
  - The complex value chain in the building sector
  - Economic, financial & market barriers

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*
  - 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

(* See also http://ibse.hk/SBS5421/DesignStrategy.pdf)

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

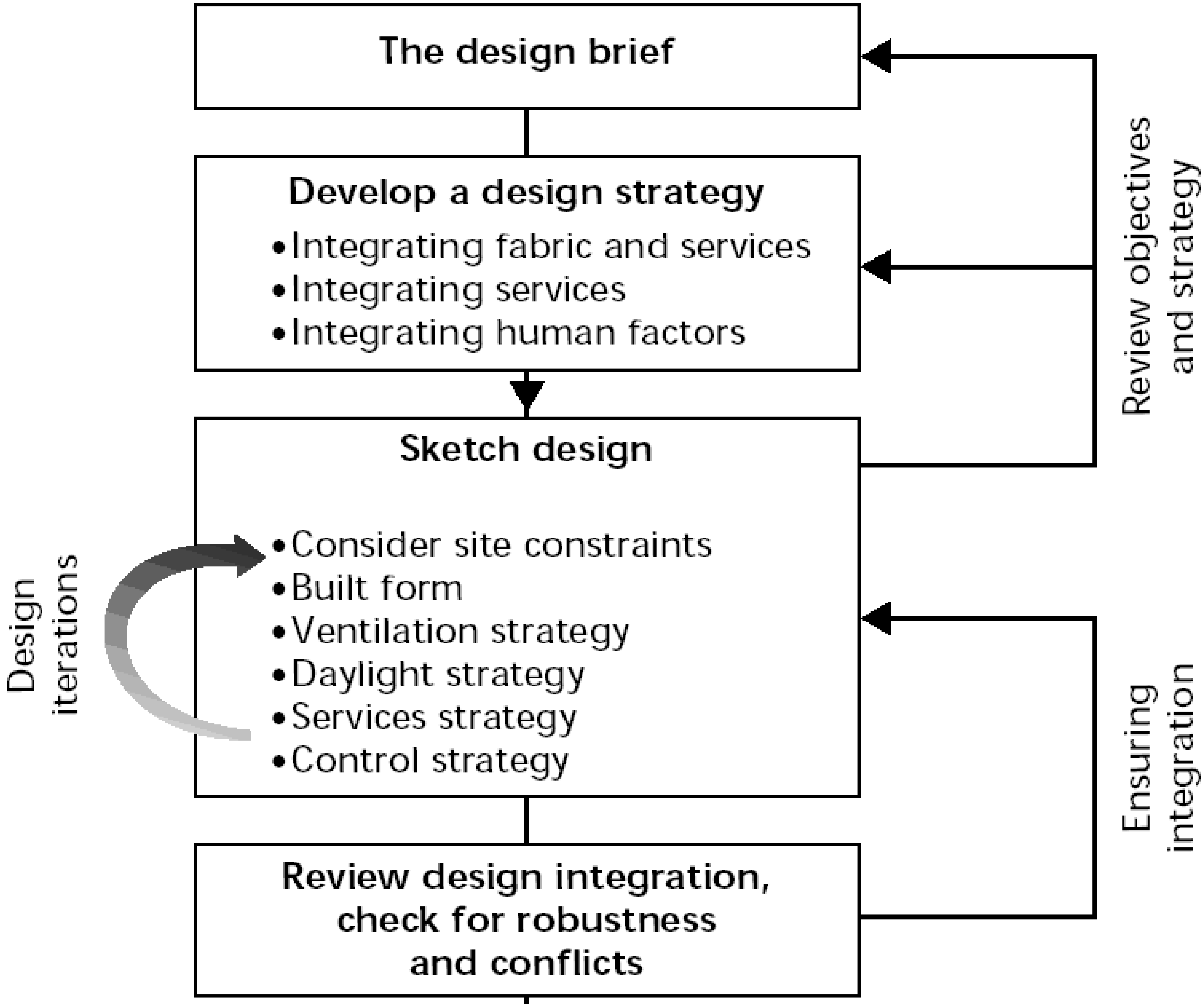
Building Energy Design

- 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

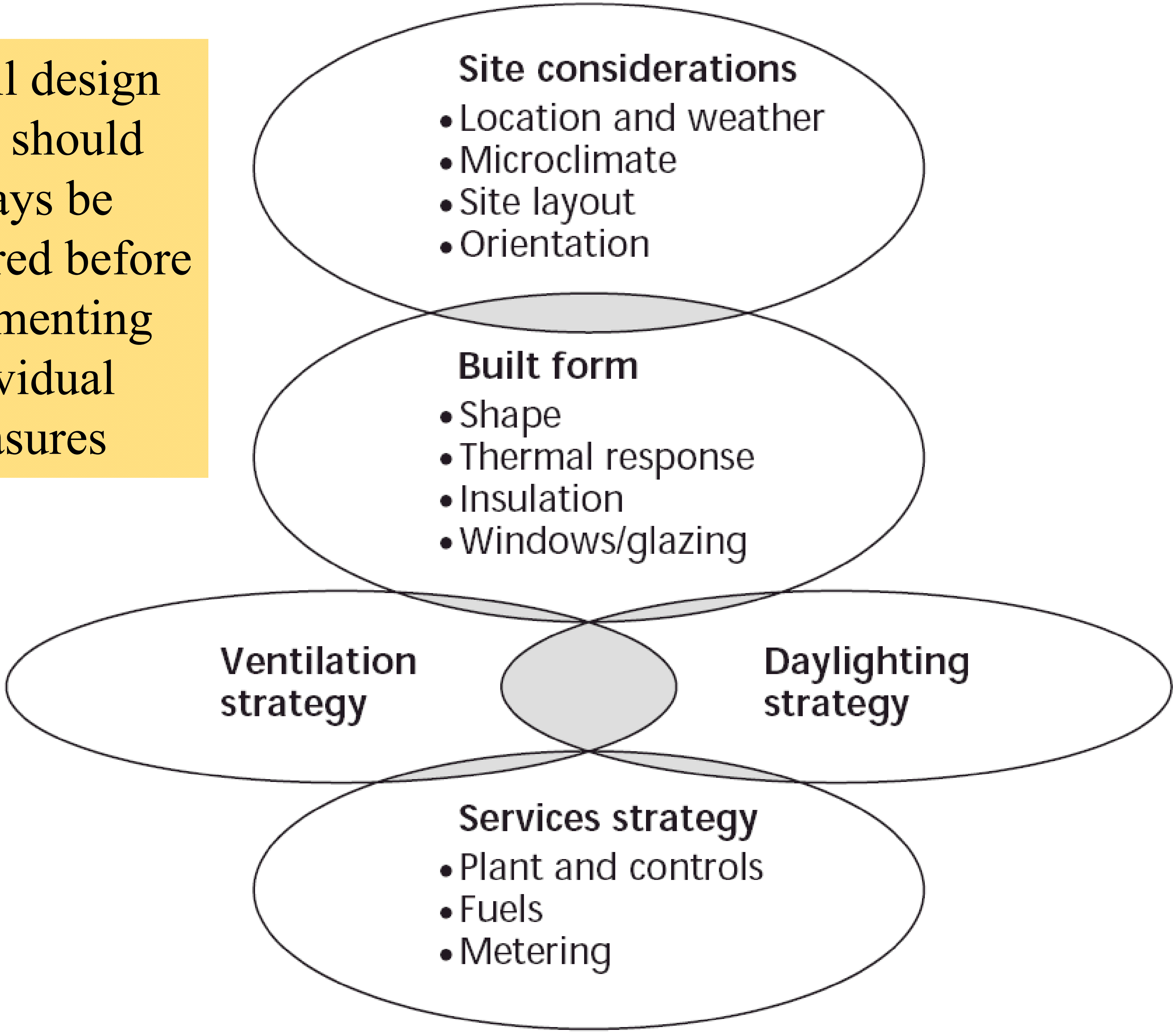
- Building design as an iterative process
  - Review objectives, strategy & design criteria
  - Re-think fundamental aspects of the design
- Integrated approach to energy efficient design
  - Integrate fabric (Arch/Struct) and services (BSE)
  - Integrate building services
  - Integrate human factors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

Holistic approach to building energy design



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

Overall design intent should always be considered before implementing individual measures



(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

(* See also http://ibse.hk/SBS5421/DesignStrategy.pdf)

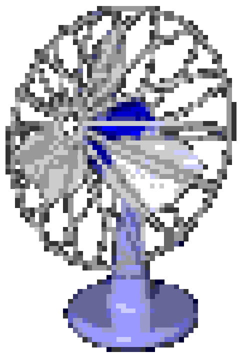
Building Energy Design

- 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

Strong interaction between the building envelope, heating and cooling systems, lighting, etc

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



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)

Human factors are key

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

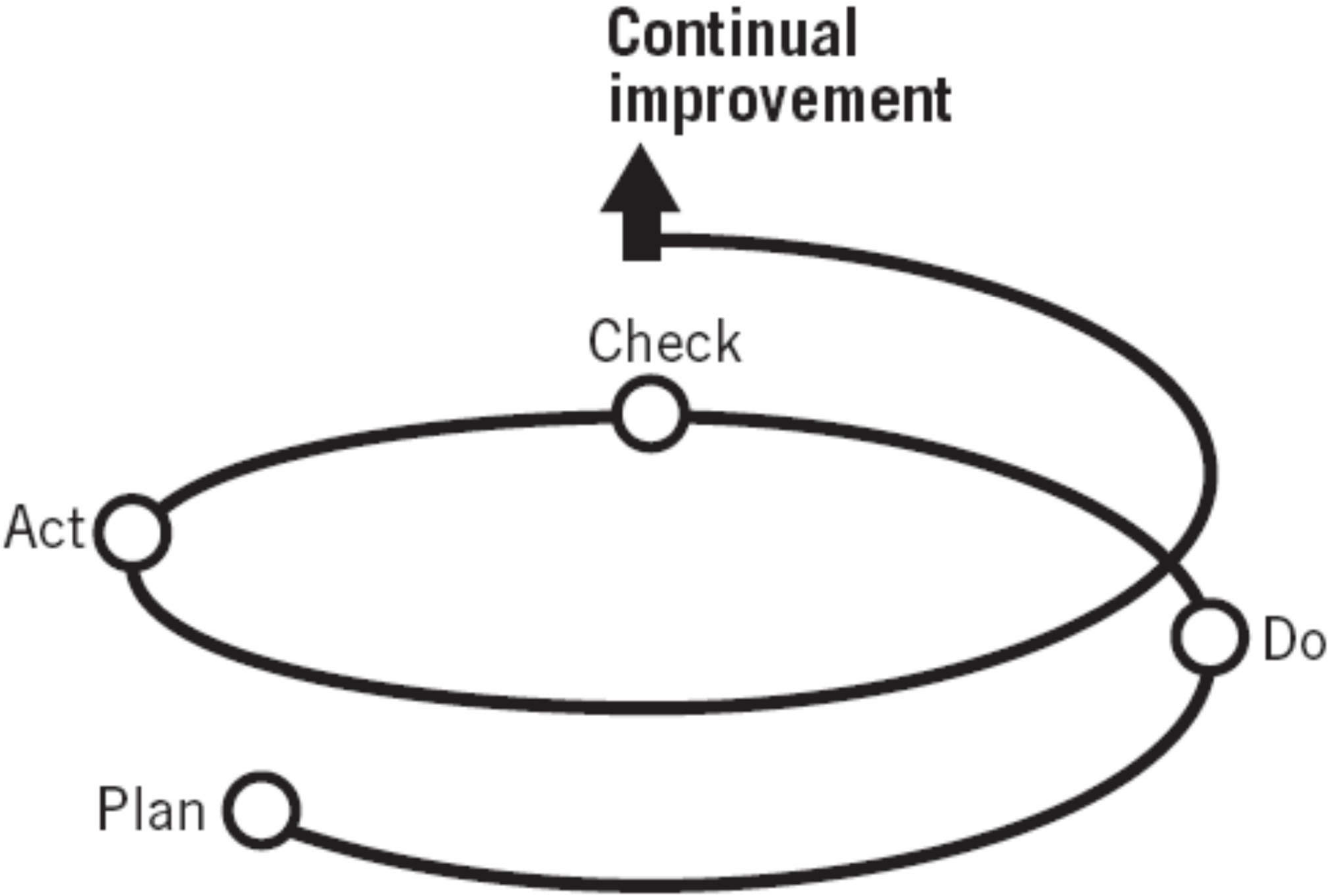
W. Edwards Deming
1900 - 1993

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

(See also: https://www.brighthubpm.com/methods-strategies/97802-a-look-at-demings-system-of-profound-knowledge/)

Four steps of the management process (for continual improvement):

PDCA (Plan-Do-Check-Act)



(See also: https://en.wikipedia.org/wiki/PDCA)

Bldg Energy Management

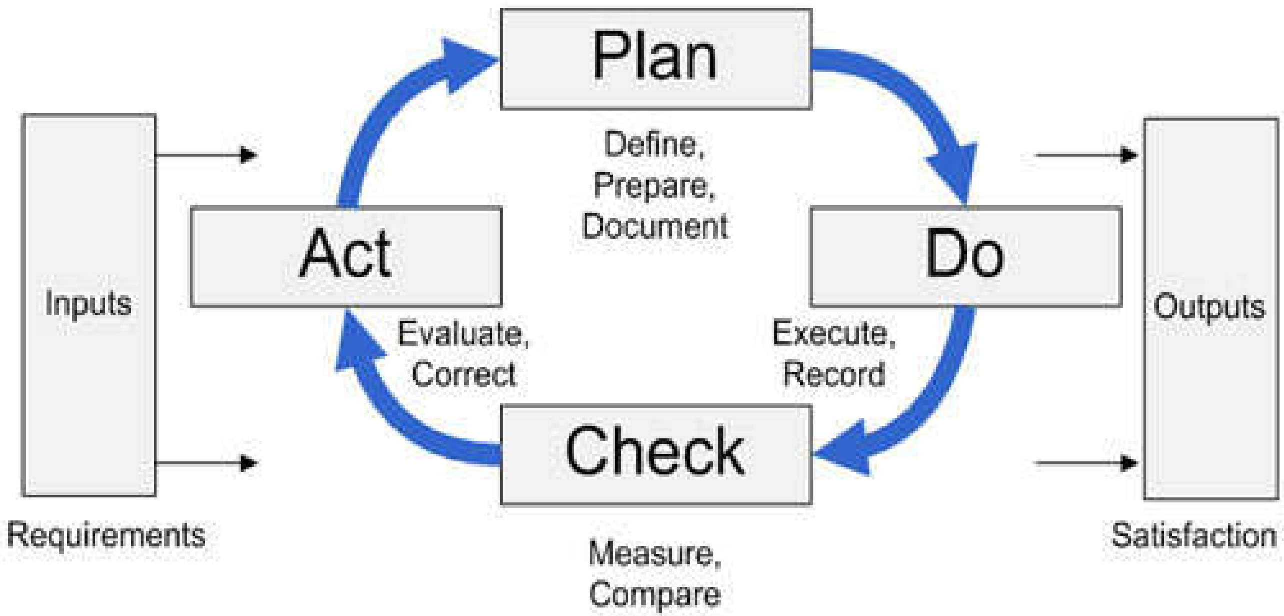
- **Plan**
  - Obtain insight (energy audit)
  - Get management commitment
  - Nominate energy champion
  - Policy, objectives, structure
  - Assign responsibilities
  - Develop programme(s)
  - Set targets and measures
  - Set priorities, develop action plans

Bldg Energy Management

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

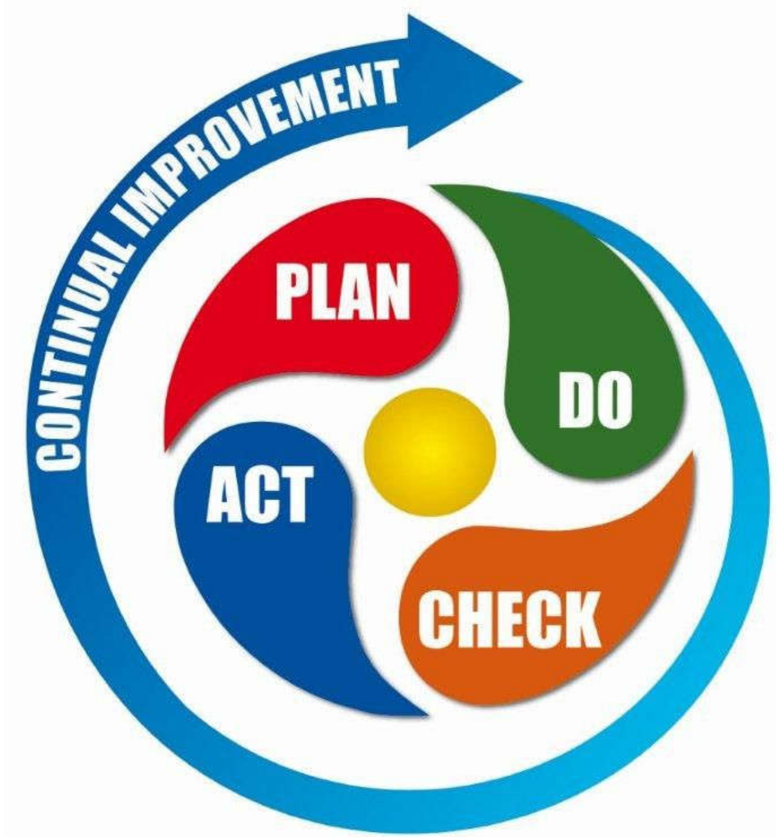
Bldg Energy Management

- **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

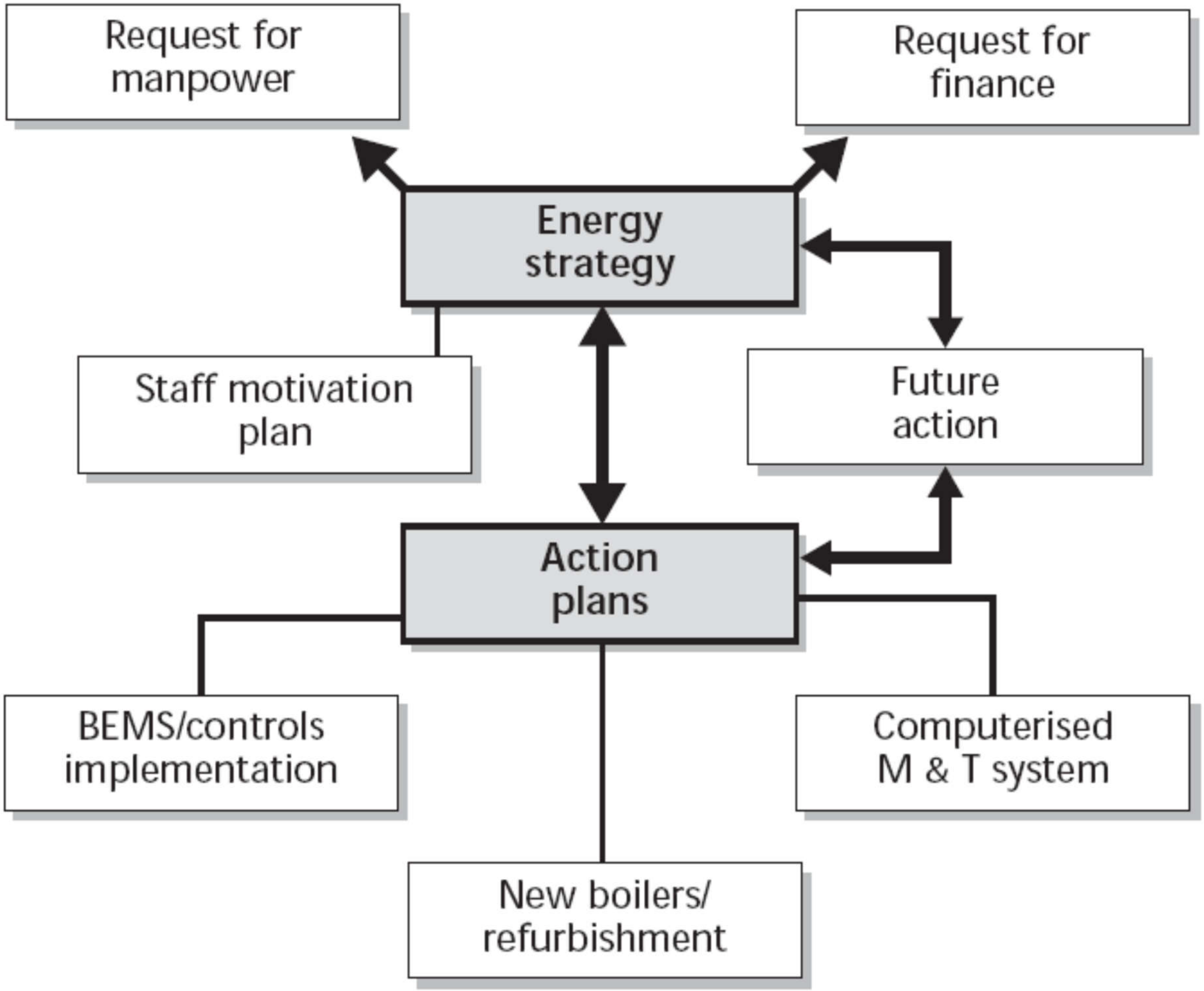
Bldg Energy Management

- 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

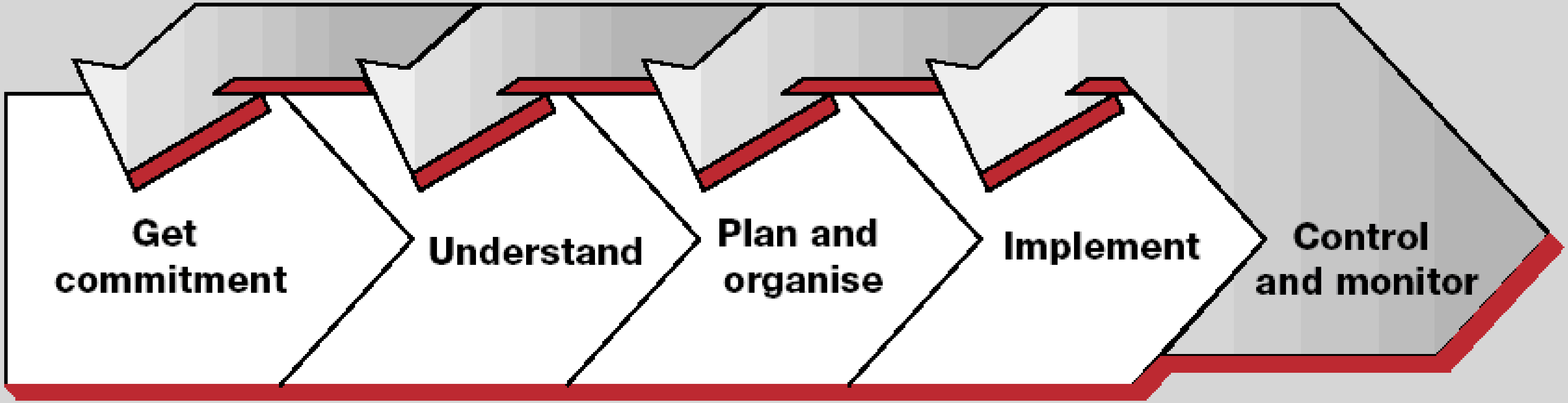
A framework for developing energy policy



* M & T = monitoring & targeting

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

A systematic approach to building 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

- 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 is teamwork

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

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

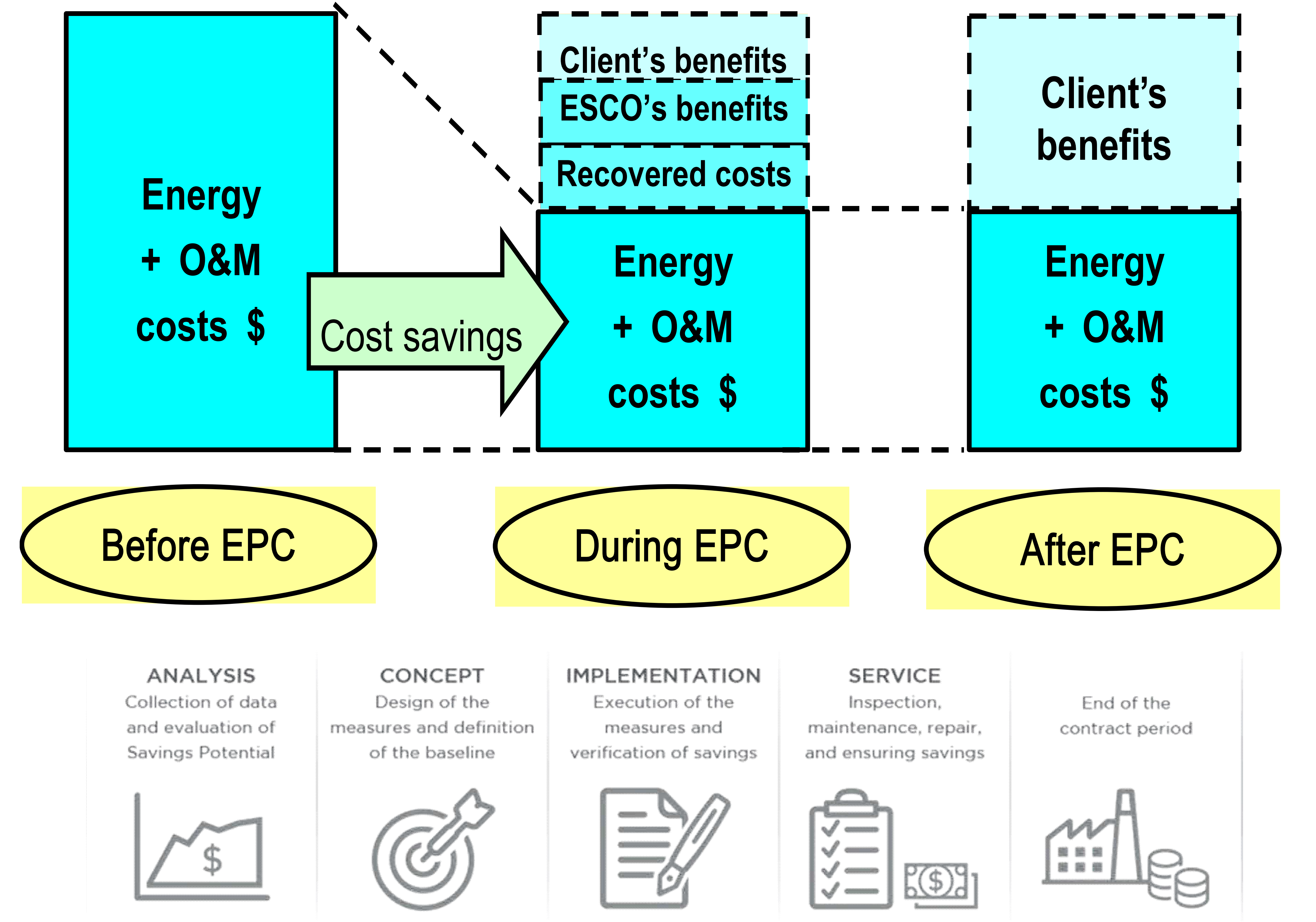
- Retrofitting energy saving measures
  - Identify high energy users
  - Establish the potential for energy saving through measurement, audits etc.
  - Identify practicable measures to achieve savings
  - Establish the financial case for introducing these measures, as well as other benefits
  - Implement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

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

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

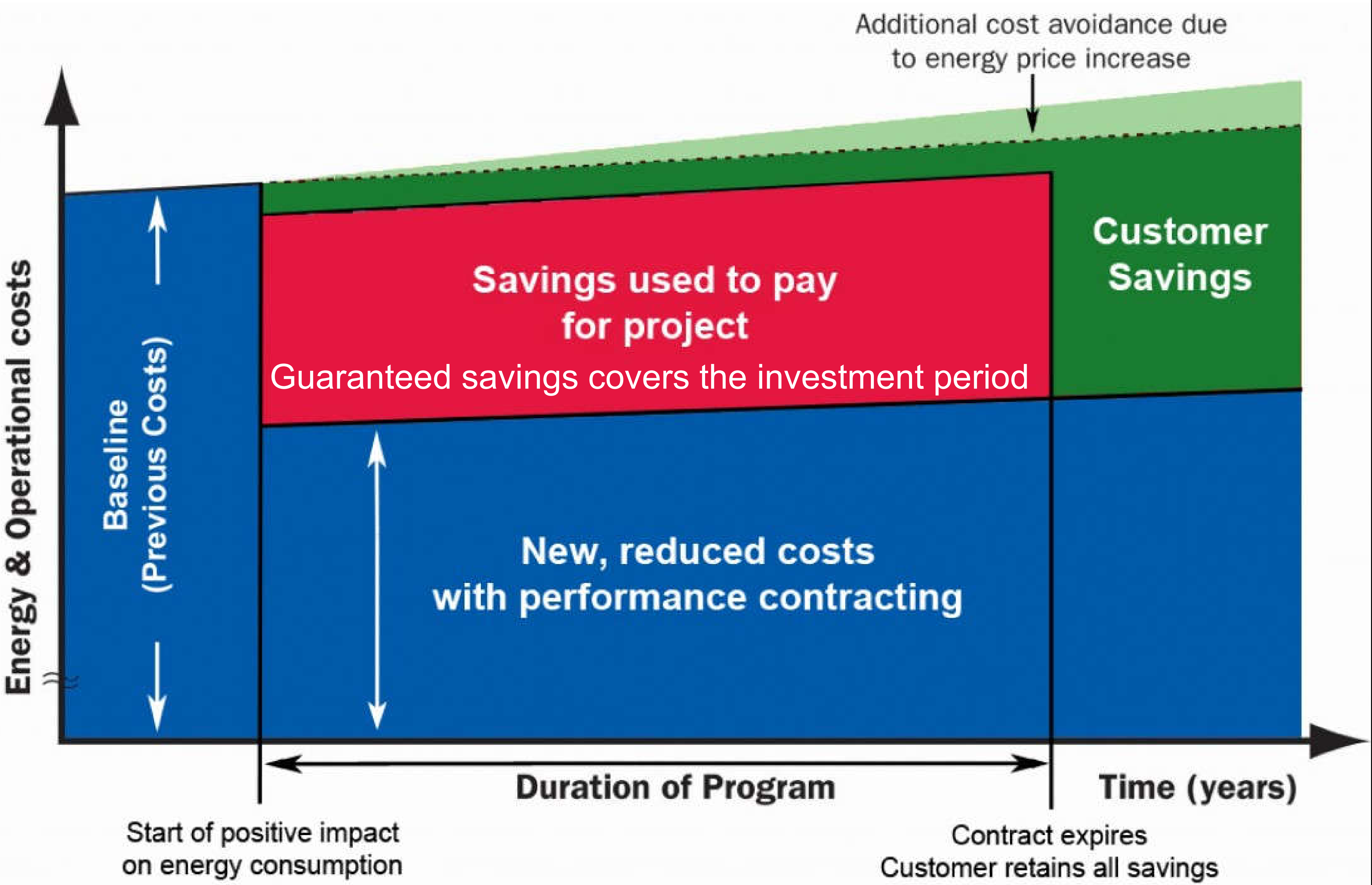
Basic concept of energy performance contracting (EPC)



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)

Customer cash flow of energy performance contracting (EPC)



(Source: http://sandermechanical.com/incentives-financing/energy-performance-contracting/)

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

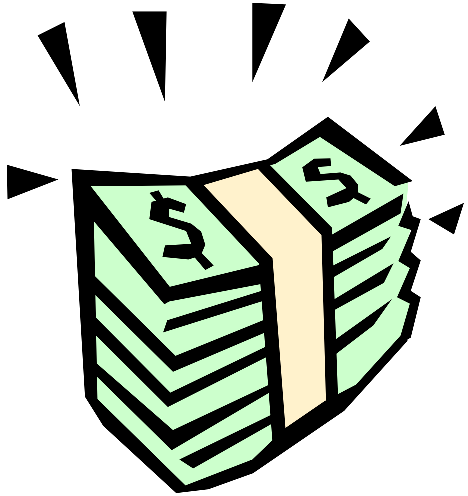
- Typical EPC project stages
  - Stage 1: The opportunity assessment
  - Stage 2: Preliminary energy services
  - Stage 3: Develop detailed proposal
  - Stage 4: Project implementation
  - Stage 5: Performance assurance + M&V services
- Technical knowledge, risk management skills & understanding of local 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

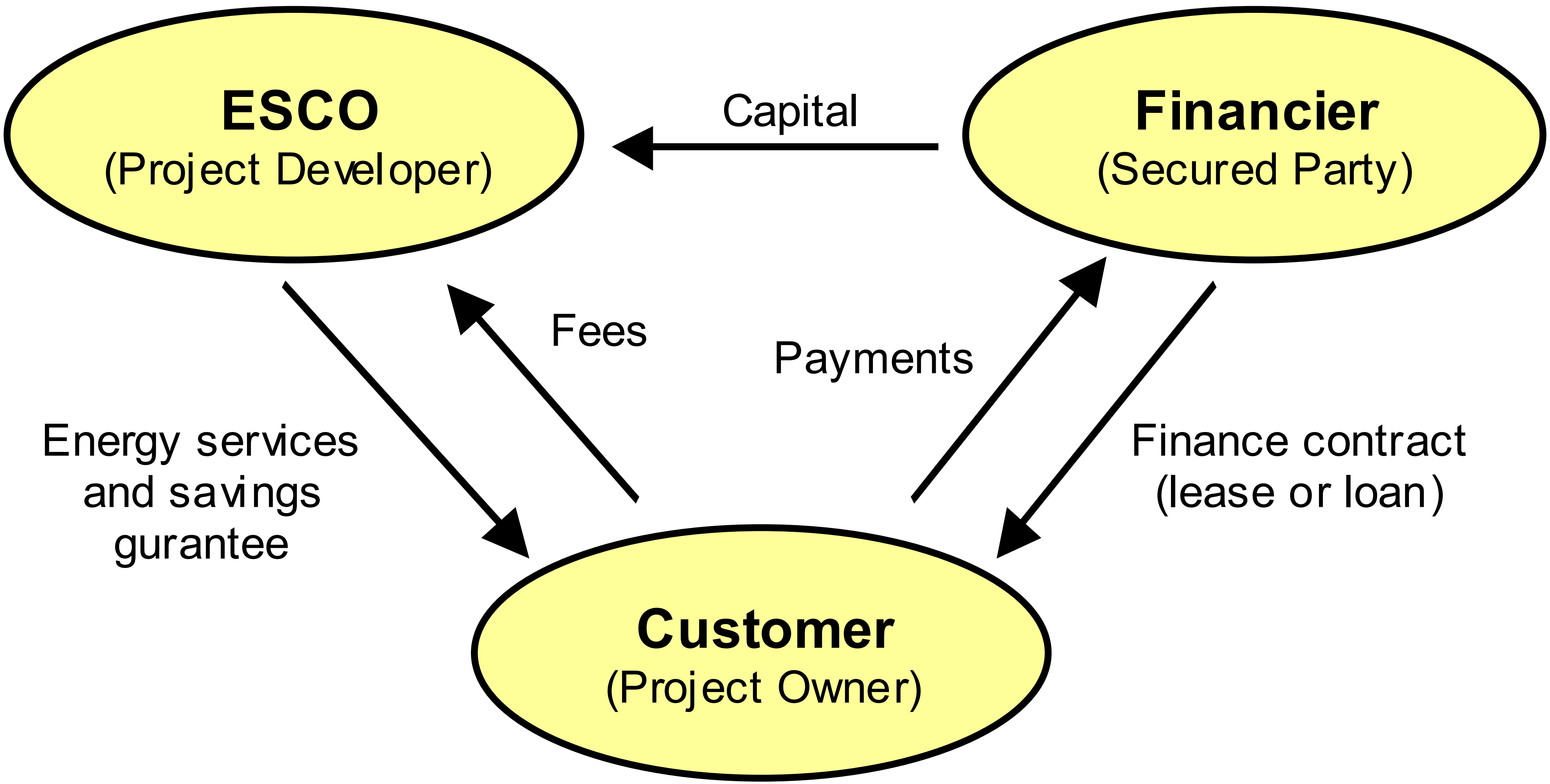
Energy Performance Contracting

- 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

(* IPMVP = International Performance Measurement & Verification Protocol)

M&V options and typical applications

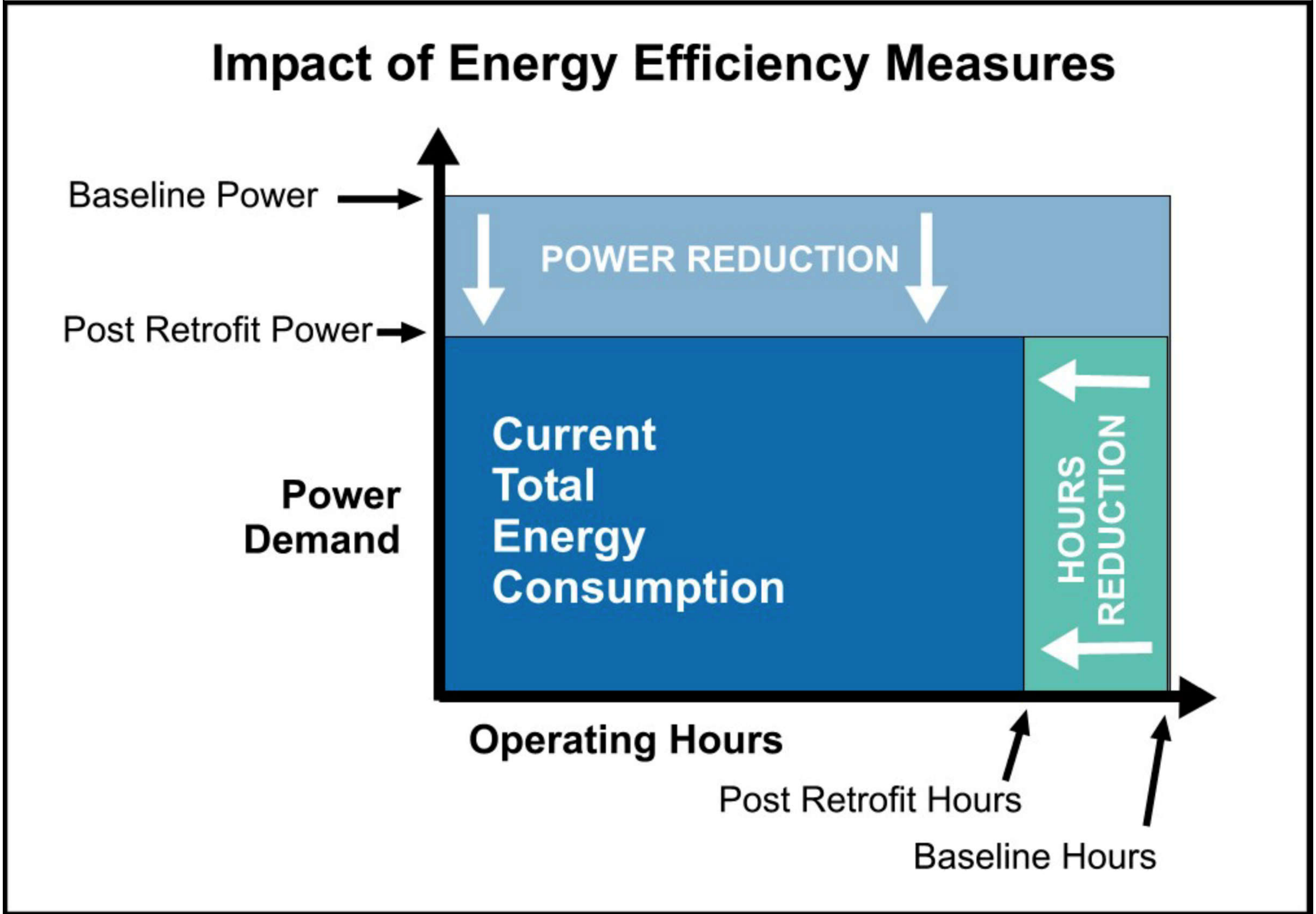
	Description	**Typical applications**
A. Retrofit isolation: key parameter measurement	Savings are determined by partial field measurements of the energy use of the system(s) to which an ECM was applied. Some, but not all, parameters may be stipulated.	Lighting retrofit where pre- and post-retroft fixture Wattages are measured. Operating hours of the lights are typically agreed upon.
B. Retrofit isolation: all parameter measurement	Savings are determined by field measurements of the energy use of the system(s) to which an ECM was applied.	Variable speed drive on a pump. Electricity use is measured by a kWh meter installed on the electrical supply to the pump motor.
C. Whole facility (utility bills or meter data)	Savings are determined by measuring energy use at the utility meter level. Bills may be corrected for weather.	Several ECMs affecting many systems in a building. Utility bills are used.
D. Calibrated simulation	Savings are determined using building simulation. This option is used primarily when there is no pre-retrofit utility data available.	Multifaceted energy management programme affecting many systems in a building but where no base-year data are available.

(Source: www.evo-world.org)

Energy Performance Contracting

- International Performance Measurement & Verification Protocol (IPMVP)*
  - A framework to determine energy and water savings associated with energy conservation measures (ECMs)
- An M&V plan
  - For proper savings determination and form the basis for verification
  - Fundamentally defines the meaning of the word ‘savings’ for each project

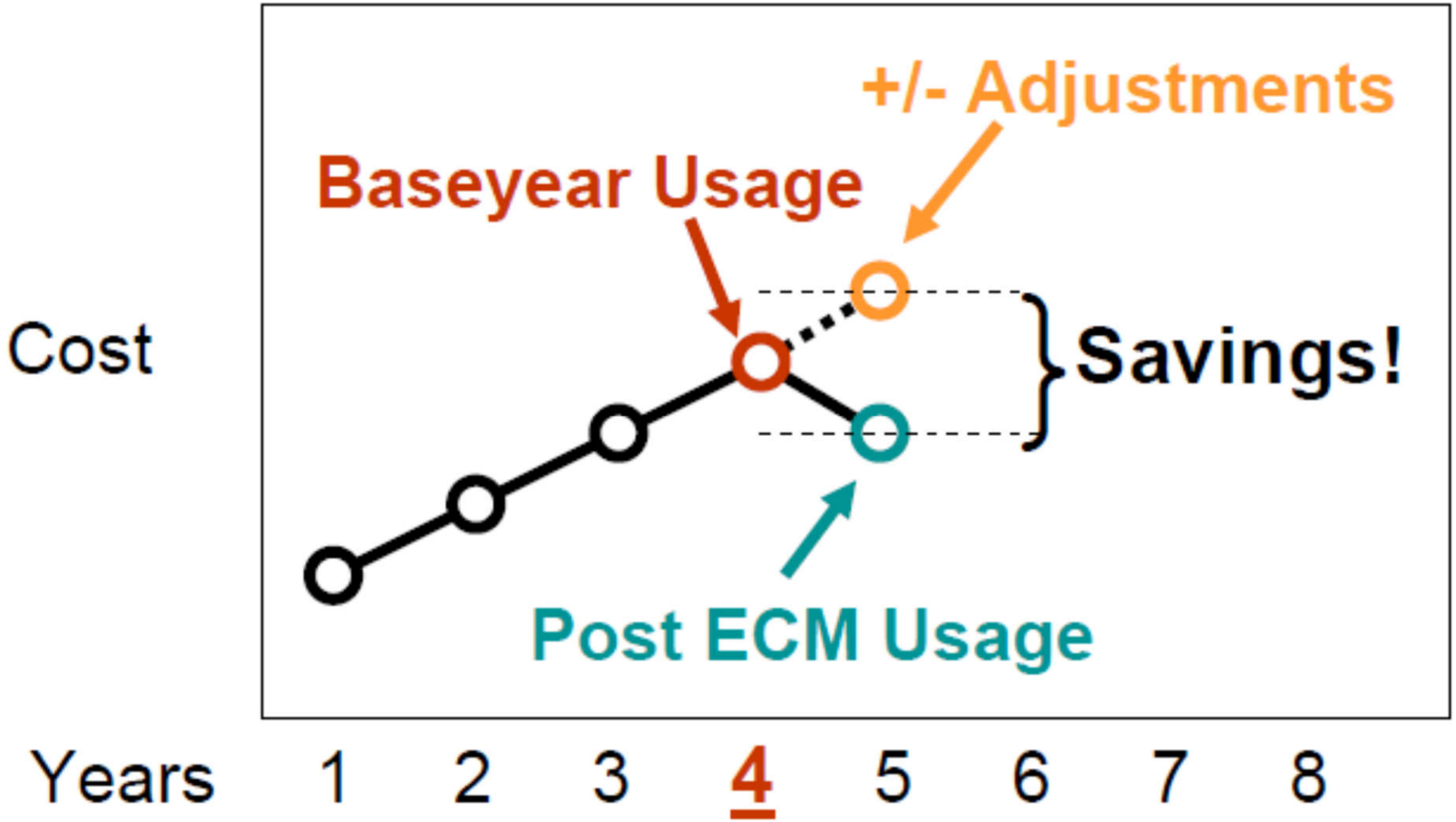
(* See also http://en.wikipedia.org/wiki/International_performance_measurement_and_verification_protocol)



(Source: http://energyperformancecontracting.org)

Credibility of savings calculation

Another term for the "calculated savings" is "cost avoidance"

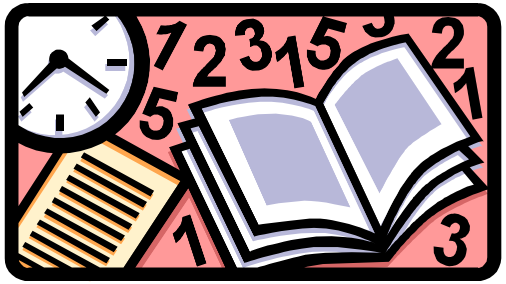


Energy Savings = Baseyear Usage – Post ECM Usage +/- Adjustments

*Key issue: how to determine the baseline & manage the adjustments

(Source: http://energyperformancecontracting.org)

Further Reading



- CIBSE Guide F: Energy Efficiency in Building
  - Chapter 2. The design process
  - Chapter 3. Developing a design strategy
  - Chapter 4. Developing an energy strategy
- Energy Data Management Systems and ISO 50001
  - http://iso50001-energy-management.com/iso50001/pdca/
- Energy Performance Contracting
  - https://e3p.jrc.ec.europa.eu/articles/energy-performance-contracting