<table>
<thead>
<tr>
<th>Topic</th>
<th>Slide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guide F</td>
<td>Slide 3</td>
</tr>
<tr>
<td>Design Factors</td>
<td>Slide 6</td>
</tr>
<tr>
<td>Measuring Energy</td>
<td>Slide 40</td>
</tr>
<tr>
<td>Improving Existing Buildings</td>
<td>Slide 56</td>
</tr>
<tr>
<td>Investment Appraisal</td>
<td>Slide 67</td>
</tr>
</tbody>
</table>
• First published 1998
• Current revision May 2012
Principles of energy efficiency

Part A Designing the building
2 The design process
3 Developing a design strategy
4 Developing an energy strategy
5 Concept design
6 Control strategies
7 Ventilation and air conditioning design
8 Refrigeration design
9 Lighting design
10 Heating and hot water design
11 Motors and building transportation systems
12 Electrical power systems and office equipment
13 Checking the design
14 Commissioning, handover and feedback

Part B Operating and upgrading the building
15 Managing the building
16 Acquisition and refurbishment
17 Maintenance and energy efficiency
18 Energy audits and surveys
19 Benchmarking, monitoring and targeting

Part C Benchmarks
20 Energy benchmarks
Holistic approach to design

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

Human factors are key

Overall design intent should always be considered before implementing individual measures

These are now the principles embedded within current building regulation and implemented through the NCM
Guide F shows how to improve energy performance, reduce running costs and minimise the environmental impact of buildings by:

- designing energy efficient new buildings and refurbishment of existing buildings
- managing and operating buildings in an energy efficient way
- upgrading buildings to improve ongoing energy efficiency
- enabling engineers to overcome barriers to energy efficiency in discussions with clients and other members of the design and construction team
- demonstrating the value of energy efficiency to clients, developers and tenants.
Human factors have greatest influence
<table>
<thead>
<tr>
<th>Services</th>
<th>Heating</th>
<th>Electric Lighting</th>
<th>Daylight/glazing</th>
<th>Natural Ventilation</th>
<th>Mechanical Ventilation and air conditioning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avoid simultaneous heating and cooling</td>
<td>Reduce incidental gains from lights to minimise cooling</td>
<td>Minimise solar gains to reduce cooling loads</td>
<td>Consider mixed-mode to use natural ventilation and avoid mech vent</td>
<td>Use free cooling and ‘coolth’ recovery</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Include contribution of lighting towards heating</td>
<td>Minimise heat loss and maximise useful heat gains thru’ glazing</td>
<td>Account for effect of open windows</td>
<td>Use heat recovery</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Use suitable switching and daylight linking controls to minimise use of electric light</td>
<td></td>
<td>Reduce electric lighting to reduce loads on air conditioning</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Solar gains from glazing may increase loads on air conditioning</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Use natural ventilation instead of air con where possible, or consider mixed-mode</td>
</tr>
</tbody>
</table>

**SERVICES INTER-REACTION**
• Occupants prefer ability to alter their own environment
• Management and systems must be responsive to the needs of the occupant
• Tight comfort bands are not always necessary to achieve acceptable environment
• Design for manageability, maintainability and flexibility

*Comfort is often linked to energy efficiency*
Site Considerations
- Location and weather
  - Microclimate
  - Site layout
  - Orientation

Built Form
- Shape
- Thermal response
  - Insulation
  - Air-tightness
  - Windows/glazing

Ventilation Strategy

Day - lighting Strategy

Services Strategy
- Plant and controls
  - Fuels
  - Metering
What should the sketch design include:

- **Site considerations**
  - Weather, site layout orientation etc.
- **Built form and fabric**
  - Shape, thermal response, thermal insulation, etc.
  - Windows and glazing
  - Airtightness, ventilation and daylighting strategies
- **Services**
  - Concepts for services
  - Fuel selection
Site Considerations

- Local Pollution
- Noise
- Bearing Capacity
- Legislation

Surrounding Buildings

Prevaling Wind & Site Exposure

Building Orientation

Sun Path

Shelter Belts and Shading

Access and Parking
Consider Services / Controls

- Efficient source but avoid oversizing
- Look at part load efficiency
- Good zoning
- Consider mixed-mode
- Effective controls that revert to OFF
- Simple user controls
- Good feedback mechanisms
Consider Fuel Selection

- Cost
- Practicality
  - Availability, access, space, storage
- Metering
- Environmental
  - Electricity 0.541 kg CO$_2$/kWh
  - Gas 0.19 kg CO$_2$/kWh
Introduce energy efficient controls which operate systems efficiently, safely and economically, whilst still allowing individual occupants to adjust their own comfort levels, but avoiding systems defaulting to ON.
GOOD CONTROLS CAN:

- Increase comfort
- Prevent systems running unnecessarily
- Switch systems on and off to minimise consumption
- Ensure the right level of service
- Minimise maintenance requirements
- Optimise energy consumption

Even a well designed system can perform badly with poor controls
• Seek a balance
  – automatic control
  – user adjustability
  – local vs central
• Need good interfaces
• Strategy should be made obvious

Avoid complexity - keep it simple

OVER COMPLEX SYSTEMS lead to vicious circle of poor management, staff dissatisfaction and high running costs
REMEMBER - CONTROLS DON’T PREVENT POOR MANAGEMENT
Checks against benchmarks should be carried out at a number of levels across all the main energy end-uses, including:

- overall building CO2 emissions
- overall energy consumption (kW·h·m–2) of each fuel
- installed power loads (W·m–2) of each major service, e.g. lighting, pumps, fans etc.
- end-use energy consumption (kW·h·m–2) of each major service
- efficiency indicators, such as specific fan power and lighting (W·m–2 per 100 lux).

Many of these are checked as part of the CO2 emissions model but this is only for **compliance** and not necessarily for optimum efficiency.
Figure 13.1 Tree diagram showing an example of actual versus benchmarks for lighting and ventilation (see CIBSE TM22(2)).
Good installation, commissioning, documentation and handover are essential in achieving energy efficiency. Lack of attention to these issues has resulted in poor building performance leading to greater requirements for pre- and post-occupancy performance checks and troubleshooting.

The period immediately after completing construction can be a make-or-break situation for future energy efficiency. It is during this period that the robustness of the design should be tested, the plant checked and set into operation. This time also allows steps to be taken to ensure that building managers understand how the building and its services are meant to work.

Beyond this period, initial and ongoing post-occupancy evaluation provides an important tool to get the building operating correctly and to keep in this state.
Post-occupancy evaluation to:

- review how a building is performing in relation to its design brief (repeat clients can also consider how successful the brief has been and areas which may need to be changed)

- identify whether environmental systems and/or facilities provision are satisfactory from the staff’s perspective, and where improvements should be directed

- evaluate the performance of facilities, energy, or environmental management

- demonstrate to project sponsors that money (including public funds) has been well spent

- help a project team to see how they have performed and to learn lessons for their next project

- evaluate the impact of a building on business performance.
“If you can’t measure it then you can’t manage it!”

CIBSE Guide F - Energy In Buildings
Develop a strong element of feedback to improve understanding from previous good and bad experience related to these principles.

Introduce appropriate metering to improve information and to detect faults rapidly by comparing with norms.
GIGO!
The main energy end uses are determined by adding up the sub meters. e.g. OFFICE EQUIPMENT = Risers 1+2+3

The energy figures shown are the DESIGNERS ESTIMATES of what the plant will use based on the design assumptions. These can be used to compare against actual performance - see table xx later.

Some meters may be thought of as virtual meters. In this case hours run are monitored to give a reasonable estimate of energy consumption.

The building regulations require 90% of each fuel to be sub-metered so some energy consumption may not be metered - in this case around 7%.

In new buildings, the designer will have provided a metering strategy in the log book. This shows how all the metering fits together to monitor energy performance.

The energy figures shown are the DESIGNERS ESTIMATES of what the plant will use based on the design assumptions. These can be used to compare against actual performance - see table xx later.

Some meters may be thought of as virtual meters. In this case hours run are monitored to give a reasonable estimate of energy consumption.

The building regulations require 90% of each fuel to be sub-metered so some energy consumption may not be metered - in this case around 7%.

In new buildings, the designer will have provided a metering strategy in the log book. This shows how all the metering fits together to monitor energy performance.

The energy figures shown are the DESIGNERS ESTIMATES of what the plant will use based on the design assumptions. These can be used to compare against actual performance - see table xx later.

Some meters may be thought of as virtual meters. In this case hours run are monitored to give a reasonable estimate of energy consumption.

The building regulations require 90% of each fuel to be sub-metered so some energy consumption may not be metered - in this case around 7%.

In new buildings, the designer will have provided a metering strategy in the log book. This shows how all the metering fits together to monitor energy performance.

The energy figures shown are the DESIGNERS ESTIMATES of what the plant will use based on the design assumptions. These can be used to compare against actual performance - see table xx later.

Some meters may be thought of as virtual meters. In this case hours run are monitored to give a reasonable estimate of energy consumption.

The building regulations require 90% of each fuel to be sub-metered so some energy consumption may not be metered - in this case around 7%.
Electricity End-Use Comparison 2002

Consumption in kWh/m²

- Other (unmetered) electricity
- Catering (Electricity)
- Computer Room
- Humidification
- Pumps
- Cooling
- Fans
- Office Equipment
- Lighting

ACTUAL SUB METERED
DESIGN ESTIMATES
GOOD PRACTICE BENCHMARKS
### 20.1 Overall building benchmarks

Table 20.1 Fossil and electric building benchmarks\(^{1-22}\) (figures in shaded columns may be regarded as upper limits for new design)

<table>
<thead>
<tr>
<th>Building type</th>
<th>Energy consumption benchmarks for existing buildings / (kW-h/m(^2)) per year (unless stated otherwise)</th>
<th>Basis of benchmark</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Good practice</td>
<td>Typical practice</td>
</tr>
<tr>
<td></td>
<td>Fossil fuels</td>
<td>Electricity</td>
</tr>
<tr>
<td>Catering:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>— fast food restaurants</td>
<td>480</td>
<td>820</td>
</tr>
<tr>
<td>— public houses</td>
<td>1.5</td>
<td>0.8</td>
</tr>
<tr>
<td>— restaurants (with bar)</td>
<td>1100</td>
<td>650</td>
</tr>
<tr>
<td>— restaurants (in public houses)</td>
<td>2700</td>
<td>1300</td>
</tr>
<tr>
<td>Entertainment:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>— theatres</td>
<td>420</td>
<td>180</td>
</tr>
<tr>
<td>— cinemas</td>
<td>515</td>
<td>135</td>
</tr>
<tr>
<td>— social clubs</td>
<td>140</td>
<td>60</td>
</tr>
<tr>
<td>— bingo clubs</td>
<td>440</td>
<td>190</td>
</tr>
<tr>
<td>Education (further and higher)(^{1,2,6,4})</td>
<td></td>
<td></td>
</tr>
<tr>
<td>— catering, bar/restaurant</td>
<td>182</td>
<td>137</td>
</tr>
<tr>
<td>— catering, fast food</td>
<td>438</td>
<td>200</td>
</tr>
<tr>
<td>— lecture room, arts</td>
<td>100</td>
<td>67</td>
</tr>
<tr>
<td>— lecture room, science</td>
<td>110</td>
<td>113</td>
</tr>
<tr>
<td>— library, air conditioned</td>
<td>173</td>
<td>292</td>
</tr>
<tr>
<td>— library, naturally ventilated</td>
<td>115</td>
<td>46</td>
</tr>
<tr>
<td>— residential, halls of residence</td>
<td>240</td>
<td>85</td>
</tr>
<tr>
<td>— residential, self catering/flats</td>
<td>200</td>
<td>45</td>
</tr>
<tr>
<td>— science laboratory</td>
<td>110</td>
<td>155</td>
</tr>
<tr>
<td>Education (schools)(^{20,1}):</td>
<td></td>
<td></td>
</tr>
<tr>
<td>— primary</td>
<td>113</td>
<td>22</td>
</tr>
<tr>
<td>— secondary</td>
<td>108</td>
<td>25</td>
</tr>
<tr>
<td>— secondary (with swimming pool)</td>
<td>142</td>
<td>29</td>
</tr>
</tbody>
</table>
20.3 **Detailed end-use benchmarks**

20.3.1 **Offices**

The benchmarks in Tables 20.9 and 20.10 are taken from Energy Consumption Guide ECG 19[100], and relate to treated floor area.

**Table 20.9** Offices: system and building energy benchmarks

<table>
<thead>
<tr>
<th>System</th>
<th>Delivered energy for stated office types / (kW·h·m$^{-2}$) per year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Type 1</td>
</tr>
<tr>
<td></td>
<td>Good practice</td>
</tr>
<tr>
<td>Gas/oil heating and hot water</td>
<td>79</td>
</tr>
<tr>
<td>Catering gas</td>
<td>0</td>
</tr>
<tr>
<td>Cooling</td>
<td>0</td>
</tr>
<tr>
<td>Fans, pumps and controls</td>
<td>2</td>
</tr>
<tr>
<td>Humidification</td>
<td>0</td>
</tr>
<tr>
<td>Lighting</td>
<td>14</td>
</tr>
<tr>
<td>Office equipment</td>
<td>12</td>
</tr>
<tr>
<td>Catering electricity</td>
<td>2</td>
</tr>
<tr>
<td>Other electricity</td>
<td>3</td>
</tr>
<tr>
<td>Computer room</td>
<td>0</td>
</tr>
<tr>
<td>Total gas or oil</td>
<td>79</td>
</tr>
<tr>
<td>Total electricity</td>
<td>33</td>
</tr>
</tbody>
</table>

*Note: Type 1: cellular naturally ventilated; Type 2: open plan naturally ventilated; Type 3: 'standard' air conditioned; Type 4: 'prestige' air conditioned*
• meter, as appropriate
• allocate responsibilities
• Analyse
• look for trends and act on exceptions
• set sensible targets

• accumulated data allows better purchase
• knowledge allows better management
MAKING EXISTING BUILDINGS MORE EFFICIENT

CIBSE Guide F
The key improving the efficiency is to understanding the building:

- gain a strategic overview of the design intent
  - occupancy
  - usage
  - plant (heating, cooling, ventilation, lighting)
  - BMS / meterig
- ensure that the building is well documented
  - building log book
  - O & M manuals
- identify the current status of the building
  - energy audit
  - energy survey
  - condition reports
  - post occupancy evaluation
- identify and address problem areas
  - root cause analysis
  - post correction review
Definition
Energy audit: a study to determine the quantity and cost of each form of energy to a:
- Building...
- Process/manufacturing unit...
- Piece of equipment...
- Site...
...over a given period, usually a year.
Energy survey: a technical investigation of the control and flow of energy in a:
- Building...
- Process/manufacturing unit...
- Piece of equipment...
- Site...
  ...with the aim of identifying cost-effective energy saving measures.

Energy surveys can be conducted on entire sites, individual manufacturing units, utility systems or specific items of equipment.
Appendix 18.A1: Site survey checklist

Building fabric
As a retrofit measure, major energy saving building fabric measures are best applied when repairing or refurbishing the fabric. Major alterations are usually difficult to justify on energy saving grounds alone due to high capital costs and the resultant extended paybacks. Consequently, these projects often go ahead for other reasons, e.g. deterioration of existing fabric. When this is the case, it presents an opportunity to significantly improve the fabric energy efficiency in which case paybacks should be related to the marginal cost of including a superior specification. See section 4 and FEB 16(19).

Identifying problems
Problems can be identified by the following methods:
- **Thermography:** detects damaged or missing insulation and air leakage by identifying areas of fabric with high temperature in winter.
- **Building air pressure testing:** establishes the magnitude of infiltration leakage paths through the building fabric(20); used in conjunction with smoke pencils or thermography, pressure testing can identify primary leakage paths.
- **Building simulation:** computer models are used to highlight major areas of heat loss and predict the effect of fabric changes on energy use.

Roofs
- Check the thickness of insulation above ceilings in pitched roof spaces. Areas may be found where insulation is missing or defective. Old, compact insulation may need to be upgraded.
- Installing a suspended ceiling beneath flat or pitched roofs could reduce the transmittance and the treated volume. Fitting

Doors
- Examine the condition of doors for maintenance problems such as faulty catches or automatic closers, and misaligned or seriously distorted frames needing re-hanging or replacement.
- Consider providing personnel access doors to avoid frequent use of large vehicle access shutters or doors.

Floors
- Note problems of air infiltration under or through suspended or ventilated floors. Internal floor covering can be effective, provided the floor structure does not suffer adversely when ventilation is restricted.

Draught proofing
Draught proofing is often one of the most cost effective means of improving building fabric since uncontrolled air infiltration can be a cause of significant heat loss from buildings, particularly those that are well insulated.

**External doors and entrances:**
- [ ] Add draught lobbies to busy entrances, although capital cost may be high.
- [ ] Install weather stripping on doors or replace, if worn or broken.
- [ ] Use automatic door-closers on external doors, or entrances to unconditioned or unheated spaces.
- [ ] Provide signs and instructions for the operation of doors; and a reminder to keep closed.
- [ ] Consider using expandable entrance enclosures to connect to...
What are the Top 10 Things to Reduce Carbon Emissions in Existing Buildings?
1. Develop a corporate energy strategy
2. Appoint an energy manager
3. Invest in the energy campaign
4. Identify specific measures
5. Implement the measures
6. Monitor against targets
7. Change staff behaviour
8. Purchasing policies
9. Consider renewables and CHP
10. Introduce carbon emissions trading
• Switch off office equipment
• Switch off lights and heating in vacant spaces
• Don’t run heating and air conditioning at the same time
• Stop draughts
• Stop dripping taps
• Don’t obstruct radiators
• Fix compressed air leaks
• Door closing mechanisms
• Variable speed drives for variable loads
• Simple heating controls
• Fit presence detecting light controls
• Fit good time switches and thermostats
• Maintain for peak performance
• Replace inefficient motors
• Fit high frequency fluorescent lighting
• Upgrade heating / cooling / refrigeration plant
• Evaluate performance of all equipment
• Implement Monitoring and Targeting programme to relate utility consumption to output / activity
Consider all the options

- Simple payback
- Discounted Cash Flow
- Net Present Value
- Life Cycle costing
How much does it cost?

- A compact bulb over its life of 10,000 hours costs £2 to buy and £17 to use
- Ten GLS 100W bulbs over their combined life of 10,000 hours cost £3 to buy and £80 to use

A saving of over £64 for one light point!
Heating

Reducing room temperature by 1°C can reduce fuel use by around 10%

Reducing the ON time by 2 hours per day can save around 10% in running costs
USING GUIDE F TO ACHIEVE
LOW CARBON SYSTEMS FOR WORKS IN EXISTING BUILDINGS
Encourage energy efficient operation of buildings through management, policy, maintenance, monitoring and control
Ensure that building services are properly commissioned and handed over to managers, operators and occupants.
Establish the:-

- high energy users
- potential for savings
- practical savings measures
- financial case
- other benefits

Implement the savings

then

monitor the savings
CONTRIBUTORS TO POOR BUILDING PERFORMANCE

• Client expectations not being achievable within the capacity of the existing plant
• Unsatisfactory design, equipment selection, installation or commissioning
• Poor understanding and management of systems and building
• Excessive internal gains
• Excessive air infiltration
• Poor quality and standard of maintenance
• Systems conflicting
• Inadequate commissioning of engineering plant and equipment
• Controls not set up correctly
• Unsatisfactory part load performance of plant
• Over complex systems and controls

See WHY BUILDINGS FAIL Guide F, Part B
QUESTIONS?