Self-evaluation Exercise (2008-2009) (Suggested Solutions)

1. (a) (* Outline of the solution only)

Possible benefits of 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

Key strategies to achieve energy efficiency for new buildings and existing buildings (w/ discussions):
- For new buildings
  - Designing the building
    - Design strategy
    - Control strategies
    - Commissioning
- For existing buildings
  - Operating and upgrading the building
    - Building management
    - Refurbishment/renovation/retrofitting
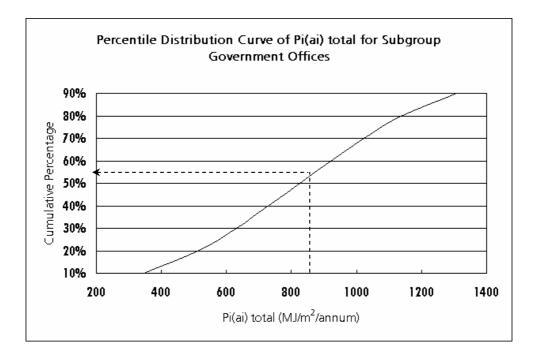   - Maintenance and monitoring

1. (b) (* Outline of the solution only)

Average cost of electricity = \$3.5 x 10^6 / 3.2 x 10^6 kWh = **$1.09 per kWh**

Net floor area = 0.7 x Gross floor area = 0.7 x 20,000 = 14,000 m^2
Energy charge = annual electricity cost x (1 – 15%)

   i) Energy utilization index, based on net floor area is:
      3.2 x 10^6 / 14,000 = **228.6 kWh/m^2/year**   (or 823 MJ/m^2/year)

   ii) Energy cost index, based on net floor area is:
      \$3.5 x 10^6 x (1 – 15%) / 14,000 = **$212.5 /$m^2$/year**

From the given energy benchmark graph, at 823 MJ/m^2/year the percentile is about 54%. That means, 46% of the building population in this group is having energy consumption level higher than this building while 54% of the building population is having energy consumption level lower than it. This building is close to the average in the group.

Percentile Distribution Curve of Pi(ai) total for Subgroup Government Offices

2.   (a)   (* Outline of the solution only)

The EU directive, came into force on 4 Jan 2003, is an important move by the European Union and will contribute to reducing carbon dioxide emissions under the Kyoto protocol (Europe overall -8% emission). It will also set out a trend for promotion & assessment of building energy performance in the world.

How does the EU directive work? It facilitated requirements to measure building energy use by:
- Introducing agreed measurements of relative energy performance
- Regular inspections and re-evaluations
- Requiring higher standards for upgrading larger buildings
- Improving standards for new buildings

Four major requirements of the directive and their implications (w/ brief description):
1. Methodology for integrated buildings energy performance standards
2. Application of these standards on new and existing buildings
3. Certification schemes for all buildings
4. Inspection & assessment of boilers/heating and cooling installations

2.   (b)   (* Outline of the solution only)

Annual energy cost savings in dollars:
   Option A = [(360,000 – 180,000) / 3.6] x ($1/kWh) = **$50,000**
   Option B = [(360,000 – 252,000) / 3.6] x ($1/kWh) = **$30,000**

Simple payback (SPB):
   Option A = $200,000 / $50,000 = **4 years**
   Option B = $100,000 / $30,000 = **3.3 years**

Return on investment (ROI):
   Option A = $50,000 / $200,000 x 100% = **25%**
   Option B = $30,000 / $100,000 x 100% = **30%**

With interest rate 10% and the study period 10 years, present worth factor is:

PWF = [1 – 1/(1 + 0.1)10]/0.1 = 6.145

Net present value (NPV):

Option A = -$200,000 + $50,000 x 6.145 = **$107,250**
Option B = -$100,000 + $30,000 x 6.145 = **$84,350**

Since Option A has a higher NPV, it is preferred.

3.   (a)   (* Outline of the solution only)

Prescriptive approach:
- Advantages:
    - Simple to use & follow
    - Easy to check & enforce
- Drawbacks:
    - Rather restrictive
    - Barrier to innovation & performance optimization
    - Hinder cross-country product trading

Performance approach:
- Advantages:
    - More clearly explains what the code intends
    - Permits innovation & alternative solutions
    - More flexible regulatory environment, easily updated
    - Encourage building/technology research
- Drawbacks:
    - Often more efforts are needed for analysis/compliance
    - Can be very complex & require energy expertise

Four situations where simulation method is not recommended:
- If it can't answer the design question (such as airflow & occupant behaviours)
- If the design has proceeded too far (unlikely anything can be changed)
- If project is too small or time is too tight (not economical to carry out simulation)
- If you do not understand the benefits & limitations of the simulation

3.   (b)   (* Outline of the solution only)

From the pump law, estimated new annual energy consumption is:

(8,000 kWh) x (70/100)3 = 2,744 kWh

Therefore, Estimated annual energy savings = (8,000 – 2,744) = **5,526 kWh**

Estimated annual energy cost savings = (5,526 kWh) x ($1/kWh) = $5,256

Net annual cost saving = $5,256 - $200 = **$5,056**

Simple payback = $20,000 / $5,056 = **3.96 years**

Discount factor = $(1 + r)^{-n} = (1 + 8\%)^{-n}$

Thus, cash flow analysis for a study period of 10 years is:

Year	Initial cost	Energy savings	Additional maint. cost	Net cost savings	Discount factor	Present value
0	-$20,000				1.000	-$20,000
1		$5,256	-$200	$5,056	0.926	$4,682
2		$5,256	-$200	$5,056	0.857	$4,333
3		$5,256	-$200	$5,056	0.794	$4,014
4		$5,256	-$200	$5,056	0.735	$3,716
5		$5,256	-$200	$5,056	0.681	$3,443
6		$5,256	-$200	$5,056	0.630	$3,185
7		$5,256	-$200	$5,056	0.583	$2,948
8		$5,256	-$200	$5,056	0.540	$2,730
9		$5,256	-$200	$5,056	0.500	$2,528
10		$5,256	-$200	$5,056	0.463	$2,341
			Total =	**$50,560**		**$13,926**

Total life cycle cost = -$20,000 + $33,926 = $13,926

Or, with interest rate 8% and the study period 10 years, present worth factor is:
$$PWF = [1 - 1/(1 + 0.08)^{10}]/0.08 = 6.71$$

Total life cycle cost = -$20,000 + $5,056 x 6.71 = $13,926