



**Energy  
Sustainability  
Unit**

# Development of Measurement & Verification Guideline for Singapore

**Seminar on EAEF Project 64 & 68  
Energy Performance Contracting & benchmarking  
13 January 2006  
School of Design & Environment, NUS**

***Ms. Li Shuo  
Energy Sustainability Unit  
National University of Singapore***



# Agenda

---



Energy  
Sustainability  
Unit

- The introduction of M&V guideline
- Basic concept and methodology of M&V
- Why Singapore needs its own M&V guideline
- EU Project 64
- The development of commercial building baseline model in Singapore
- Current and future work

Seminar on EAEF Project 64 & 68  
Energy Performance Contracting & benchmarking  
13 January 2006  
School of Design & Environment, NUS



# Introduction of M&V



Energy  
Sustainability  
Unit

- **What is M&V?**

Measurement and Verification is a process or protocol to confirm the actual energy savings realized from a Demand Side Management project once the project is implemented and operating

- **Why M&V?**

Savings are guaranteed, but actual savings fluctuate every year.

Seminar on EAEF Project 64 & 68  
Energy Performance Contracting & benchmarking  
13 January 2006  
School of Design & Environment, NUS



# Current M&V guidelines worldwide



Energy  
Sustainability  
Unit

- ASHRAE Guideline -14P
- IPMVP
- FEMP M&V guideline
- Various M&V guidelines in different countries

Seminar on EAEF Project 64 & 68  
Energy Performance Contracting & benchmarking  
13 January 2006  
School of Design & Environment, NUS



# Introduction of M&V



Energy  
Sustainability  
Unit

- Basic concept

*Energy savings = Baseyear Energy Use - Post-Retrofit Energy Use ± Adjustments*

- Methodologies --- 4 Options ✨

- Implementation

Guidance on energy saving project procedures, documentations, etc.

Seminar on EAEF Project 64 & 68  
Energy Performance Contracting & benchmarking  
13 January 2006  
School of Design & Environment, NUS



# Why Singapore need its own M&V guideline?



Energy  
Sustainability  
Unit

- The tropical weather condition
- Singapore lacks standard energy saving performance contract (EPC) framework
  - Standard EPC form
  - Financial options for EPC
  - Procedure and relative documentations

Seminar on EAEF Project 64 & 68  
Energy Performance Contracting & benchmarking  
13 January 2006  
School of Design & Environment, NUS



# The EU Project 64 and its objectives



Energy  
Sustainability  
Unit

- **EU Project 64 –**

Development of a business model for building energy performance services in the ASEAN region

- **Objectives:**

- An ASEAN building energy performance model for commercial buildings
- Energy services procurement template in terms of procedure and documentation
- Project financing options and relevant documents and project progress monitoring and management documentation

Seminar on EAEF Project 64 & 68  
Energy Performance Contracting & benchmarking  
13 January 2006  
School of Design & Environment, NUS



# Developing 4 options for Singapore M&V



Energy  
Sustainability  
Unit

- **Option A**  
Example: Lighting system  
Count --- the number of lights  
Measure --- the light power  
Stipulate --- Operation hours
- **Option B**  
Example: VSD on HVAC Fan  
Measure --- Power of the VSD Fan  
Operation hours

$$E \text{ Savings} = \text{Hour}_{\text{before}} * \text{kW}_{\text{Before}} - \text{Hour}_{\text{after}} * \text{kW}_{\text{After}}$$

We keep the baseline method for Option A&B same with IPMVP

Seminar on EAEF Project 64 & 68  
Energy Performance Contracting & benchmarking  
13 January 2006  
School of Design & Environment, NUS



# Developing 4 options for Singapore M&V



Energy  
Sustainability  
Unit

- Option C (whole building approach)
  - ❖ ASHRAE standard 14P provides 7 methods to develop baseline model
  - ❖ ESU Methods:
    - Statistical regression
    - Neural Network
    - Support Vector Machine

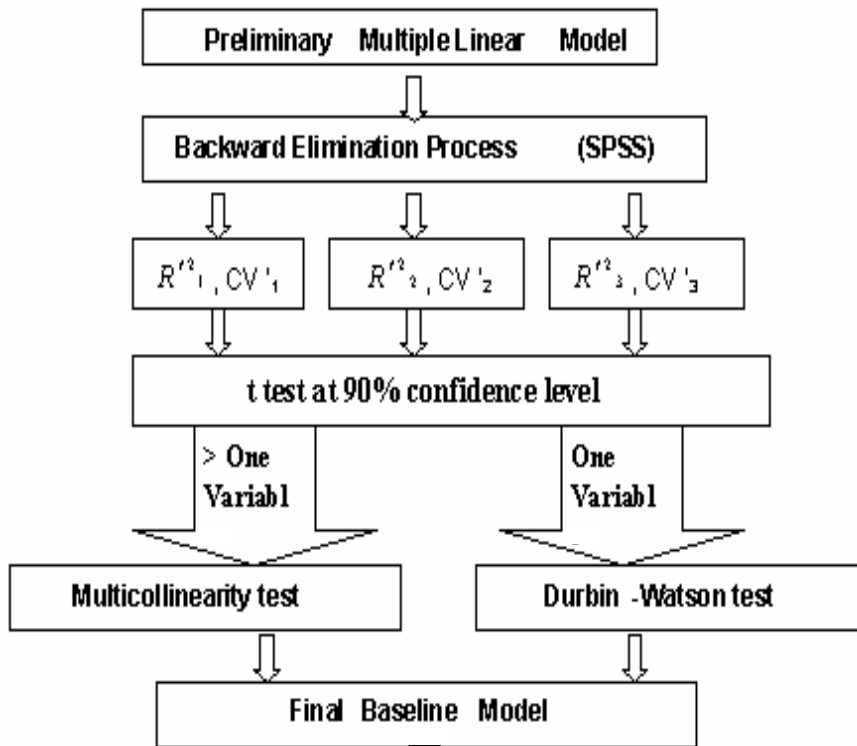
Seminar on EAEF Project 64 & 68  
Energy Performance Contracting & benchmarking  
13 January 2006  
School of Design & Environment, NUS



# Developing 4 options for Singapore M&V --- Option C

- Whole building holistic baseline method

-- *A combination of simple regression and multiple regression method*



**Independent variables:**

✓ Outdoor dry bulb temperature

✓ Relative humidity

✓ Global solar radiation

$$\hat{E} = \beta_0 + \beta_1 T_O + \beta_2 RH + \beta_3 GSR$$

# Developing 4 options for Singapore M&V --- Option C



Energy Sustainability Unit

Building	Regression Equation
A	$\hat{E} = -32.46 + 2.23T_0 - 0.02GSR$
B	$\hat{E} = -30.64 + 1.85T_0$
C	$E = -31.15 + 2.32T_0$
D	$\hat{E} = -35.83 + 2.18T_0$
E	$\hat{E} = -50.11 + 2.76T_0$
F	$\hat{E} = -20.01 + 1.74T_0$
G	$\hat{E} = -47.69 + 1.78T_0 + 0.28RH$
H	$\hat{E} = -19.6 + 2.01T_0 - 0.02GSR$
I	$\hat{E} = -20.21 + 2.37T_0 - 0.25RH$
J	$\hat{E} = -28.76 + 2.01T_0$

Seminar on EAEF Project 64 & 68  
 Energy Performance Contracting & benchmarking  
 13 January 2006  
 School of Design & Environment, NUS



This project has been supported by ASEAN Centre for Energy through the EC-ASEAN Energy Facility

# Neural Network & Support Vector Machine --- Option C



Energy  
Sustainability  
Unit

- Advantage

More accurate in prediction compared with statistical regression method
- Disadvantage
  - The large pool of data are needed for model training
  - Time consuming
  - Limited to access to software

Seminar on EAEF Project 64 & 68  
Energy Performance Contracting & benchmarking  
13 January 2006  
School of Design & Environment, NUS



# Developing 4 options for Singapore M&V --- Option D



Energy  
Sustainability  
Unit

- **Option D**

- **ESU Methods**

- DesignBuilder (Engine: EnergyPlus)  
<http://www.designbuilder.co.uk/>
- E-Quest (Engine: DOE2)  
<http://www.doe2.com/equest/>
- Visual DOE  
<http://www.archenergy.com/products/visualdoe/>

- **Advantage:**

Detailed system performance analysis and diagnostic

- **Disadvantage:**

- Very detailed building and system information are needed
- Limited to access to software and manpower
- Time consuming

Seminar on EAEF Project 64 & 68  
Energy Performance Contracting & benchmarking  
13 January 2006  
School of Design & Environment, NUS



# Comparison among ESU methods



Energy  
Sustainability  
Unit

- Mean Absolute Error (MAE)

$$MAE(\%) = \frac{\overline{E}_{predicted} - \overline{E}_{measured}}{\overline{E}_{measured}} \times 100$$

Option	Method	MAE (%)
Option C	Single Linear Regression	0.8 – 15.33
	Multiple Linear Regression	0.14 – 3.49
	Neural Network	0.64 – 7.33
	Support Vector Machine	0.14 – 0.73
Option D	DesignBuilder	0.004
	E-Quest	-7.33
	Visual DOE	11.00

Seminar on EAEF Project 64 & 68  
Energy Performance Contracting & benchmarking  
13 January 2006  
School of Design & Environment, NUS



# Summary of ESU methods



Energy  
Sustainability  
Unit

Methods	Description	Output
Statistical Methods	<ul style="list-style-type: none"> <li>•Single variant linear regression</li> <li>•Multiple variant linear regression</li> </ul>	<ul style="list-style-type: none"> <li>•Easy to establish</li> <li>•Most commonly used</li> </ul>
Computer Simulation	<ul style="list-style-type: none"> <li>•DesignBuilder</li> <li>•Visual DOE</li> <li>•E-Quest</li> </ul>	<ul style="list-style-type: none"> <li>•High accuracy</li> <li>•Not easy to use</li> <li>•Need detailed physical and system data</li> </ul>
Artificial Intelligence	<ul style="list-style-type: none"> <li>•Neural Network</li> <li>•Support Vector Machines</li> </ul>	<ul style="list-style-type: none"> <li>•High accuracy</li> <li>•Need large pool of data</li> </ul>

Seminar on EAEF Project 64 & 68  
Energy Performance Contracting & benchmarking  
13 January 2006  
School of Design & Environment, NUS



# Implementation of M&V



Energy  
Sustainability  
Unit

- To implement M&V to real project, energy performance contract is needed.
- The EPCs in several countries were reviewed
  - ✓ *US*
  - ✓ *Australia*
  - ✓ *UK*
  - ✓ *Belgium*
  - ✓ *Malaysia*
  - ✓ *Singapore*
- Singapore standard energy performance contract is coming soon

Seminar on EAEF Project 64 & 68  
Energy Performance Contracting & benchmarking  
13 January 2006  
School of Design & Environment, NUS



# Review of Energy Performance Contract



Energy Sustainability Unit

Country	Resource	Financing	M&V Clause
US	Mississippi state	Guaranteed	✓
UK	Energy saving project for EU	Design & Build	✓
Australia	AEPCA		✓
Belgium		Guaranteed	✓
Singapore	NEA, EMA, NUS, EDB, BCA, DTSA	Guaranteed/Shared	✓ Detail M&V requirement (ASHRAE&IPMVP)
	Local ESCO	Guaranteed	✓ Basic
Malaysia	MIEEIP	Government funding	✓ (Optional)
	MESA PTM MODEL	Shared	✓

Seminar on EAEF Project 64 & 68  
 Energy Performance Contracting & benchmarking  
 13 January 2006  
 School of Design & Environment, NUS



# What we will do next?

- The framework of Singapore M&V guideline
- The Singapore standard EPC form
- The financial options for EPC in Singapore



Energy  
Sustainability  
Unit

Seminar on EAEF Project 64 & 68  
Energy Performance Contracting & benchmarking  
13 January 2006  
School of Design & Environment, NUS



# Reference & Further Reading



Energy  
Sustainability  
Unit

- **Baseline Model**

[1] B. Dong, S.E. Lee, M.H. Sagar, “A holistic utility bill analysis method for baselining whole commercial building energy consumption in Singapore”, *Energy and Buildings*, vol.37(2), pp. 167-174, 2005

[2] B. Dong, C.Chen, S.E.Lee, “Applying support vector machines to predict building energy consumption in the tropics”, *Energy and Buildings*, vol.37(5), pp. 545-553, 2005

[3] B. Dong. Baseline Model Development for Commercial Buildings in the Tropics , Master candidate thesis, Department of Building, School of Design and Environment, National University of Singapore, 2005

[4] Bing Dong, Lee Siew Eang, Majid Haji-Sapar, *Evaluating utility bill analysis for predicting the whole building energy use in Tropical Region*, Improving Energy Efficiency in Commercial Building Conference, Frankfurt, Germany , April 19-22, 2004

[5] Bing Dong, *Baselining Office Building Energy Consumption*, Seminar on Energy Management Best Practices & Technologies ,SAFEco and NUS , 7 April 2005, Hotel Le Meridien, Singapore

- **Energy Performance Contract**

- Malaysia, <http://www.ptm.org.my/mieeip/document.html>

- UK, [http://energyefficiency.jrc.cec.eu.int/ESCO/esco\\_Model%20Third%20Party%20Financing%20Contracts.htm](http://energyefficiency.jrc.cec.eu.int/ESCO/esco_Model%20Third%20Party%20Financing%20Contracts.htm)

- Australia, <http://www.aepca.asn.au>

Seminar on EAEF Project 64 & 68  
Energy Performance Contracting & benchmarking  
13 January 2006  
School of Design & Environment, NUS



# Thanks!



Energy  
Sustainability  
Unit

*This document has been produced with the financial assistance of the European Union. The contents of this document are the sole responsibility of CTBP and can under no circumstances be regarded as reflecting the position of the European Union.*

Seminar on EAEF Project 64 & 68  
Energy Performance Contracting & benchmarking  
13 January 2006  
School of Design & Environment, NUS



# 4 options in M&V



Energy  
Sustainability  
Unit

M&V Option	How savings are calculated
<b>Option A:</b> Based on <i>measured</i> equipment performance, measured or <i>stipulated</i> operational factors, and annual verification of ' <i>potential to perform.</i> '	Engineering calculations.
<b>Option B:</b> Based on <i>periodic or continuous measurements</i> taken throughout the term of the contract at the device or system level.	Engineering calculations using measured data.
<b>Option C:</b> Based on <i>whole-building</i> or facility level utility meter or sub-metered data adjusted for weather and/or other factors.	Analysis of utility meter data.
<b>Option D:</b> Based on <i>computer simulation</i> of building or process; simulation is calibrated with measured data.	Comparing different models.

Seminar on EAEF Project 64 & 68  
Energy Performance Contracting & benchmarking  
13 January 2006  
School of Design & Environment, NUS

