# Short-Term Load Forecasting with Predicted Weather Data

ZHU Guangya, Tin Tai Chow, Norman TSE

Speaker: ZHU Guangya

PhD student, City University of Hong Kong

Supervisor: Tin Tai Chow

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Organisers:

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# 1. Introduction

Energy consumption in building sector

Load forecasting Benefits

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# Global Perspective

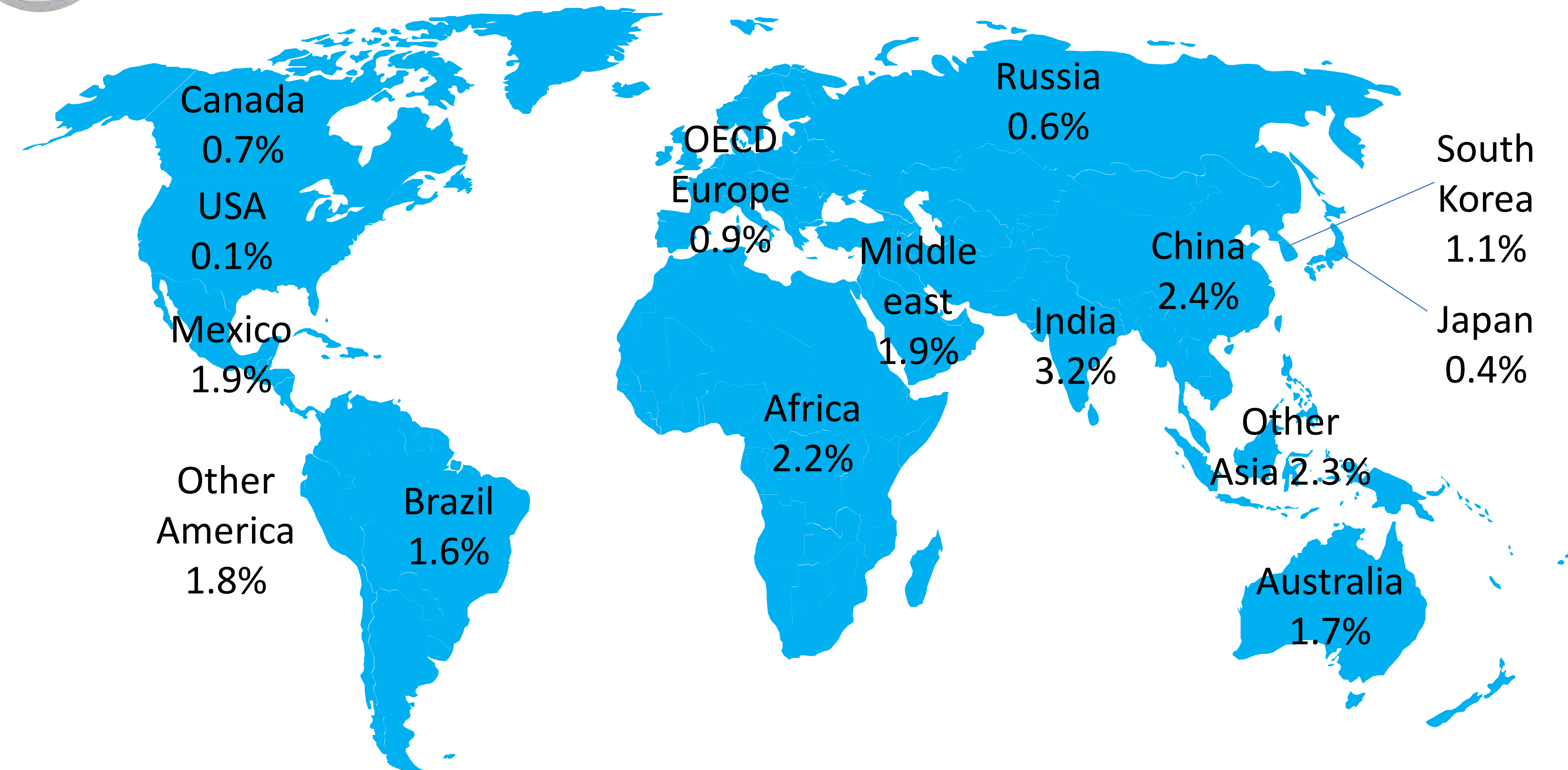
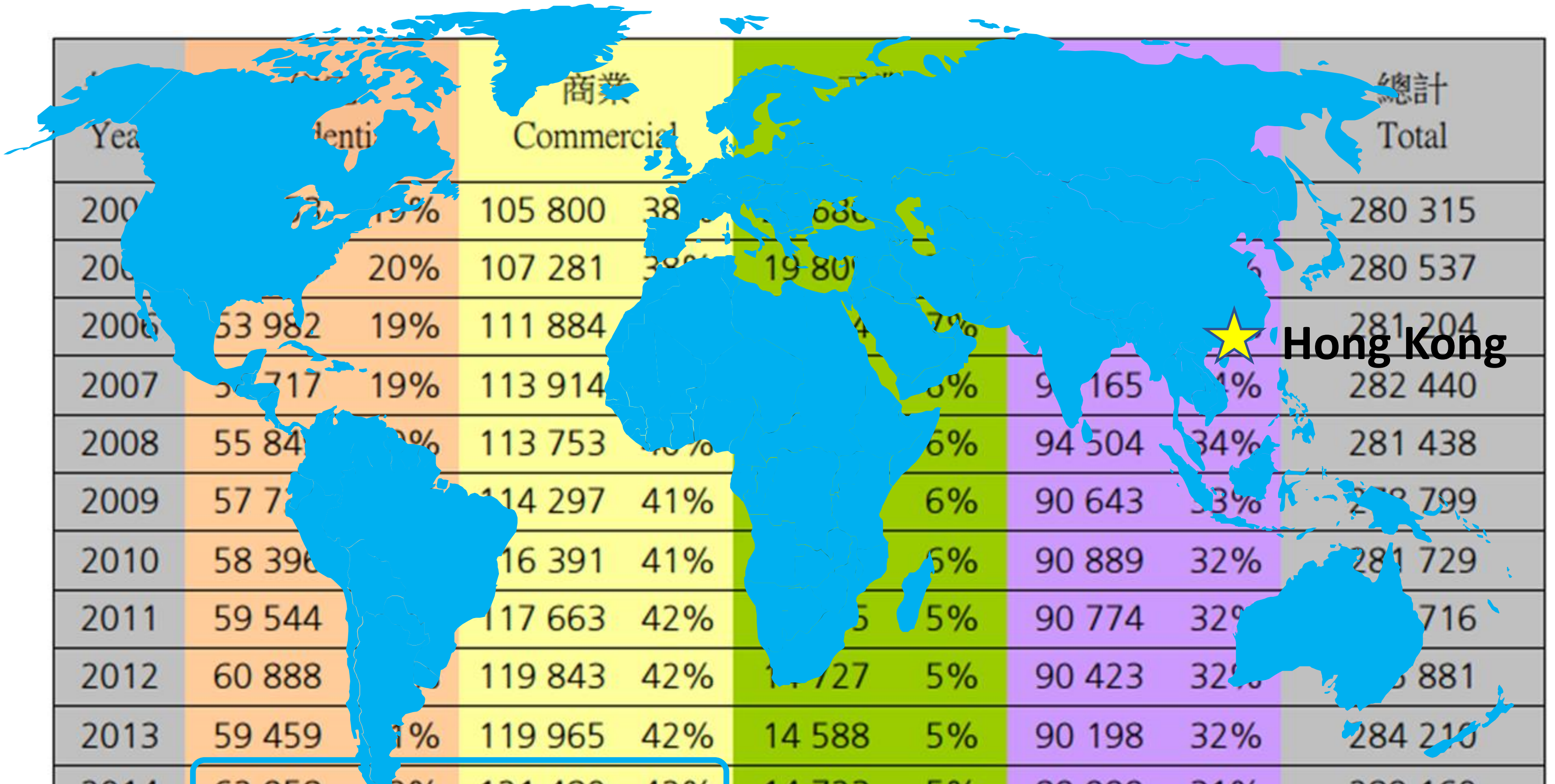



Fig. Average annual change in residential Building sector energy consumption, 2012–40 (percent per year)

Source: International Energy Outlook 2016, Chapter 6

# Local Perspective

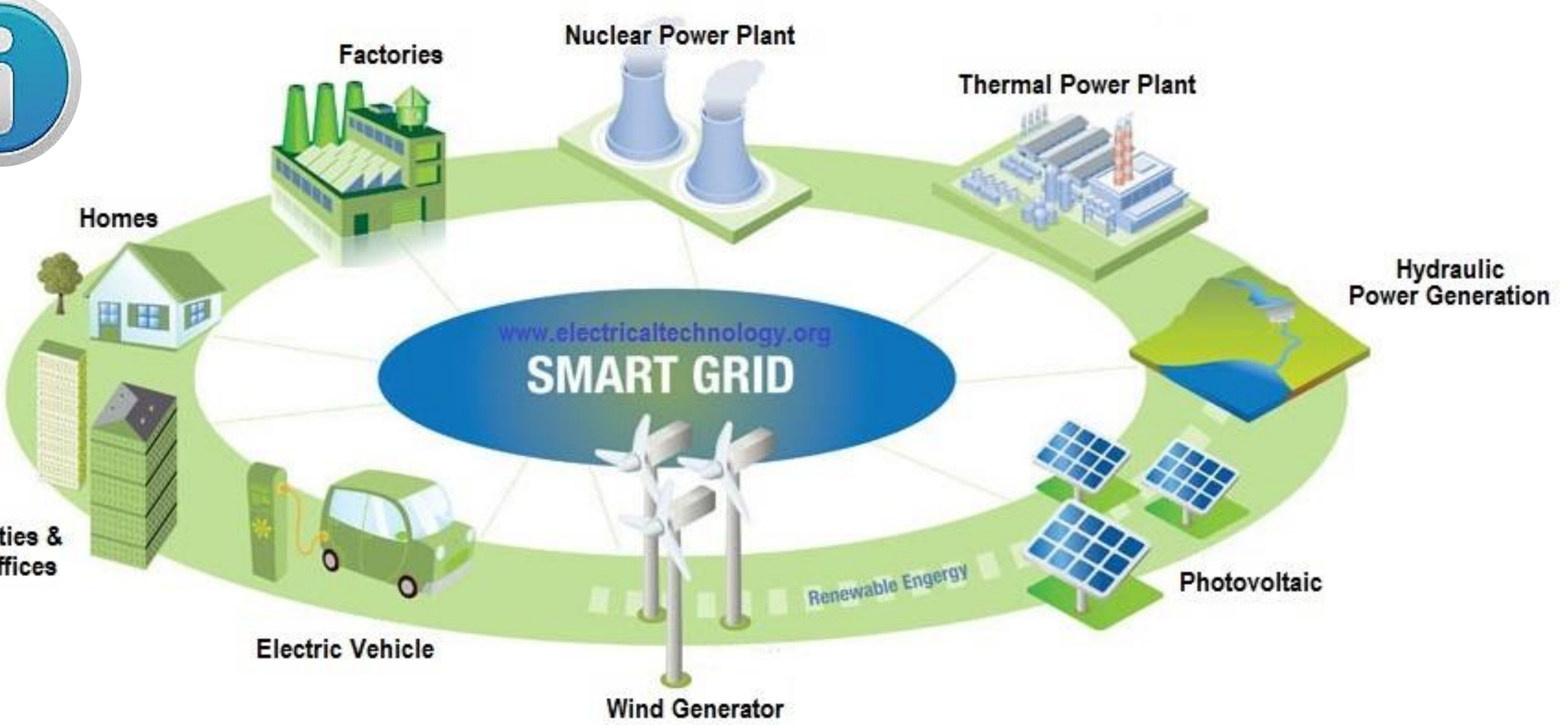


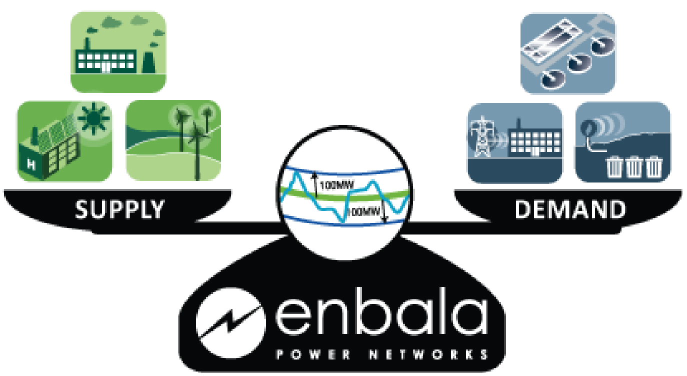

| Yea[illegible] | [illegible]enti[illegible] | | 商業 Commercial | | [illegible] | | [illegible] | | 總計 Total |
|---|---|---|---|---|---|---|---|---|---|
| 200[illegible] | [illegible] | [illegible]9% | 105 800 | 38[illegible] | [illegible]68[illegible] | [illegible] | [illegible] | [illegible] | 280 315 |
| 20[illegible] | [illegible] | 20% | 107 281 | 3[illegible] | 19 80[illegible] | [illegible] | [illegible] | [illegible] | 280 537 |
| 2006 | [illegible]3 982 | 19% | 111 884 | [illegible] | [illegible] | [illegible]7% | [illegible] | [illegible] | 281 204 |
| 2007 | [illegible]717 | 19% | 113 914 | [illegible] | [illegible] | [illegible]% | 9[illegible]165 | [illegible]% | 282 440 |
| 2008 | 55 84[illegible] | [illegible]% | 113 753 | [illegible]% | [illegible] | 6% | 94 504 | 34% | 281 438 |
| 2009 | 57 7[illegible] | [illegible] | [illegible]14 297 | 41% | [illegible] | 6% | 90 643 | [illegible]3% | [illegible]799 |
| 2010 | 58 39[illegible] | [illegible] | [illegible]16 391 | 41% | [illegible] | [illegible]6% | 90 889 | 32% | 28[illegible]729 |
| 2011 | 59 544 | [illegible] | [illegible]17 663 | 42% | [illegible]5 | 5% | 90 774 | 32[illegible] | [illegible]716 |
| 2012 | 60 888 | [illegible] | 119 843 | 42% | [illegible]727 | 5% | 90 423 | 32[illegible] | [illegible]881 |
| 2013 | 59 459 | [illegible]% | 119 965 | 42% | 14 588 | 5% | 90 198 | 32% | 284 21[illegible] |
| 2014 | 62 958 | [illegible]% | + 121 480 | 42% | 14 723 | 5% | 89 999 | 31% | 289 160 |

< 單位：太焦耳 Unit : Terajoule >

64%

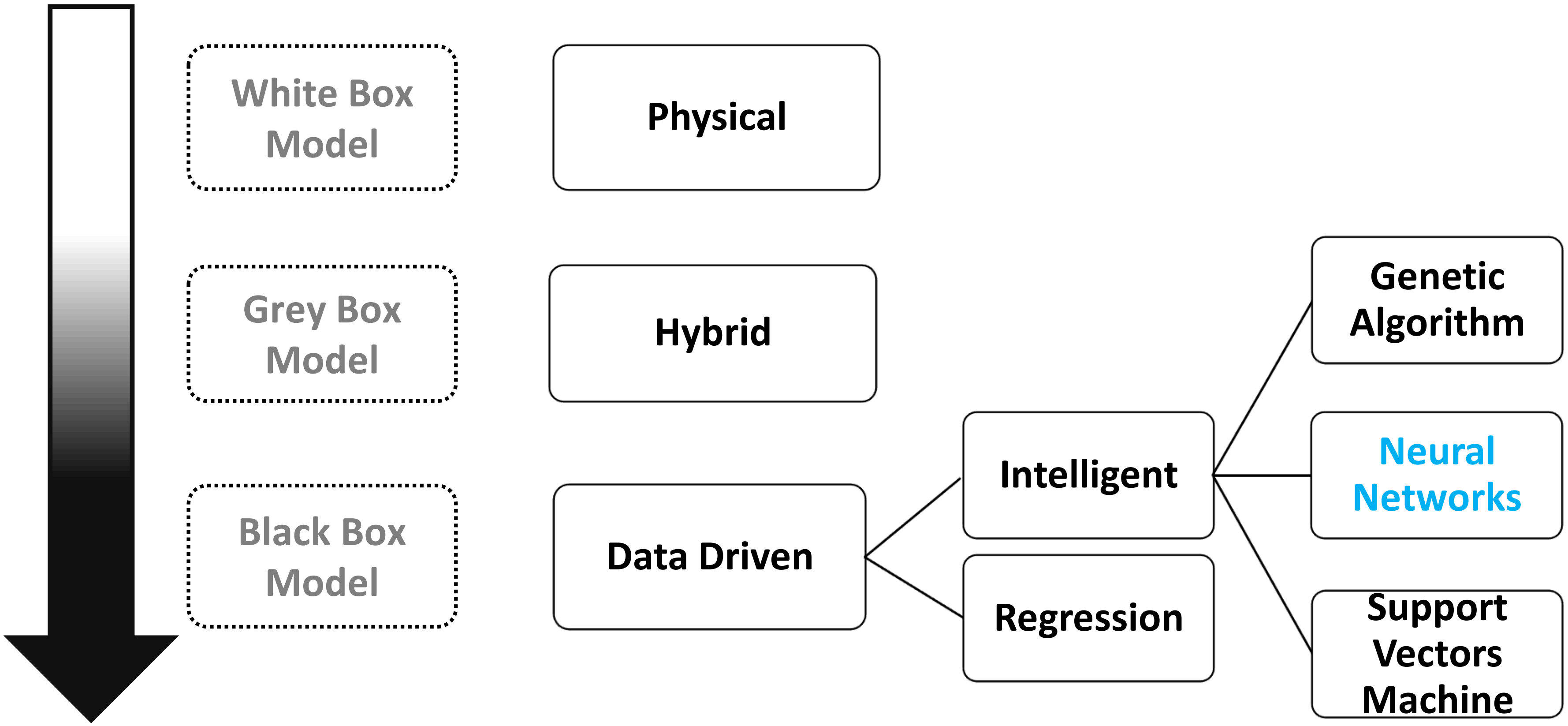
Source: EMSD (Electrical & Mechanical Services Department)
Hong Kong Energy End-use Data 2016



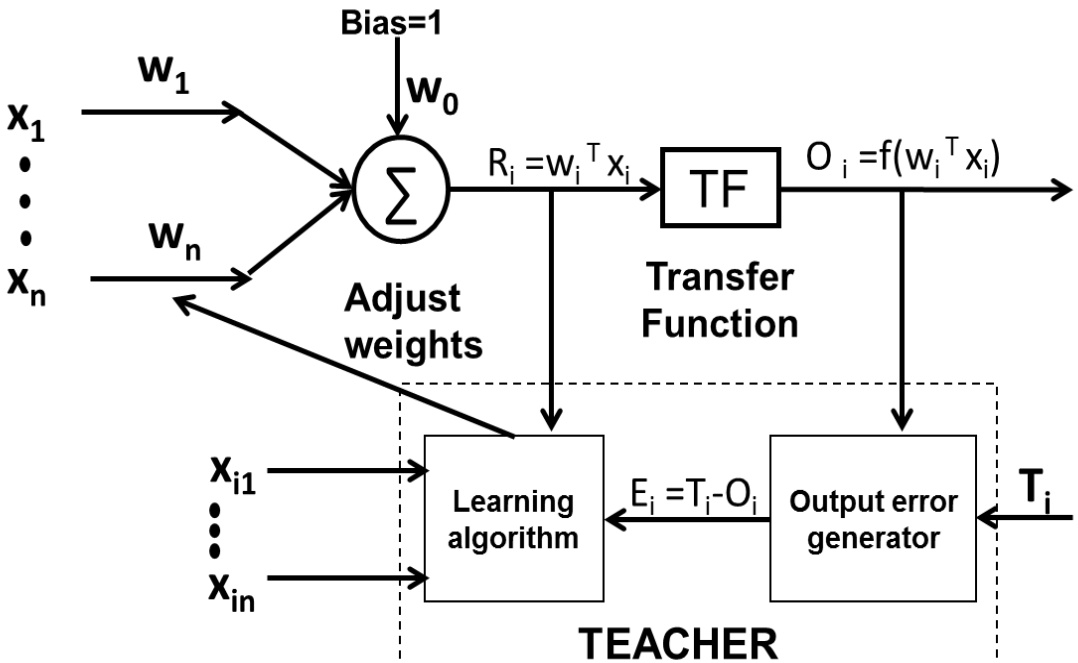

- **Energy Management System**
- **Clean Energy System Design**
- **Smart Grid and Smart Building**

# Forecasting Models

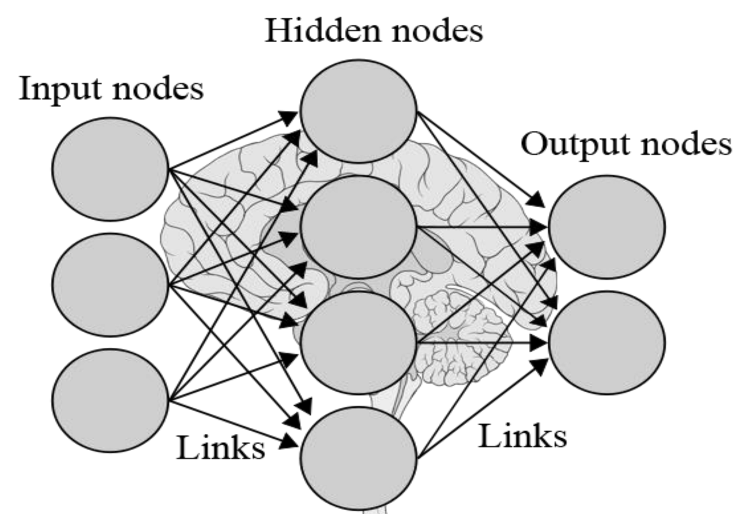



Source: N. Fumo, A review on the basics of building energy estimation, Renewable and Sustainable Energy Reviews, 2014 (31): 53-60.

# Artificial Neural Network

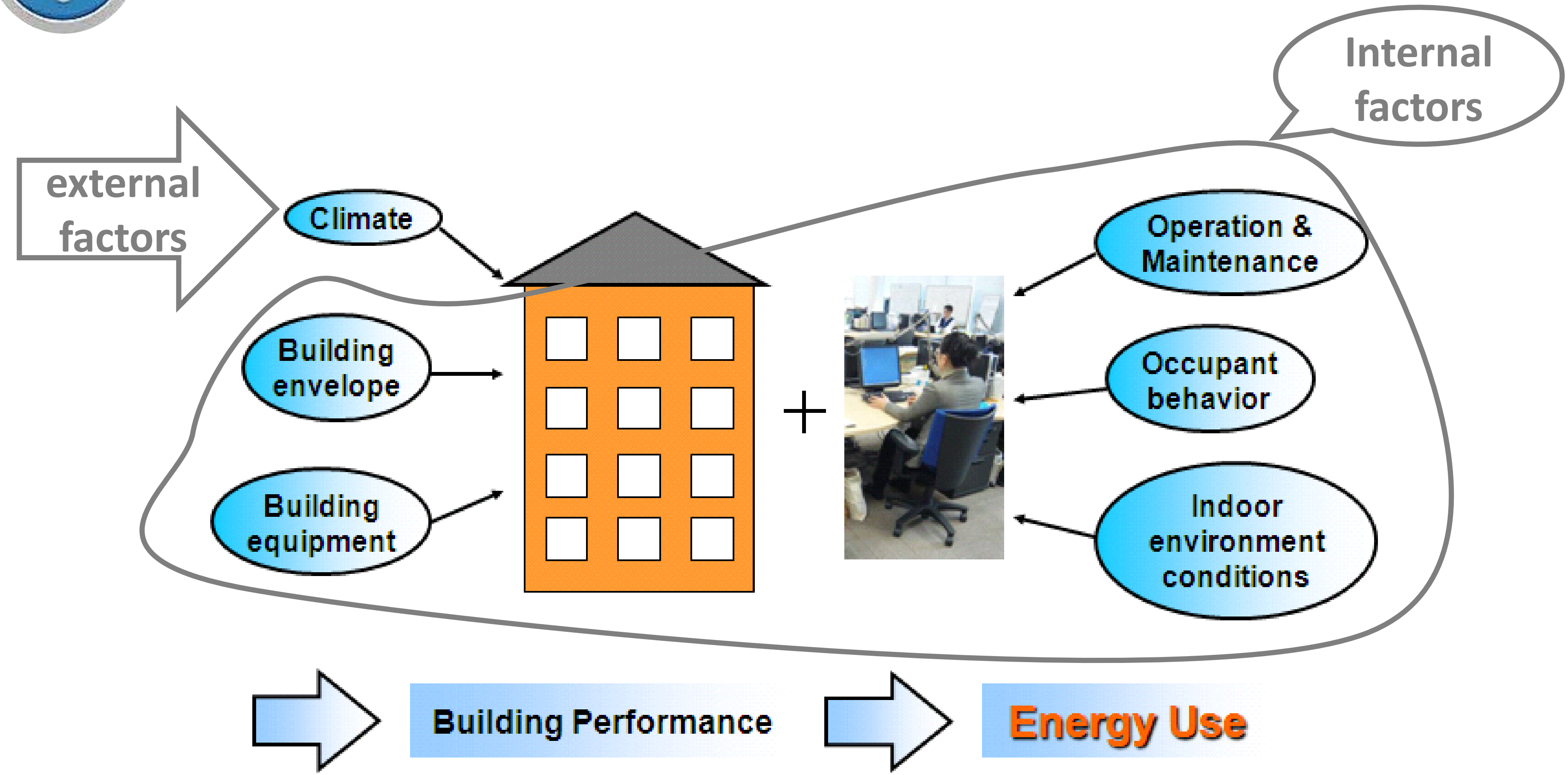



- Popular to apply in many fields
- Robust to errors
- Successfully applied in load prediction




Source: T.M. MITCHELL (1997) Machine learning. Chapter 4: 81-126.

# Building Load Influential Factors



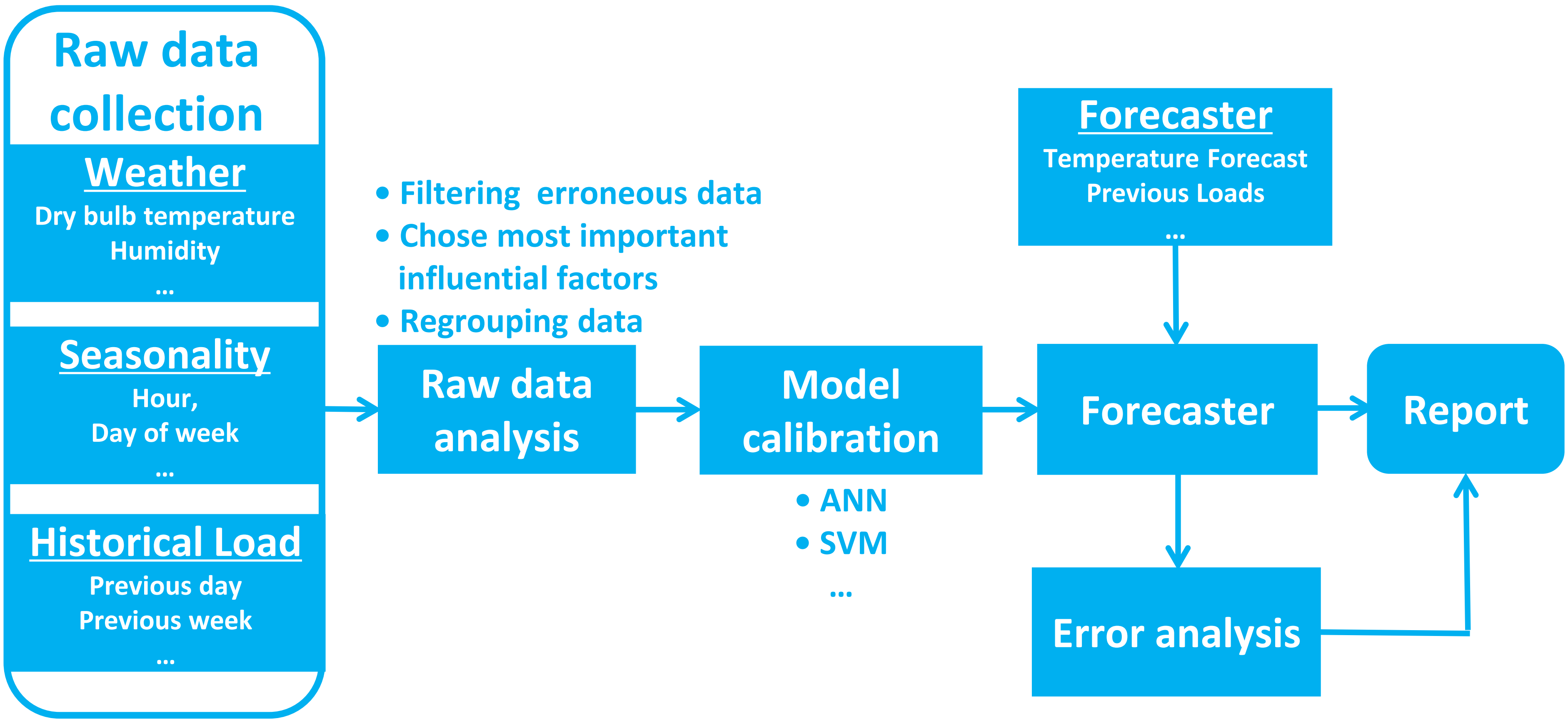

Source: M.C. Leung et al. The use of occupancy space electrical power demand in building cooling load prediction. Energy and Buildings, (2012) 55: 151-163.

# 2. Critical problem and solution

Forecasting methods

Weather Forecasting

# General Data-driven Forecasting Procedure



# Critical problems

Load Prediction

1: Which kind of data is available?

2: What is the final goal of prediction?

3: Which of the data should be chosen as inputs?

4: How many money supported of the forecasting program?

# Forecasting Framework

**Method 1** → **Method 2** → **Method 3**

**Method 1**

- General information (Public temperature forecasting, hour index)
- Forecasting model development
- Forecasting report

**Method 2**

- +Building specific information (weather forecasting information, building operation schedule, historical load data)
- Influential factors chosen
- Forecasting model development
- Forecasting report

**Method 3**

- +sub-system operation schedule, sub-system historical record
- Influential factors chosen
- Sub-system category
- Forecasting model development
- Forecasting report

# General Data-driven Forecasting Procedure

**Raw data collection**

**Weather**
Dry bulb temperature
Humidity
…

**Seasonality**
Hour,
Day of week
…

**Historical Load**
Previous day
Previous week
…

→ **Raw data analysis**

- Filtering erroneous data
- Chose most important influential factors
- Regrouping data

→ **Model calibration**

- ANN
- SVM

…

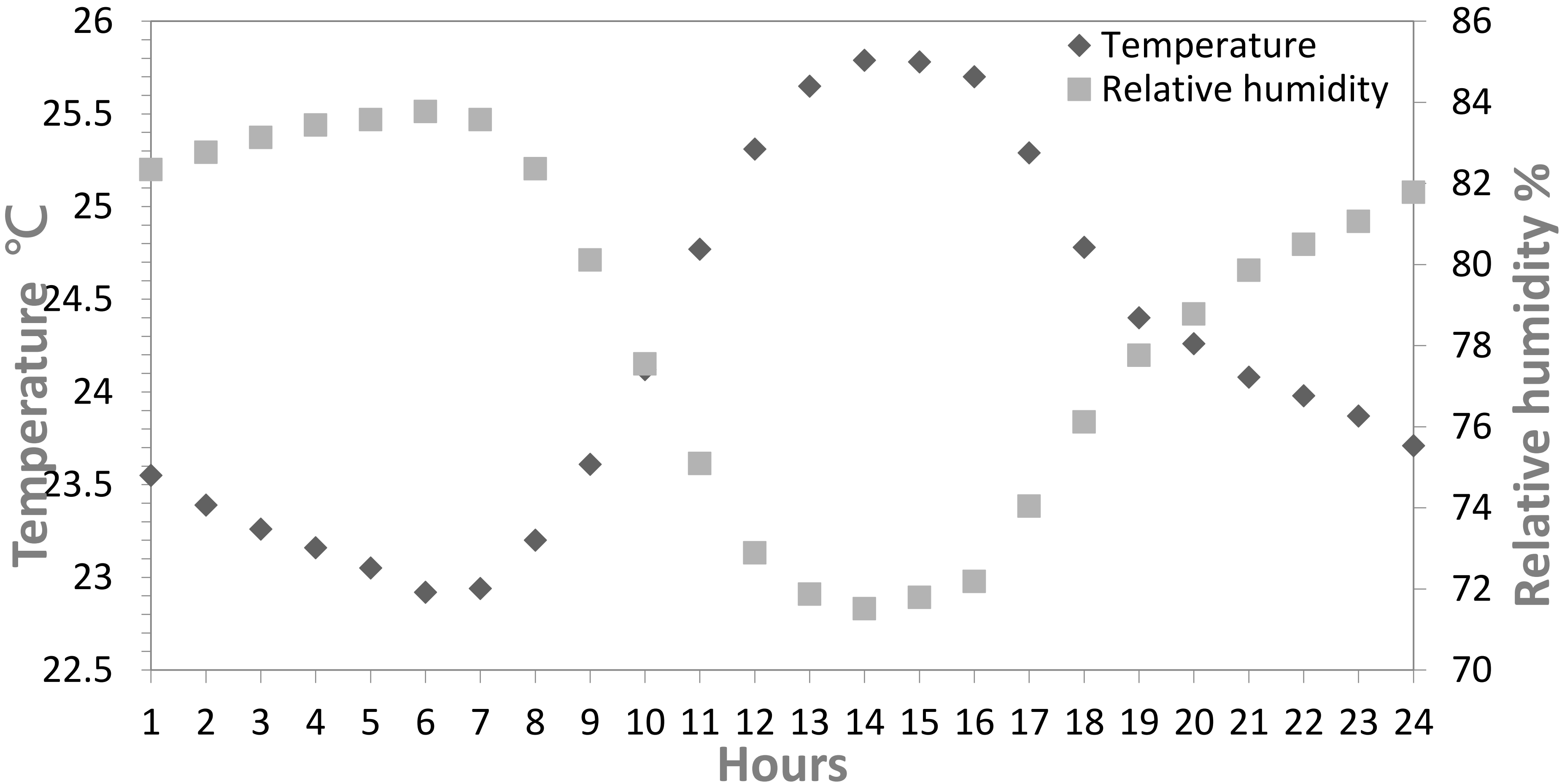
→ **Forecaster**

**Forecaster** (input)
Temperature Forecast
Previous Loads
…

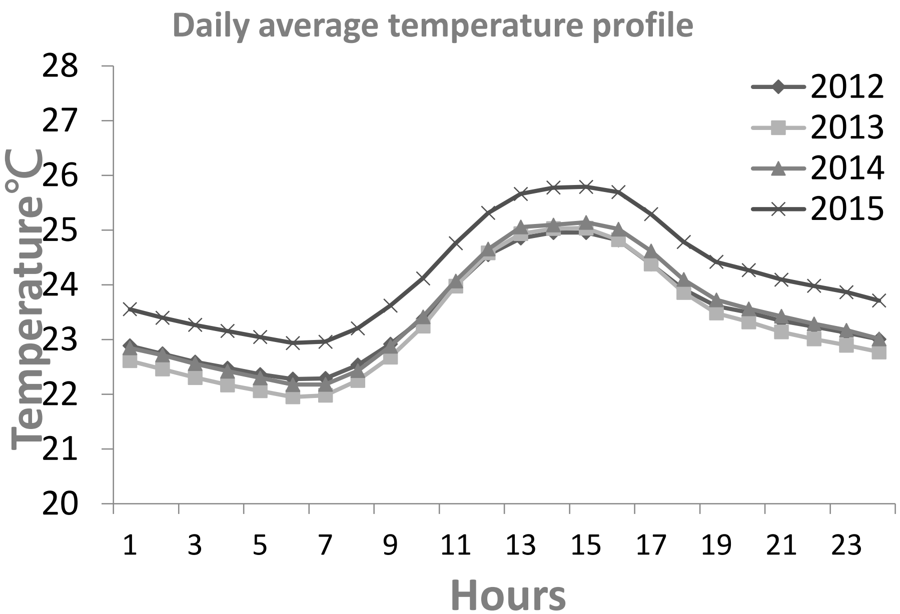
**Forecaster** → **Report**

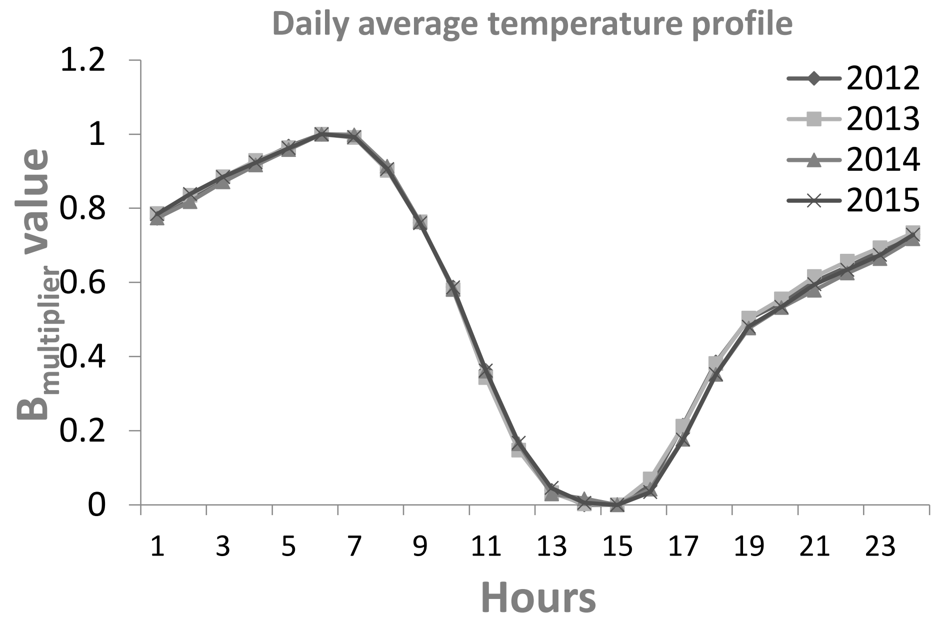
**Forecaster** → **Error analysis** → **Report**

# Typical Daily Temperature and RH Profile



# Temperature Prediction




$$T_{current} = T_{max} - \beta_{Multiplier} \times (T_{max} - T_{min})$$

$T_{current}$ = Air temperature of current Hour of Day

$T_{max}$ = User supplied Max Dry-bulb Temperature

$T_{min}$ = User supplied Min Dry-bulb Temperature

$\beta_{Multiplier}$ = Range multiplier value which provides the deviation ratio between the maximum dry-bulb temperature and given hour

# Relative Humidity Prediction

**Step1: Calculate water vapor saturation pressure**

**Step2: Generate reference water vapor pressure Pc**

**Step3: Calculate relative humidity (RH)**

$$p_{qb} = 610 \times 10^{\frac{7.45T}{235+T}}$$

where T is the temperature, $p_{qb}$ is the water vapor saturation pressure

The estimation of Pc can be calculated from the equations below: $\mathbf{P1} = \varphi_{day} \times p_{qbmax}$

$$\mathbf{P2} = \varphi_{night} \times p_{qbmin}$$

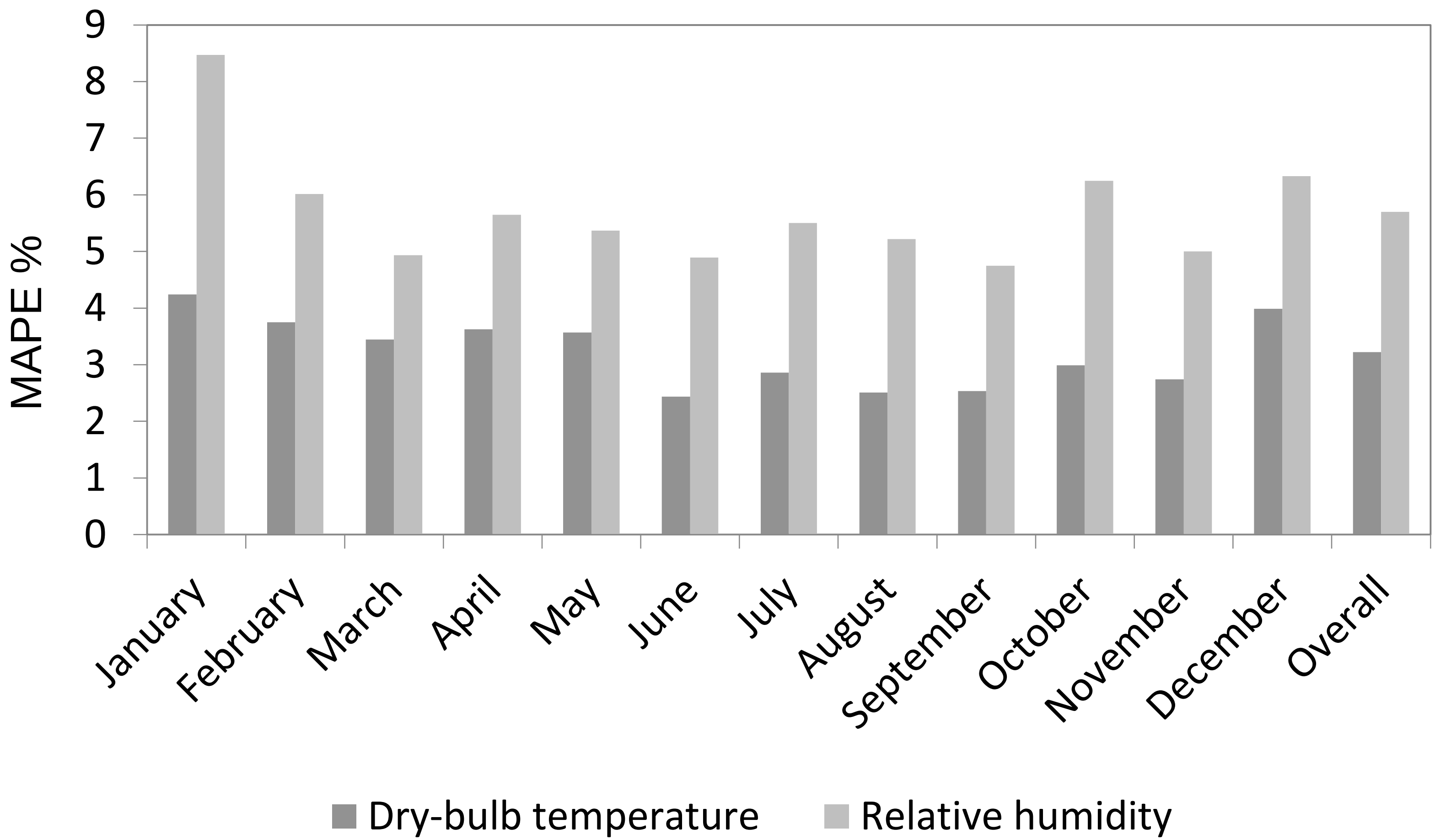
$$\mathbf{Pc} = \frac{\mathbf{P1}+P2}{2}$$

where $\phi_{day}$=daytime relative humidity, $\phi_{night}$=relative humidity at night, $p_{qbmax}$=daily Maximum water vapor saturation pressure, $p_{qbmin}$=daily Minimum saturation pressure

Because of that Hong Kong is Coastal cities, assuming the reference water vapor pressure was relatively stable within a day

$$\varphi = \frac{Pc}{p_{qb}} \times 100\%$$

# Prediction Error (MAPE)



# 3. Case study

Study Case Introduction

Raw Data Collection

3 Forecasting Methods

Forecasting Results

# Study Case

- University academic buildings

- Daily open hour :
  Weekday 07:00-23:00
  Weekend 07:00-18:00

- Cooling is also needed in the winter season

# Raw Data Collection

|  |  |  |  |
|---|---|---|---|
| **Weather Data** | **Historical Record** | **Schedule** | **Time Period** |
| The collected weather recorded data was provided by Hong Kong observatory. The weather data include dry-bulb temperature, humidity, global solar radiation, rainfall, clearness of sky, cloud condition and wind | The historical energy consumption data of study case is hourly recorded by the building management system | The building and sub-system information are provided by CDFO (Campus development and facility office) | The data cover the period of the whole year 2014 and 2015 |

# Method 1

1. Follow the general data driven prediction procedure

2. Only use public information

# Method 2

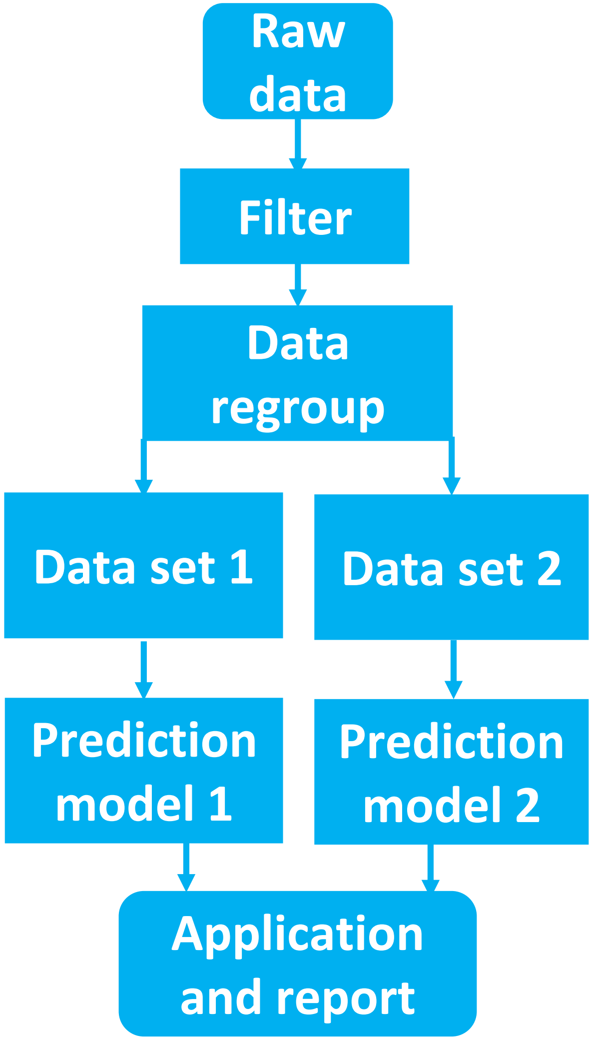
1. Prepare raw data

2. Filter less importance factors

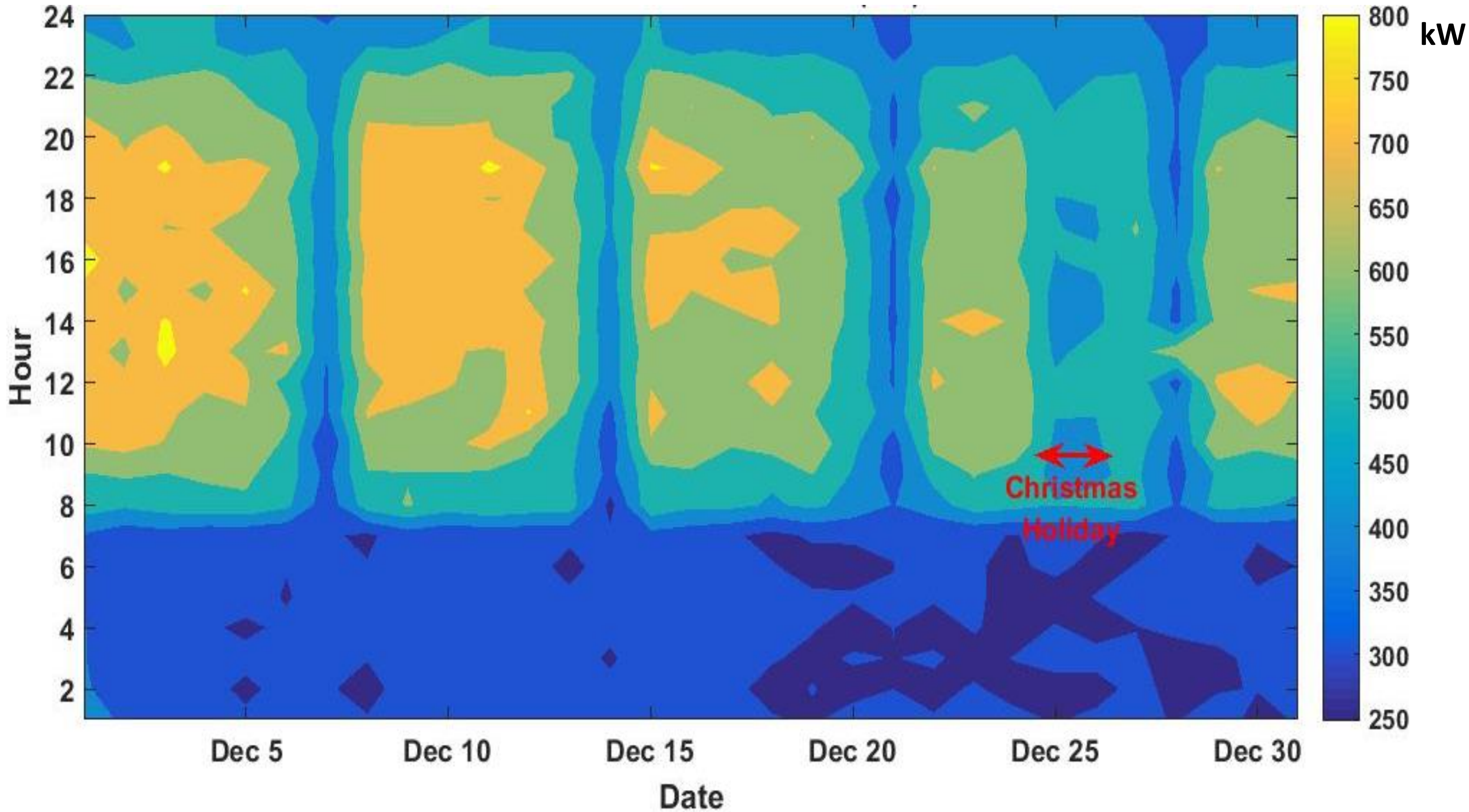
**3. Regroup data**

4. Develop prediction model

5. Forecaster application and generate report



# Load Cloud Chart




Organisers:

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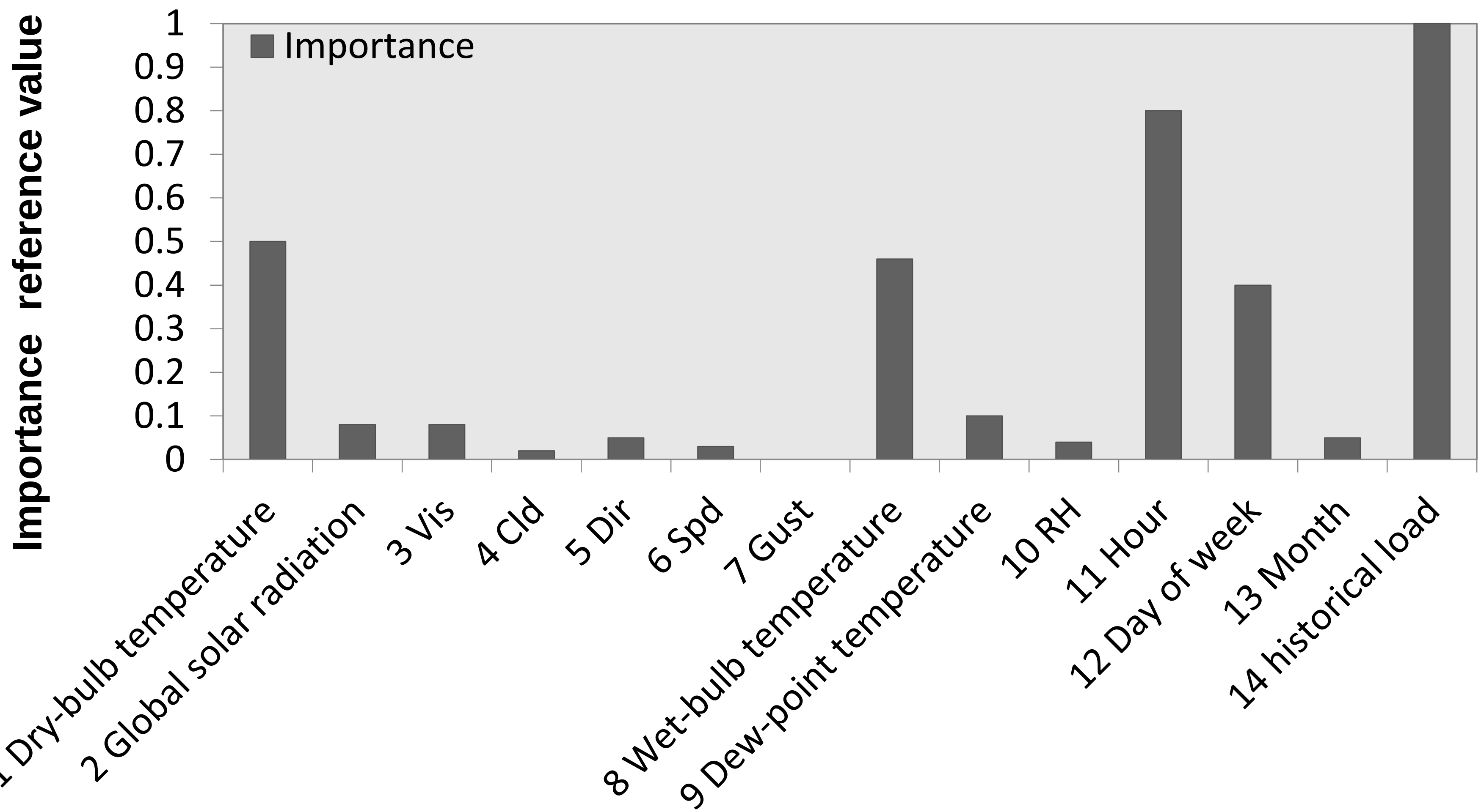
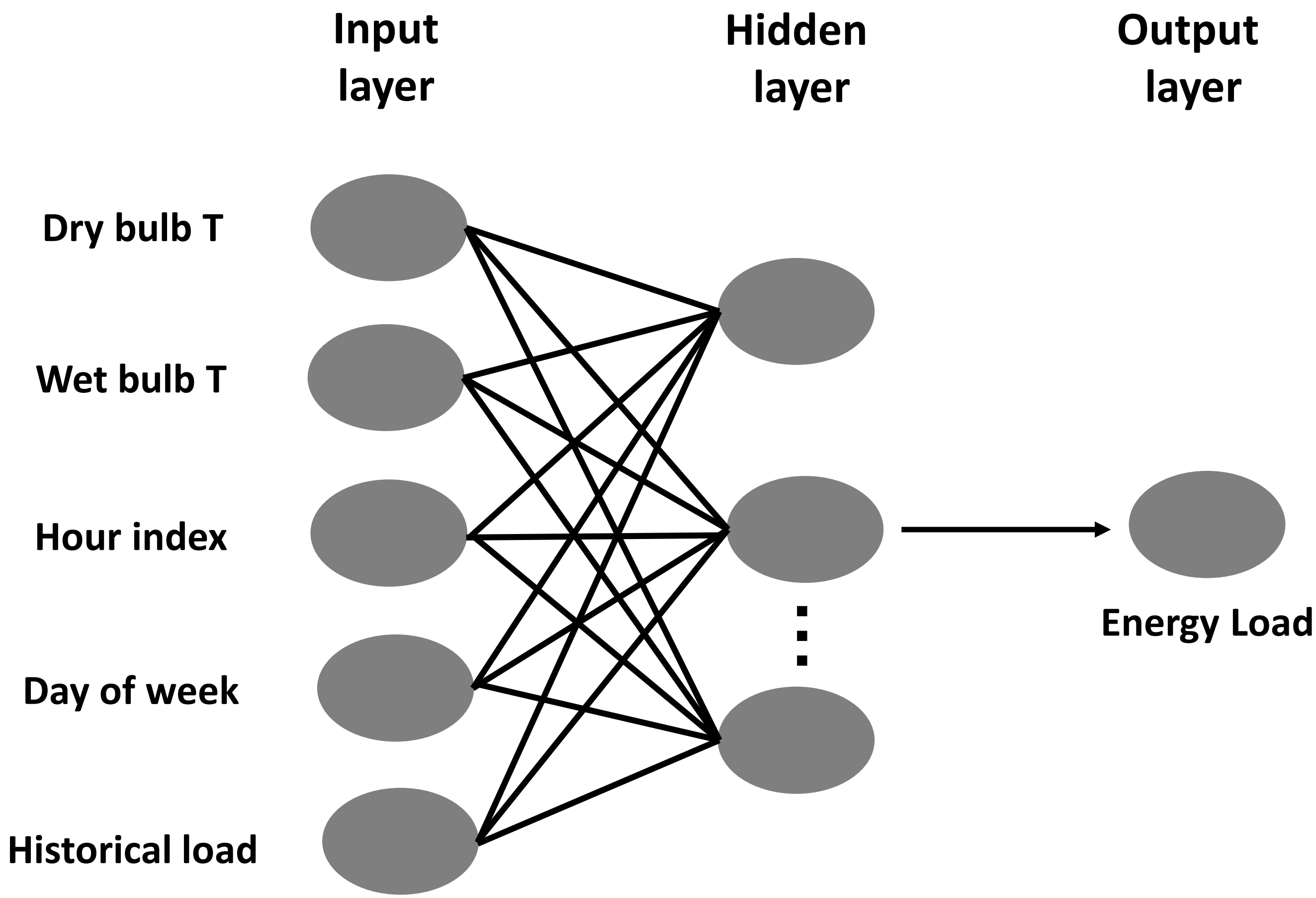
WORLD Sustainable Built Environment Conference

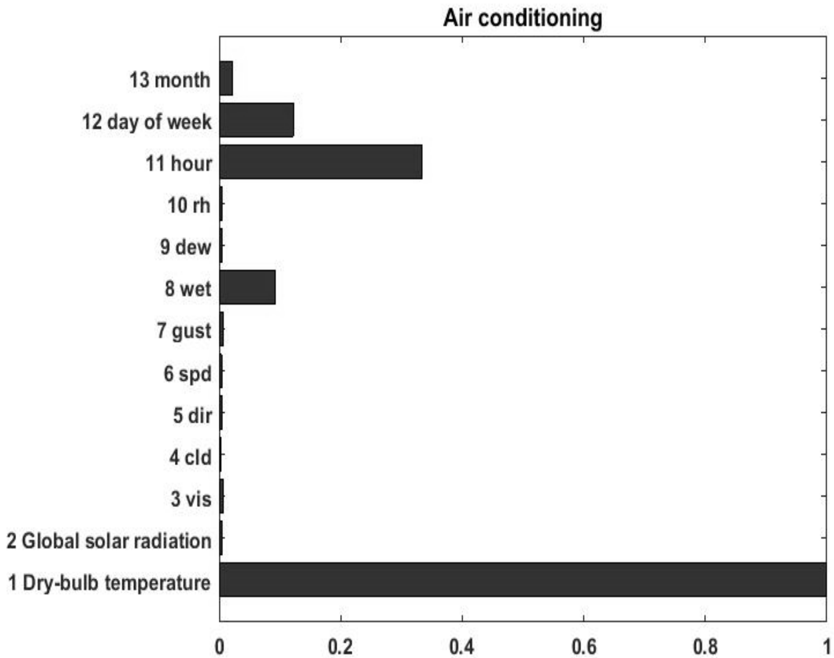
# Different Influential Factors

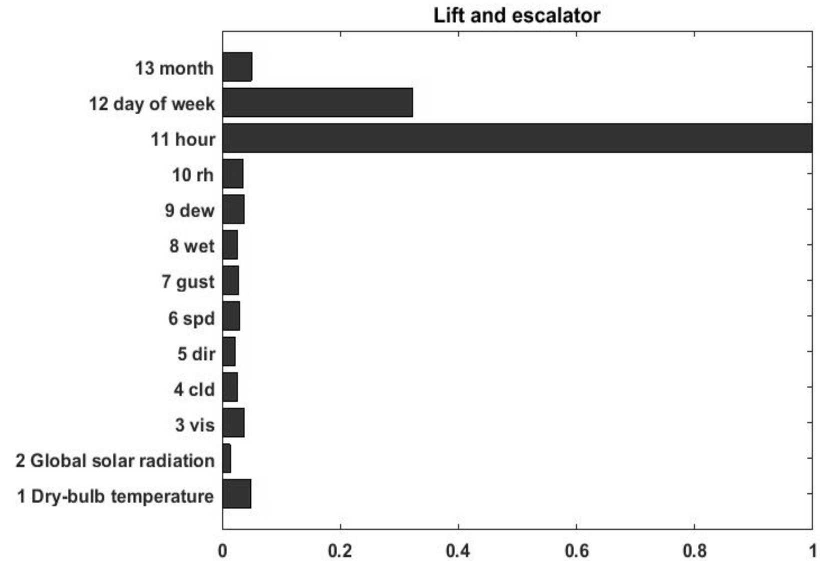


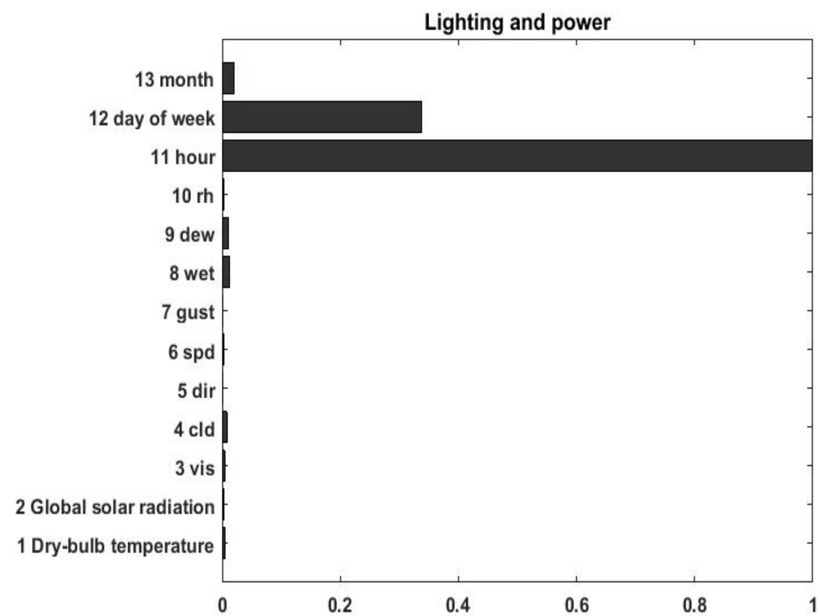
# ANN Model Architecture



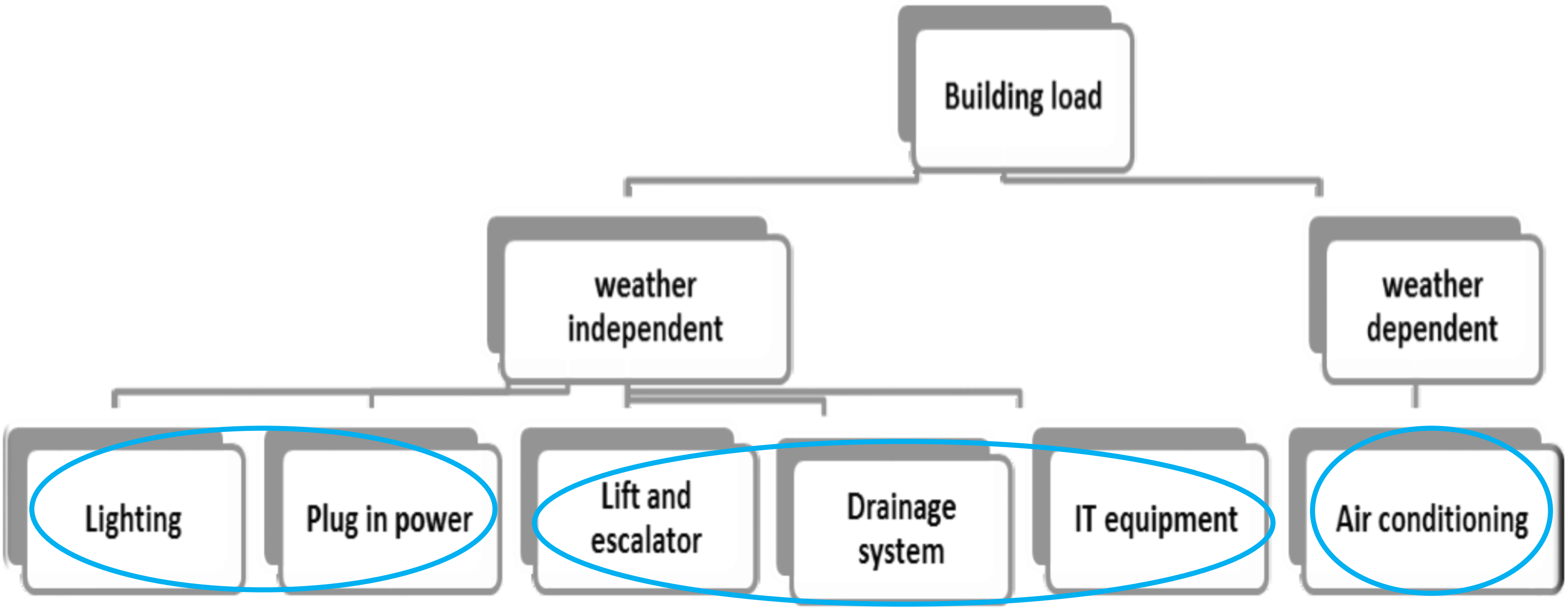
# Method 3


Air conditioning
13 month
12 day of week
11 hour
10 rh
9 dew
8 wet
7 gust
6 spd
5 dir
4 cld
3 vis
2 Global solar radiation
1 Dry-bulb temperature
0
0.2
0.4
0.6
0.8
1


Lift and escalator
13 month
12 day of week
11 hour
10 rh
9 dew
8 wet
7 gust
6 spd
5 dir
4 cld
3 vis
2 Global solar radiation
1 Dry-bulb temperature
0
0.2
0.4
0.6
0.8
1


Lighting and power
13 month
12 day of week
11 hour
10 rh
9 dew
8 wet
7 gust
6 spd
5 dir
4 cld
3 vis
2 Global solar radiation
1 Dry-bulb temperature
0
0.2
0.4
0.6
0.8
1

# Method 3

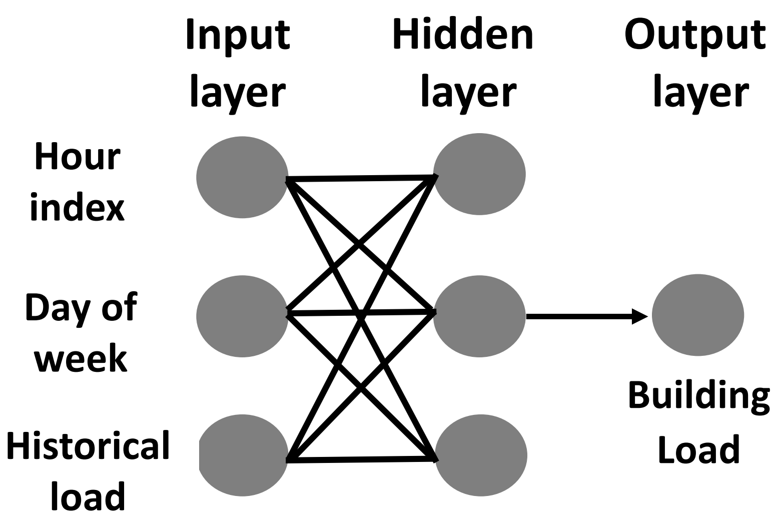



**1. Lighting and power**

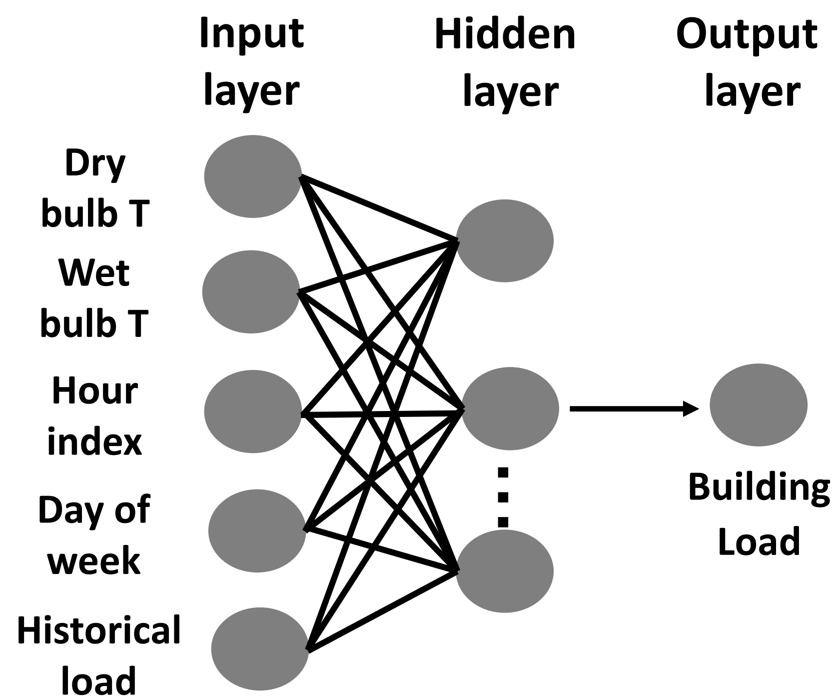
**2. Other**

**3. Air conditioning**

# Method 3

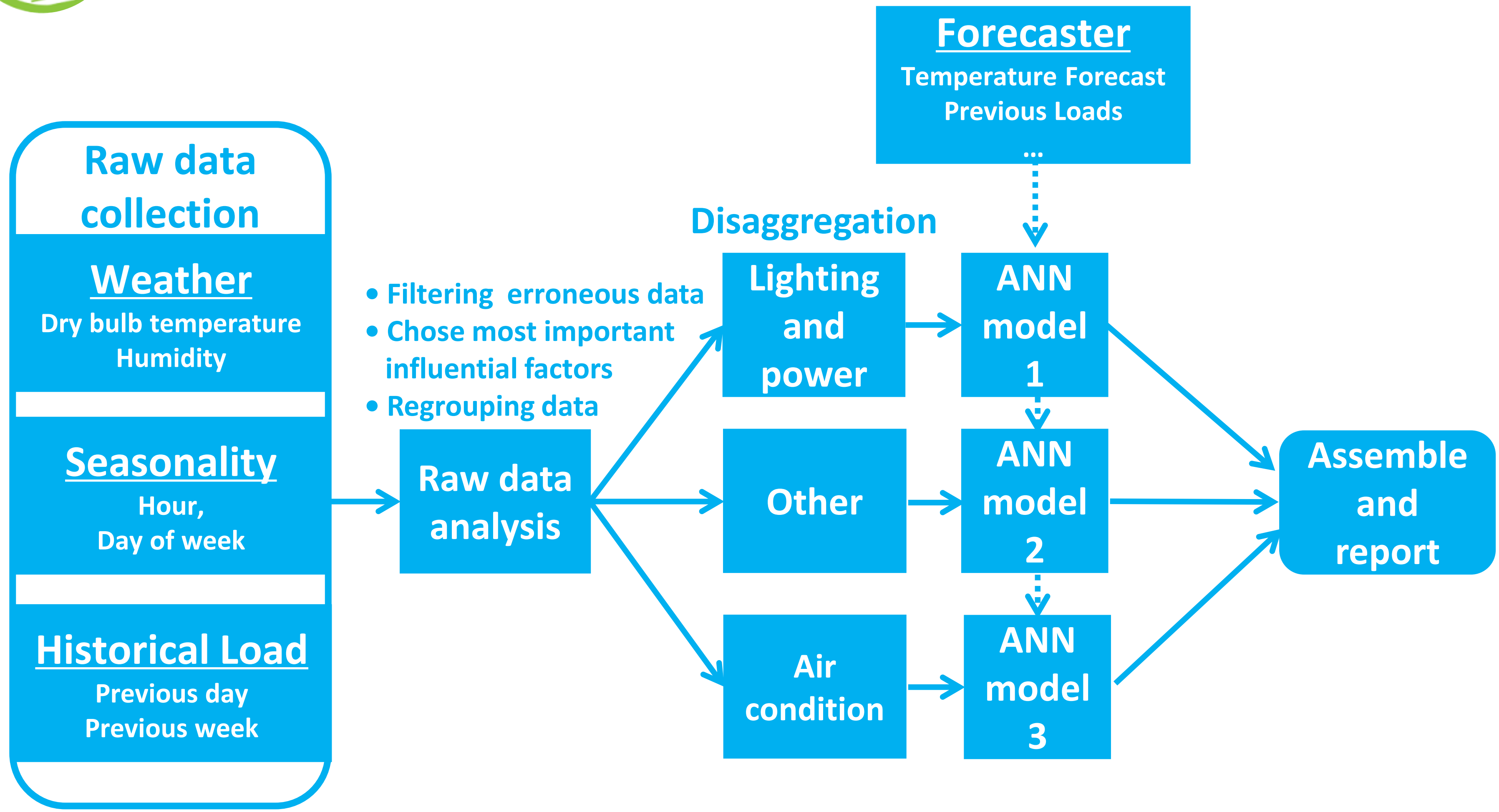



a. Weather independent ANN model

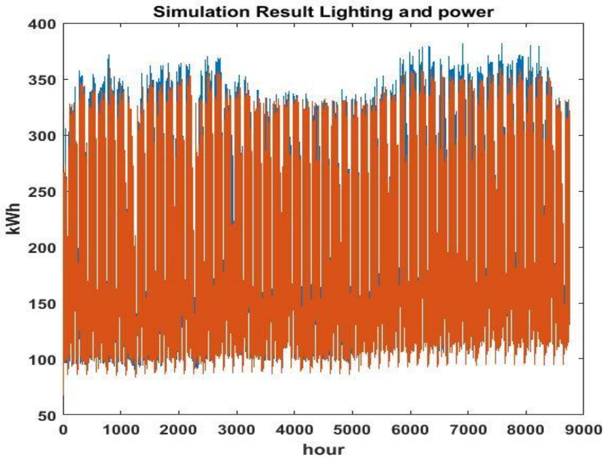


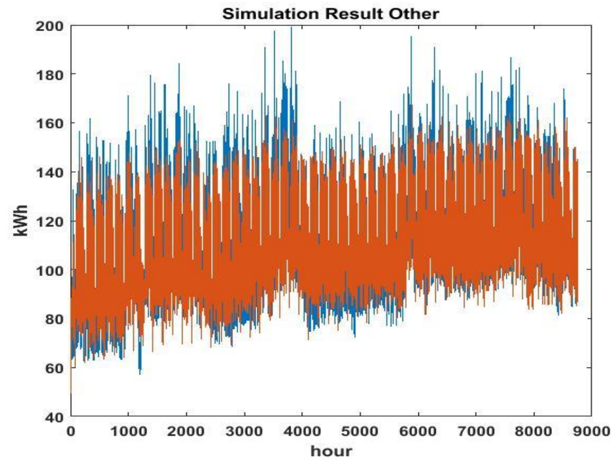

b. Weather dependent ANN model

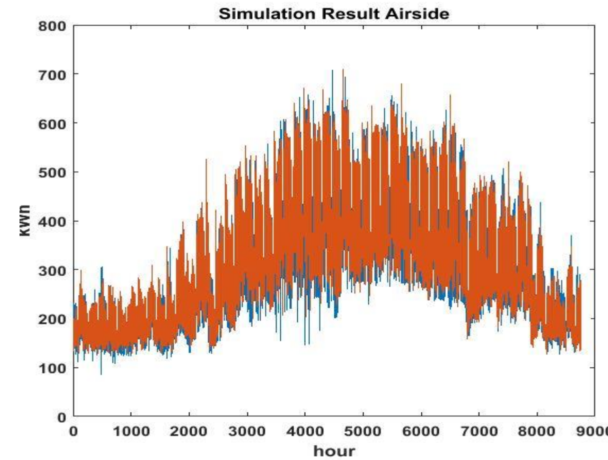
# Method 3

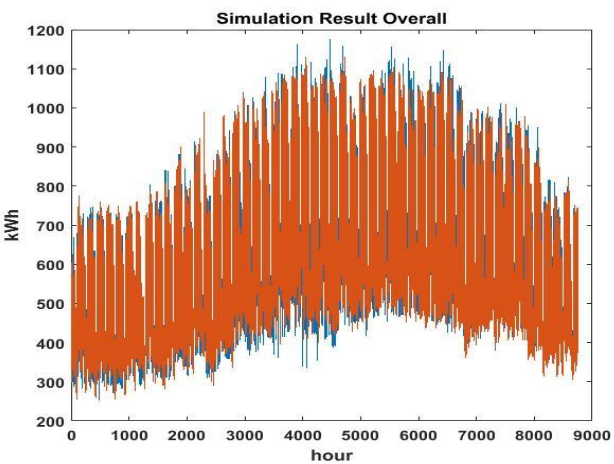

Forecaster
Temperature Forecast
Previous Loads
…
Raw data collection
Weather
Dry bulb temperature
Humidity
Seasonality
Hour,
Day of week
Historical Load
Previous day
Previous week
Filtering erroneous data
Chose most important influential factors
Regrouping data
Raw data analysis
Disaggregation
Lighting and power
Other
Air condition
ANN model 1
ANN model 2
ANN model 3
Assemble and report

# Forecasting Results




| | Method 1 | Method 2 | Method 3 | | | |
|---|---|---|---|---|---|---|
| | Overall MAPE | Overall MAPE | Lighting and Power | Air conditioning | Other | Overall |
| Record weather | 8.89 | 5.23 | 5.88 | 7.33 | 9.38 | 5.08 |
| Predict weather | 8.97 | 5.31 | X | 7.65 | X | 5.21 |

Organisers:

International Co-owners:

# 4. Conclusion

# Summary

01 The input data filtering and regrouping can improve energy consumption forecasting accuracy;

02 The proposed weather data prediction method can be applied in load forecasting;

03 Provide different methods to meet the various purposes about building load forecasting is practical.

# Thank you

If you need further discussion, please contact me:

+852-65879751

zhuguangya828@yahoo.com