Smart Grid Simulation Modelling in Thailand

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Energy Field of Study

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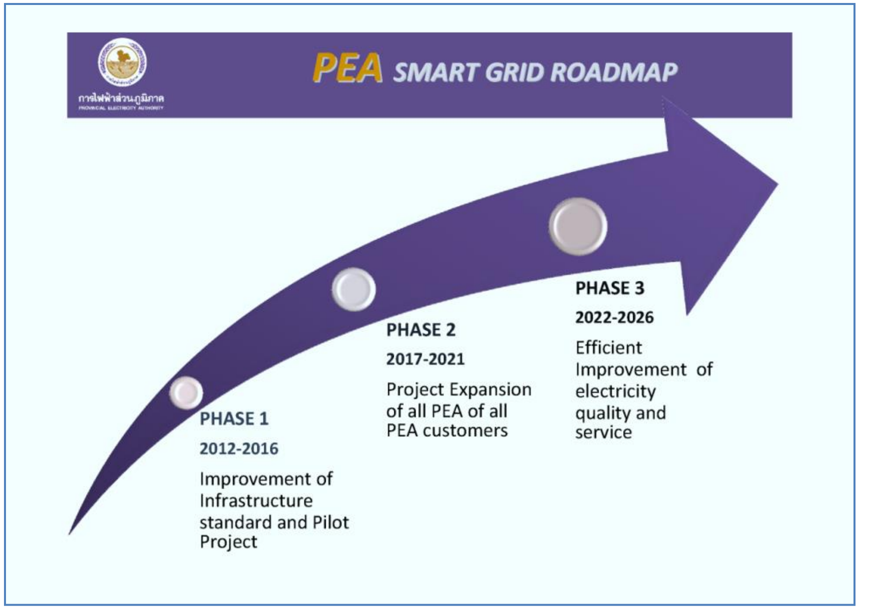
Outline

- Introduction
- Electricity Supply Industry in Thailand
- Methodology
- Model Application
- Results and Findings
- Conclusion

Introduction

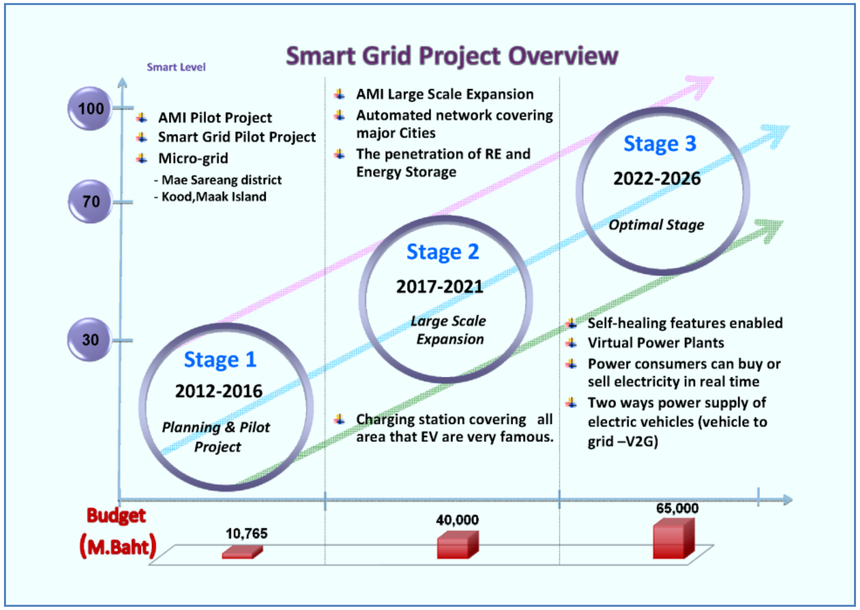
PEA's roadmap is strategized into three concepts named as "Smart energy", "Smart life" and "Smart community". The development starts with implementing relevant technologies such as advanced meter infrastructure, distribution automation, and renewable energy integration.



PEA Smart Grid Road Map
Source: PEA

Introduction

PEA brings together each technology to support one living standard and finally set out for an environmental friendly community. A pilot project for AMI initiative of 100,000 meters was announced in 2012



PEA Smart Grid Project Overview

Source: PEA

Electricity System in Thailand

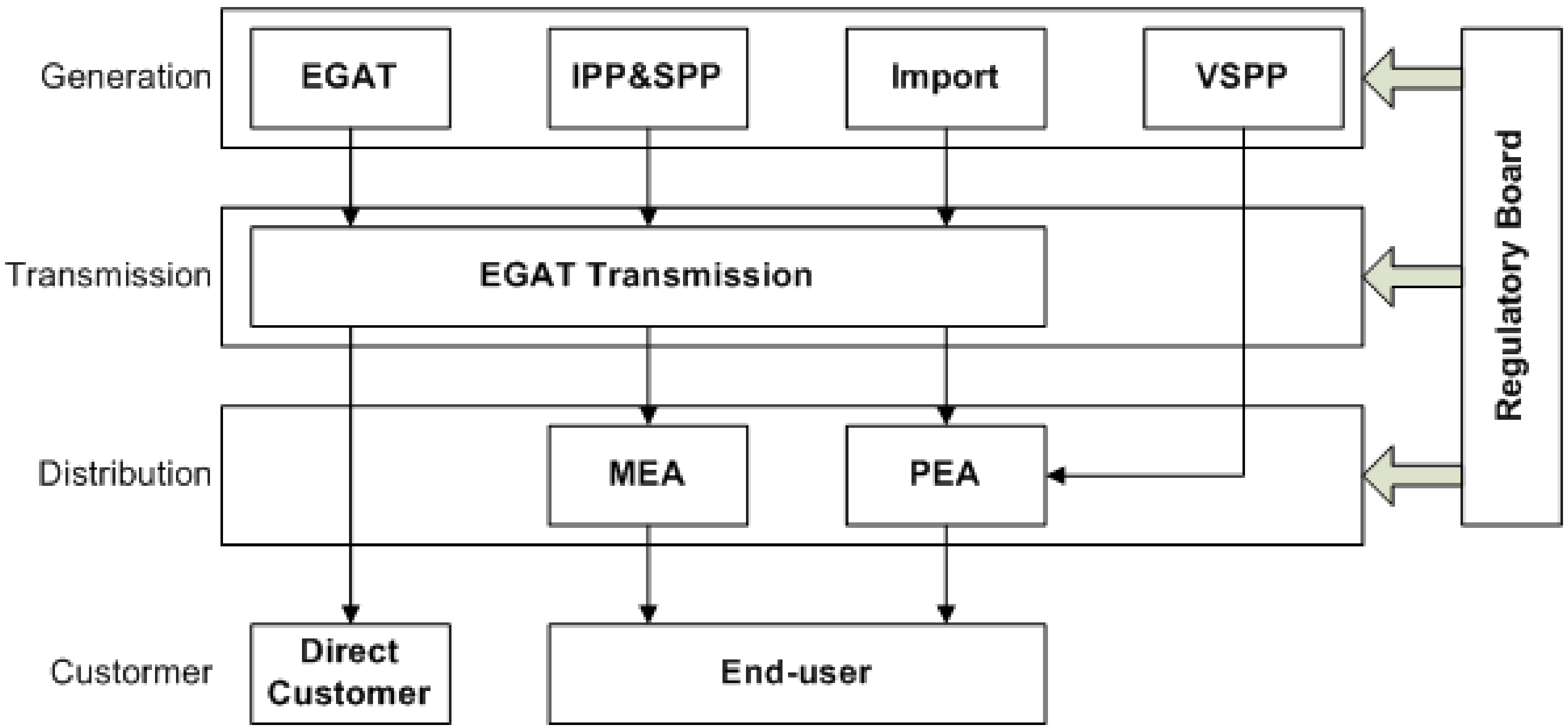


Fig. Electricity Supply Industry in Thailand

Electricity System in Thailand

Generation: EGAT, IPP, SPP, VSPP

- Rapid growth of intermittent energy

Transmission: EGAT

- Infrastructure upgrade
- Deployment of measurement units
- Advanced energy management system

Distribution: MEA, PEA

- Same aspect as Transmission

End User

- Mass AMI deployment
- End-user energy management system

Power Generation from Renewable Energy in Thailand

Generating Capacity of RE SPP and VSPP as of 17 December 2013

	Generating Capacity					Total Sale	Target	
unit : MW	operated	with PPA	approved	applied	Total		Original	New
Wind	**216**	198	1,489	759	2,662	2,457	1,200	1,800
Solar farm/rooftop	**735**	1,216	4	1056	3,011	2,901	2,000	2,200
Community solar	**0**	0	0	0	0	0	0	800
Micro hydro	**14**	15	0	0	29	28	324	324
Bio mass	**2,066**	1,336	269	289	3,960	2,566	3,630	4,800
Biogas and others	**215**	86	85	12	398	330	600	600
Biogas (napier)	**0**	0	0	0	0	0	0	3000
Municipal waste	**47**	119	31	124	321	290	160	400
New RE	**0**	0	0	0	0	0	3	3
Total	**3,293**	2,970	1,878	2,240	10,381	8,572	7,917	13,927

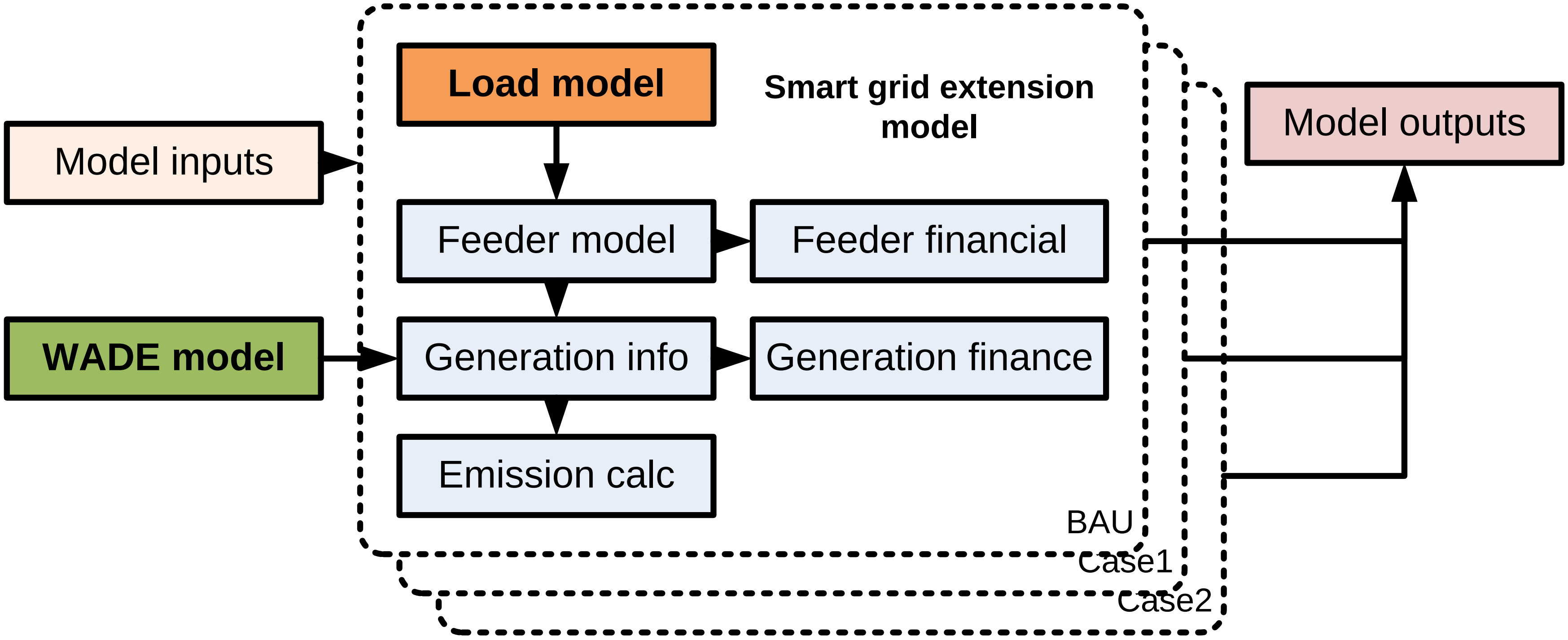
Source: E for E foundation, 2014

Methodology

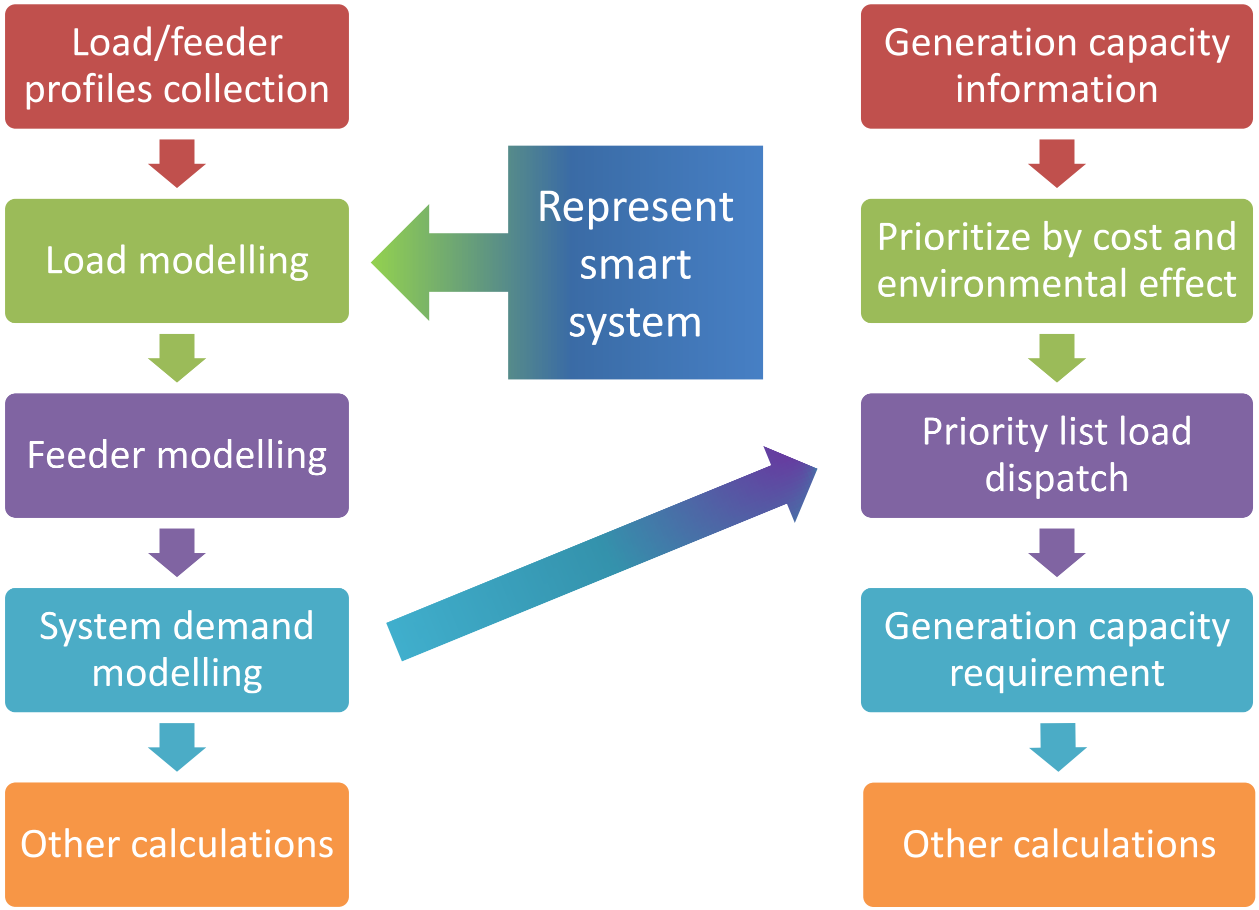
1. The model should follow these aspects
   – Demand data is categorized according to PEA tariff
   – Generation data is categorized by technology
   – Pollutant emission data follows generation categories
2. Model data shall follow Thailand's policy, plans
   – Power Development Plan
   – Alternative Energy Development plan
3. The model should consider dynamic load
   – Smart grid's load shall be equipped with demand response capability
   – Each load has an individual response depending on its profile
4. Pattaya city is chosen as the test system
   – Top selection from PEA smart grid pilot project
   – Variation of load profile

Methodology

Model diagram



Methodology



Methodology

Part	Type of data
Load model	• Hourly normalized load profile of each load type (categorized by tariff plan) • Average daily peak of each profile

Feeder model	• Combination of load per feeder
	• Monthly distributed peak ratio
	• Yearly distributed peak ratio
	• Annualized demand and energy consumption growth
	• Average distribution system loss
	  ○ Equipment loss
	  ○ Line loss
	  ○ Substation loss

Feeder financial	• Capital cost, operation and maintenance cost per component

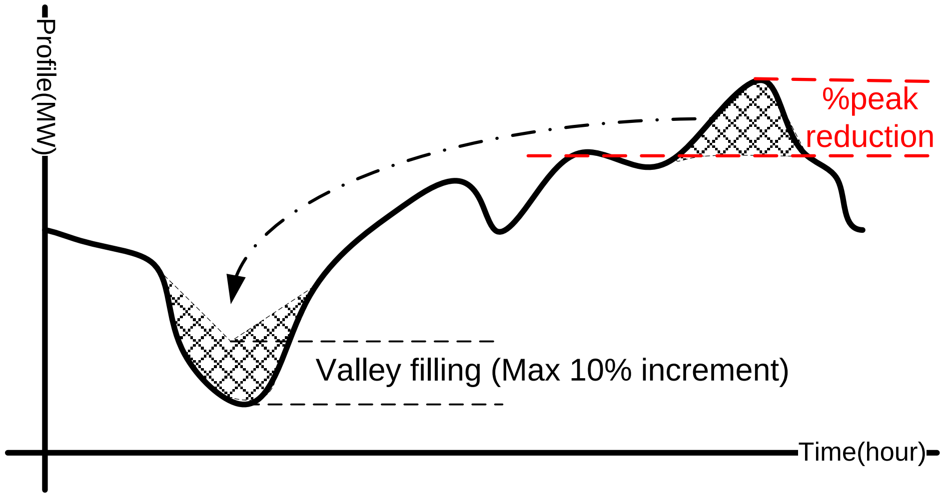
Methodology

Part	Type of data
Generation info*	• Existing and future capacity of selected CG and DE technology according to WADE model • Expected load factor of each generation technology • Reserve margin percentage • Average transmission system loss
Generation finance*	• Average capital cost, O&M cost by technology of generation according to WADE model • Average fuel cost • Average transmission and distribution costs, financial term, return on capital by technology according to WADE model
Emission calc*	• Emission factor for NO_X, SO_2, PM_{10} and CO_2 by technology of generation according to WADE model • Heat rate by technology

Methodology

Load model

- Serve as a basis for the whole model
- Normalized load profiles from PEA
- Modified profile for smart grid case



Methodology

Feeder model

- Each feeder is comprised of many load as to resemble PEA feeder profile
- Monthly demand and consumption calculation
- Yearly demand and consumption calculation

$$Workingdays = \frac{Year - (Weekends \times no.weeks + official\ holidays^{1})}{no.month}$$

$$Workingdays = \frac{365 - (2 \times 52 + 16)}{12} \approx 20$$

Methodology

Feeder financial

- Contain financial calculation relates to feeder model, mainly capital cost, O&M cost
- Investment cost for smart grid system is also calculated based on PEA roadmap
- Expected tariff is also calculated

Methodology

Generation info

- Construction is taken from WADE model so as the data
- Capacity of each technology is filled using priority list
- Priority is ordered by cost per kwh and environmental effect
- Future capacity is considered using Thailand PDP

$$Gen_{hi} = \begin{cases} (D_h) \times CP_i, & i = 1, D_h < Gen_{i,max} \\ \left(D_h - \sum_{j=1}^{i-1} Gen_{hj}\right) \times CP_i, & i \geq 2, D_h < Gen_{i,max} \\ Gen_{i,max} \times CP_i, & D_h \geq Gen_{i,max} \end{cases}$$

Methodology

Generation finance

- Generation side financial calculation mainly capital cost for generation capacity, T&D expansion, O&M cost, fuel cost
- Production cost for each technology is also calculated

$$Price_{i,y} = Price_{i,y-1} + \left(\frac{Capital\ investment_{i,y}}{total\ lifetime\ in\ hour}\right) + \left(\frac{O\&M\ cost_{i,y} + Fuel\ cost_{i,y}}{total\ Kwh_{i,y}}\right)$$

Methodology

Emission calculation

- Four major pollutant is considered, CO_2, SO_x, NO_x, PM_{10}
- Calculation using emission factor adopted from WADE model
- Renewable energy produce no emission

Methodology

Outcome

- Selected results are listed
- Comparing in 6-7 year period, as smart system may need to be re-invested due to product lifetime

Methodology

1. Business as Usual (BAU) Case
   - Percentage of each generation type remains the same as in PDP
   - No smart system applied
2. Smart grid (Modified) Case
   - Each load profile is modified by a peak shifting
   - Energy consumption remains the same
   - Three cases are considered as 5%, 10% and 15% on peak reduction.
3. Smart grid with energy conservation (Modified+ EC) Case
   - Every parameters are as the same as previous one
   - Energy consumption is reduced by 5% on average

	BAU	Modified	Modified+EC
Peak reduction [%]	0	5, 10, 15	5, 10, 15
EC [%]	0	0	5

Model application

- The area in consideration is **Pattaya city**
- There are 6 substations to be covered
  - Banglamung 100 MW capacity
  - Chom Tien 100 MW capacity
  - Pattaya Tai 100 MW capacity
  - Khao Mai Kaew 50 MW capacity
  - Pattaya Nua 100 MW capacity
  - Pattaya Tai 2* 50 MW capacity

*Only 5 of them are modeled due to lack of profile data

Model application

Tariff types	Sep-2010 Number	%
1. Residential (lower than 150 kwh)	19,064	14.09
2. Residential (higher than 150 kwh)	96,143	71.07
3. Small business	15,045	11.12
4. Medium business	868	0.64
5. Large business	28	0.02
6. Specific business	679	0.50
7. Government office or Non-profit organization	393	0.29
8. Agricultural pumping	3	0.00
9. Temporary loads	3,062	2.26
Total	**135,285**	100.00

Source: http://www.pattaya.go.th

Model application

Collected load model

- PEA's load profiles

Load profile	Model name	Peak demand [KW]
Average Residence (<150kwh/ month)	House_A	4.0
Average Residence (>150kwh/ month)	House_B	7.0
Average Small general service	Small_C	29.0
Average Medium general service	Medium_D	500.0
Average Large general service	Large_E	1300.0
Average Government and non-profit	Gov_G	120.0
Average Specific business (Hotel)	Hotel_F	50.0

Model application

- PEA's load profiles

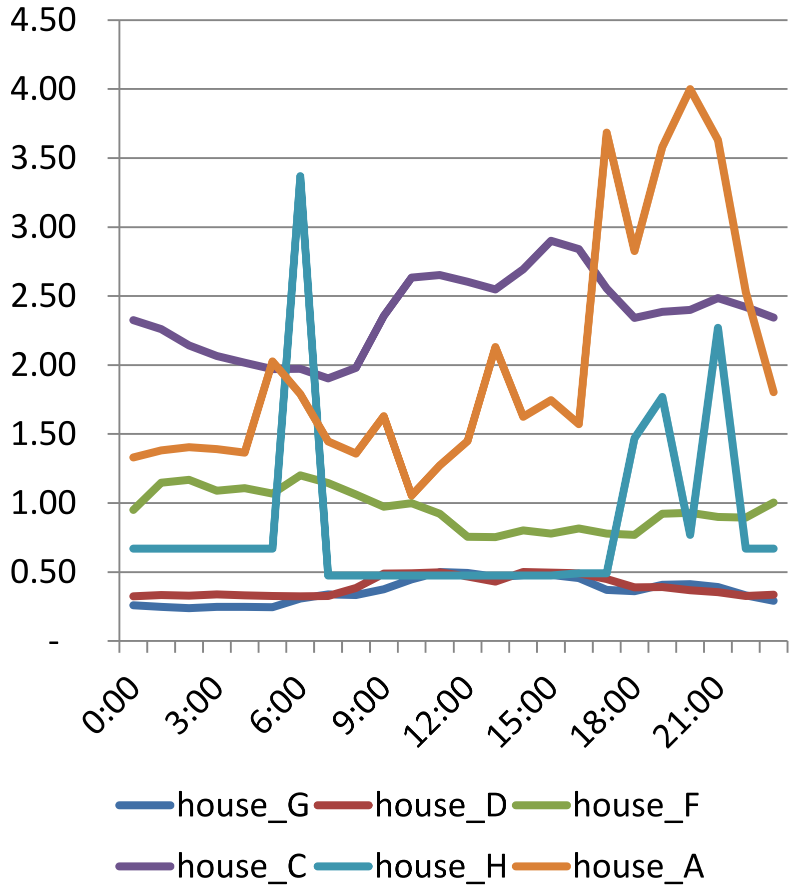
Load profile	Model name	Peak demand [KW]
Local Grocery store	Grocery_P	16.8
Local Residence	House_P	39.1
Local Bank	Bank_P	62.9
Local Nightclub	Nightclub_P	138.7
Local School	School_P	149.7
Local Government office	Gov_P	361.8
Local Factory	Factory_P	515.6
Local Shopping mall	Mall_P	1668.8
Local Hotel	Hotel_P	1746.0
Local Hospital	Hospital_P	1796.8

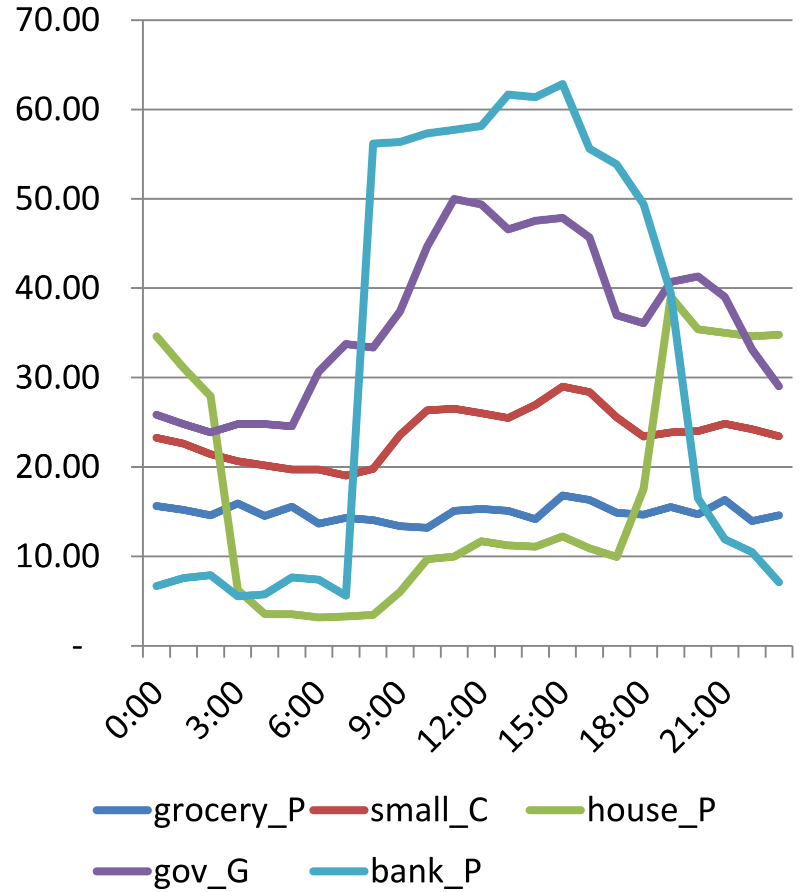
Model application

Generated profiles

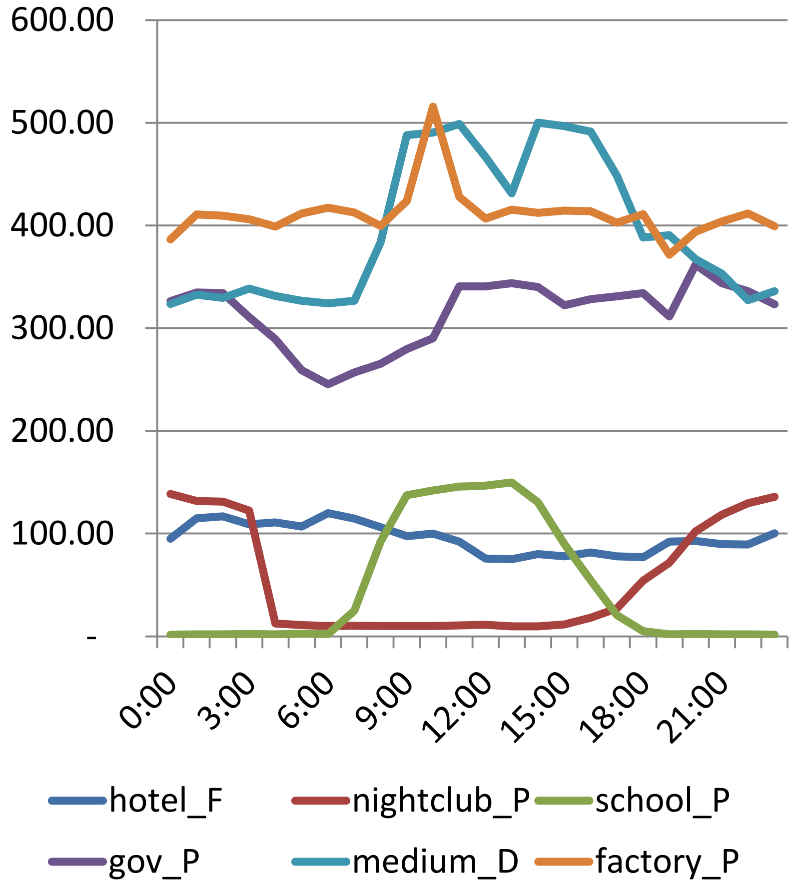
Load profile	Model name	Peak demand [KW]
Generated Residence#1	House_C	2.9
Generated Residence#2	House_D	0.5
Generated Residence#3	House_F	1.2
Generated Residence#4	House_G	0.5
Generated Residence#5	House_H	3.4
Generated Residence#6	House_I	5.8
Generated Residence#7	House_PF	5.2
Generated Residence#8	House_PM	1.7
Generated Residence#9	House_PH	1.8
Generated Residence#10	House_PT	1.8

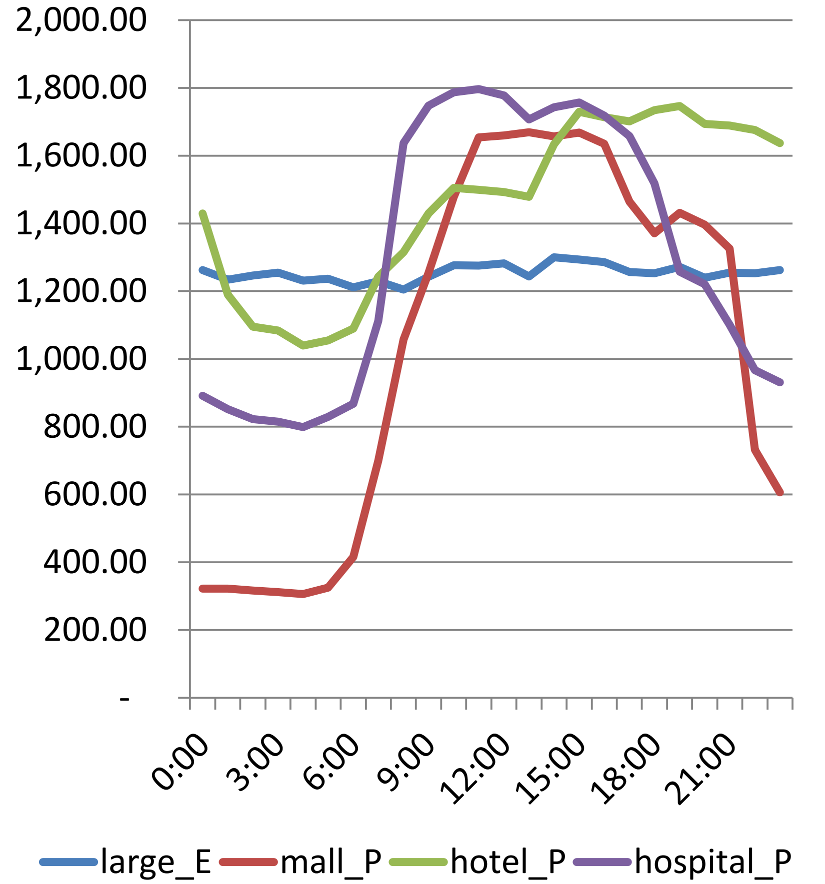
Model application





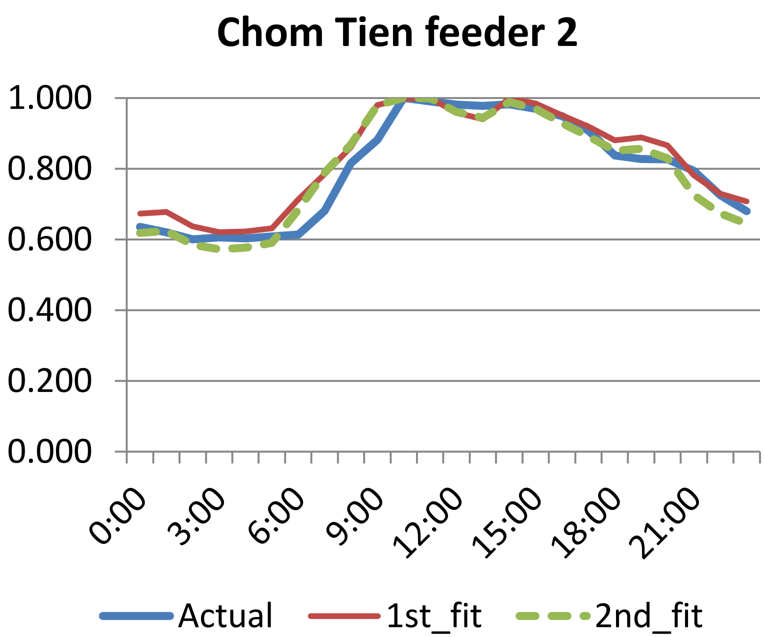
Model application

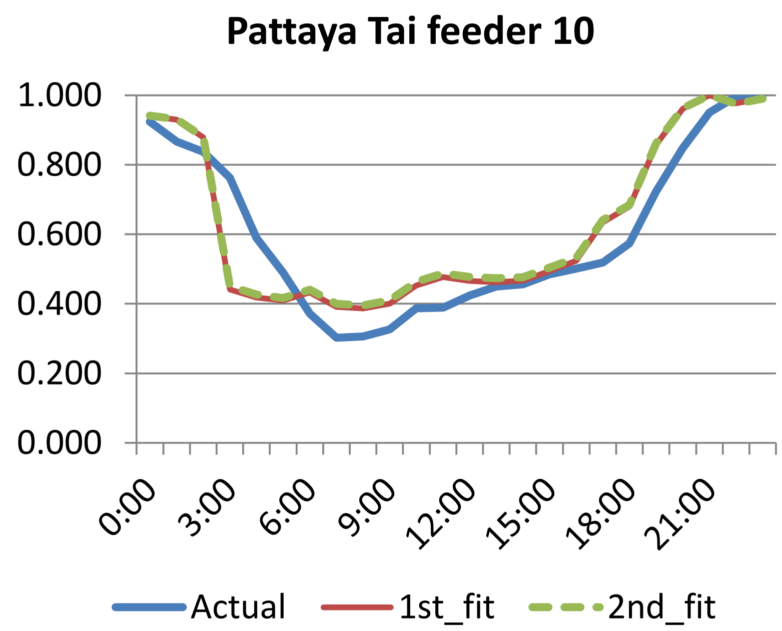




Model application

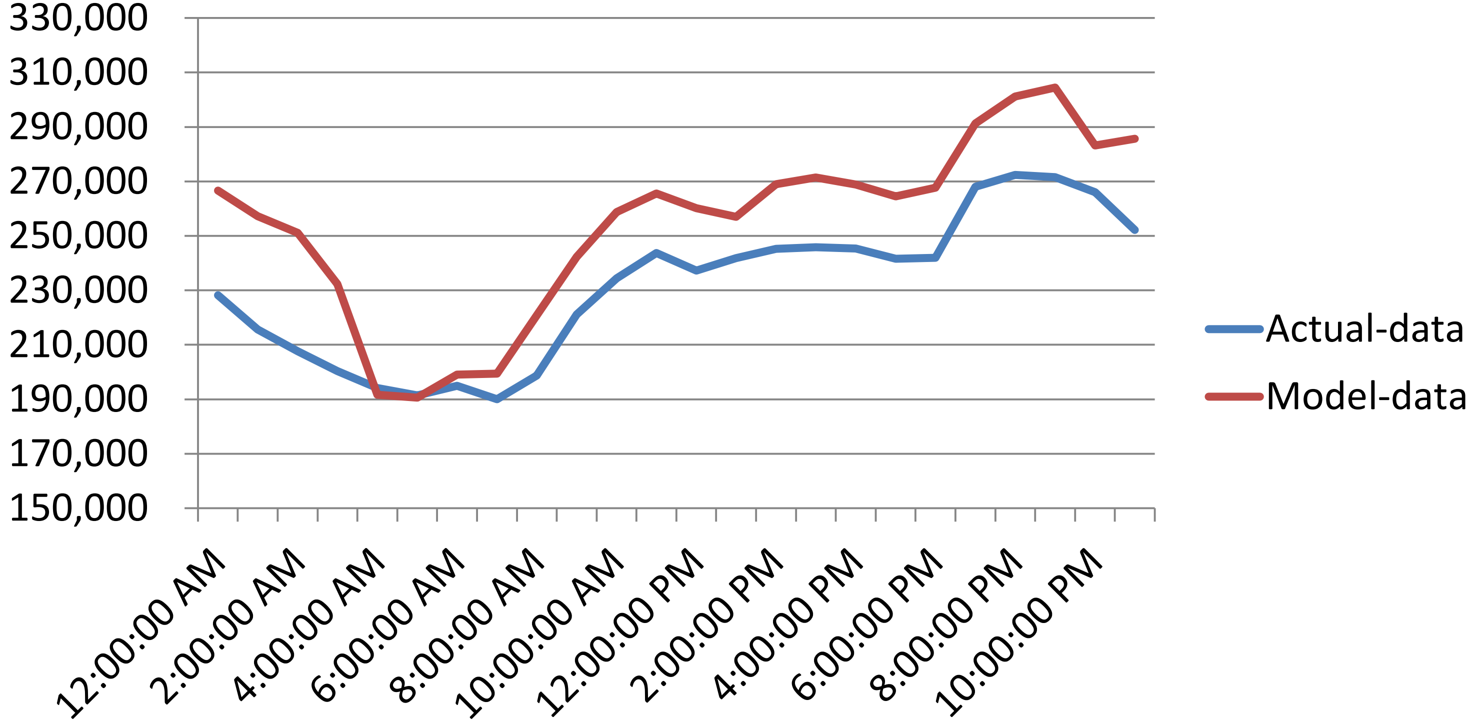
Feeder curve fitting





Model application

System load



Model application

Generation technology	Base capacity [MW]	Scaled capacity [KW]	Dispatch priority
Coal steam turbine	2,007.00	21,301	6
Lignite steam turbine	2,180.00	23,137	1
Oil steam turbine	315.00	3,343	18
Gas steam turbine	3,714.00	39,417	15
Combine cycle gas turbine	16,091.00	170,776	14
Diesel gas turbine	120.00	1,274	16
Diesel engine	4.00	42	19
Hydropower	3,424.00	36,339	2
Interconnection	2,157.00	22,893	3
Nuclear power	-	-	4

Model application

Generation technology	Base capacity [MW]	Scaled capacity [KW]	Dispatch priority
Coal CHP	370.00	3,927	7
Oil CHP	5.00	53	17
Gas CHP	1,293.00	13,723	13
Biomass	1,157.70	12,287	12
Biogas	57.26	608	8
Solar PV	10.21	108	9
Wind turbine	0.51	5	10
Hydro power – small	72.92	774	5
Waste to energy	9.40	100	11

Model application

Generation technology	Capital cost [Baht/kW]	O&M cost [Baht/kWh]	Fuel cost [Baht/kWh]	T&D cost [Baht/kW]
Coal steam turbine	33,517.80	0.53	67.73	18,642.05
Lignite steam turbine	32,900.21	0.32	15.62	18,642.05
Oil steam turbine	24,207.30	0.31	582.44	18,642.05
Gas steam turbine	13,345.05	0.25	300.34	18,642.05
Combine cycle gas turbine	17,689.95	0.16	300.34	18,642.05
Diesel gas turbine	13,345.05	0.13	1,075.39	18,642.05
Diesel engine	13,345.05	0.75	1,075.39	18,642.05
Hydropower	59,897.55	0.22	-	18,642.05
Interconnection	-	-	-	18,642.05
Nuclear power	35,690.25	0.05	22.35	18,642.05

Model application

Generation technology	Capital cost [Baht/kW]	O&M cost [Baht/kWh]	Fuel cost [Baht/kWh]	T&D cost [Baht/kW]
Coal CHP	35,690.25	0.38	67.73	11,185.23
Oil CHP	16,448.55	0.48	582.44	11,185.23
Gas CHP	43,914.53	0.16	238.08	11,185.23
Biomass	46,273.19	0.36	66.31	11,185.23
Biogas	126,746.94	1.08	66.31	11,185.23
Solar PV	41,462.76	0.15	-	11,185.23
Wind turbine	50,587.05	0.43	-	11,185.23
Hydro power – small	178,016.76	0.24	-	11,185.23
Waste to energy	35,690.25	-	66.31	11,185.23

Model application

Generation technology	NO_X [kg/GJ]	SO_2 [kg/GJ]	PM_{10} [kg/GJ]
Coal steam turbine	0.341	2.218	0.250
Lignite steam turbine	0.193	1.792	0.026
Oil steam turbine	0.142	0.946	0.065
Gas steam turbine/CCGT	0.061	0.0003	0.0008
Diesel gas turbine/engine	0.079	2.218	0.007
Coal CHP	0.020	0.020	0.01
Oil CHP	0.020	0.010	0.003
Gas CHP	0.020	0.0167	0.0028
Biomass	0.040	0	0
Biogas	0.054	0	0

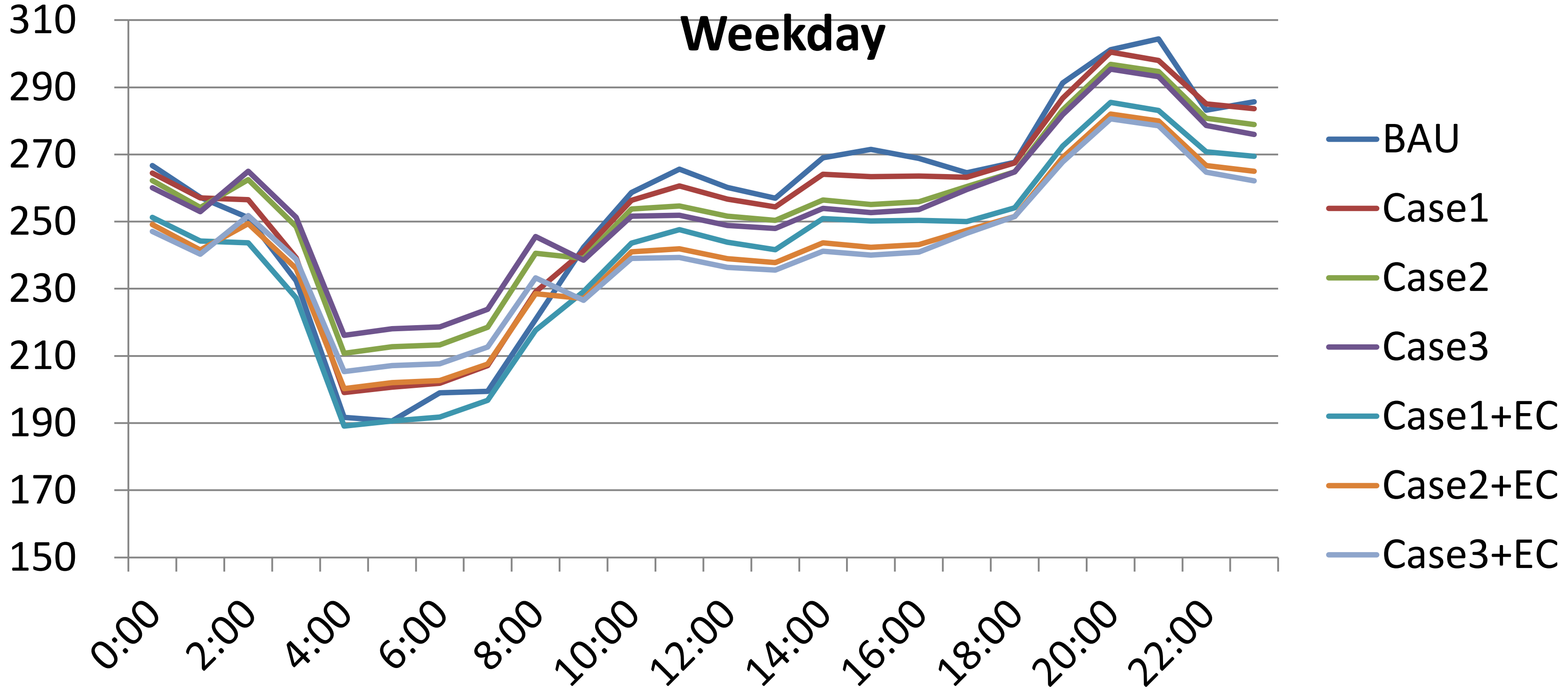
Model application

Fuel Type	CO_2 [kg/GJ]
Natural Gas	56
Furnace oil	77
Diesel	74
Lignite	101

Technology	Heat rate [kJ/kWh]
Steam Thermal	10,259
Combined Cycle	8,063
Gas Turbine	13,576
Diesel Engine	11,089
Combined Heat and Power	8,633
Biomass/Biogas	24,000
Waste to energy	20,000

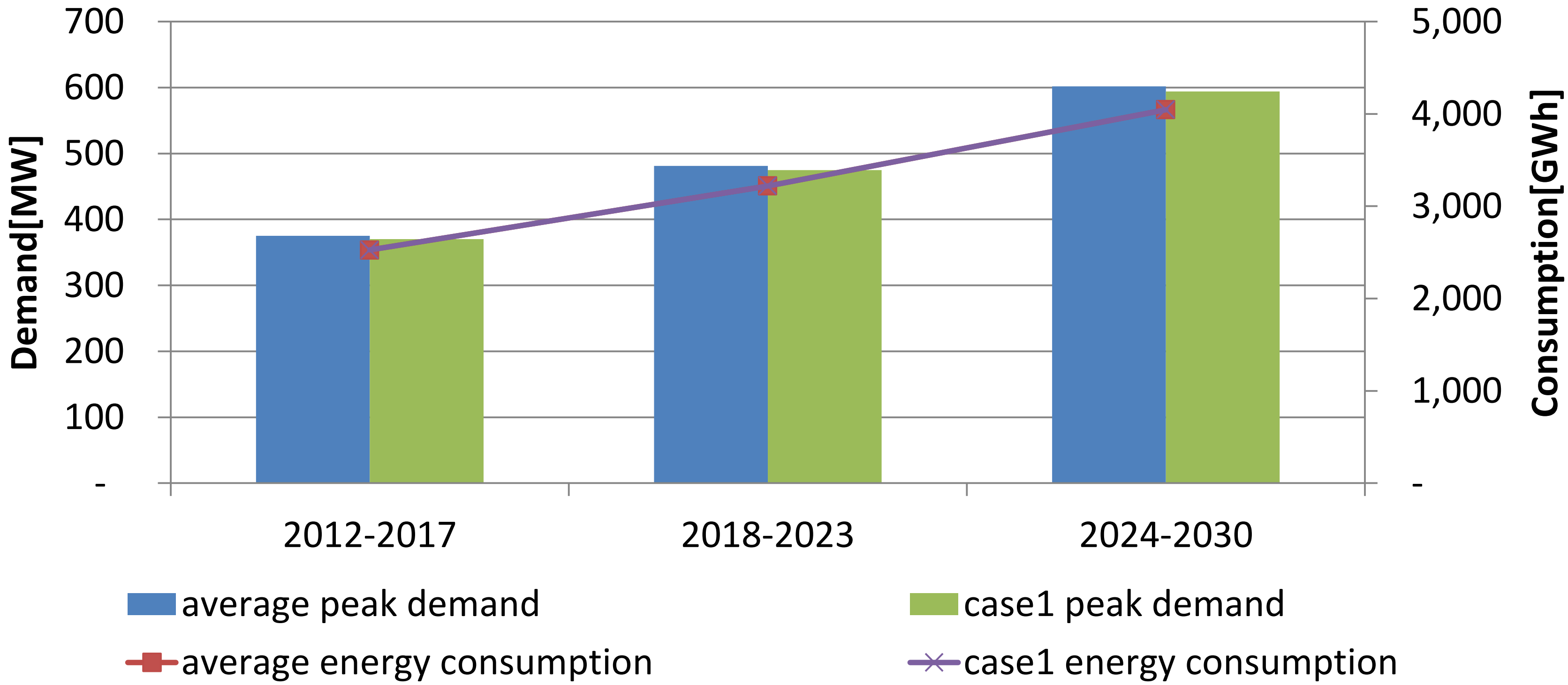
Findings and results

System profile (MW)



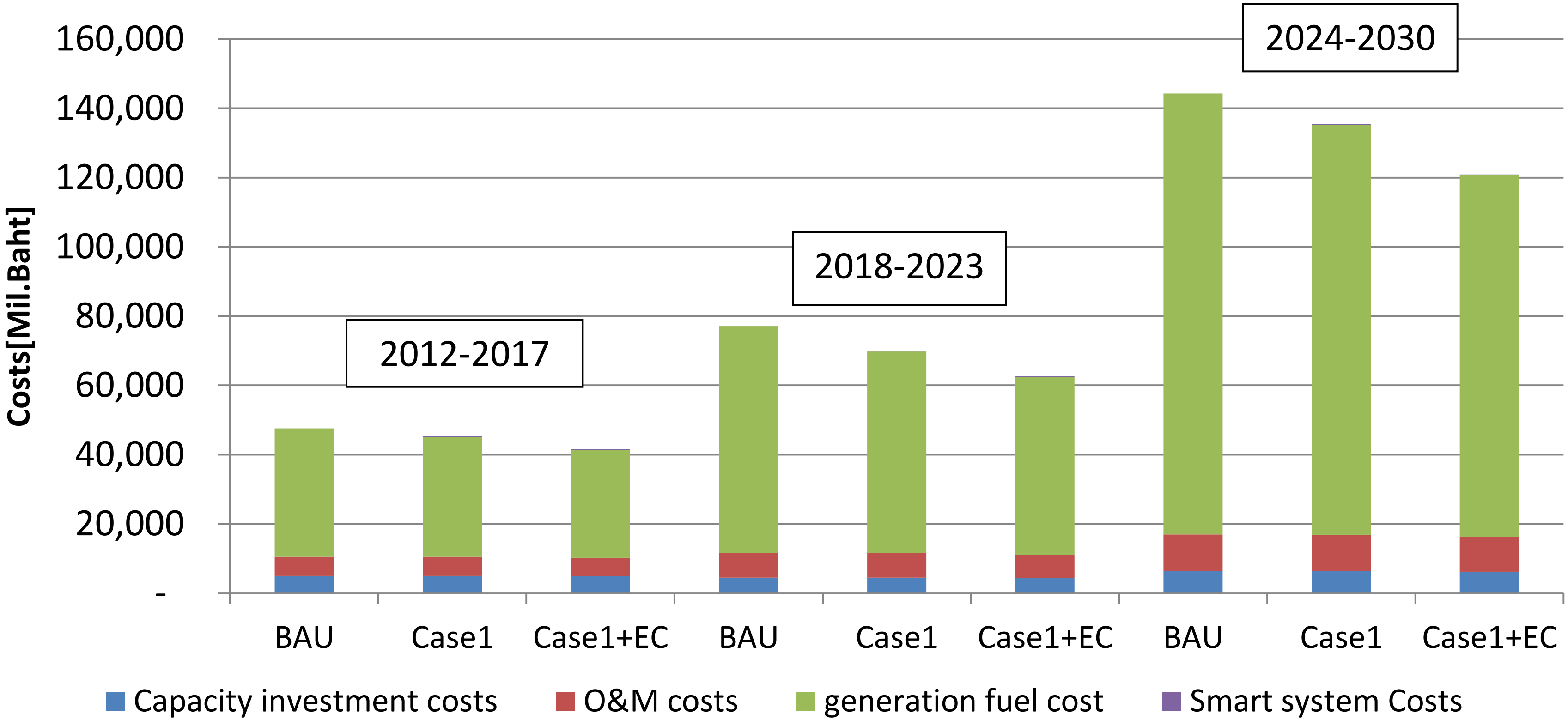
Findings and results

System growth



Findings and results

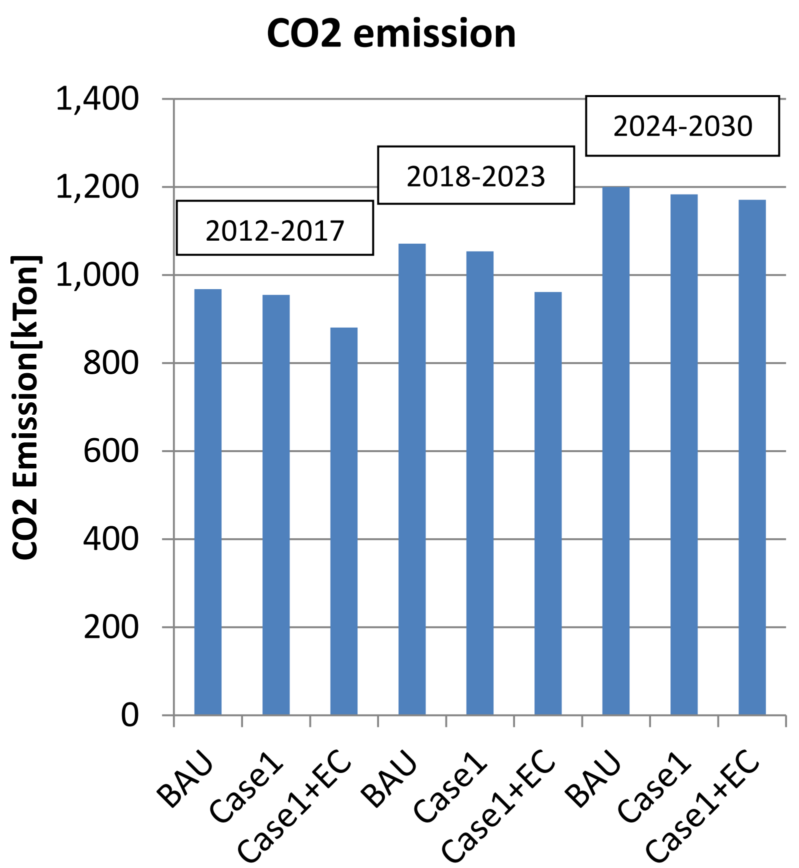
Overall cost

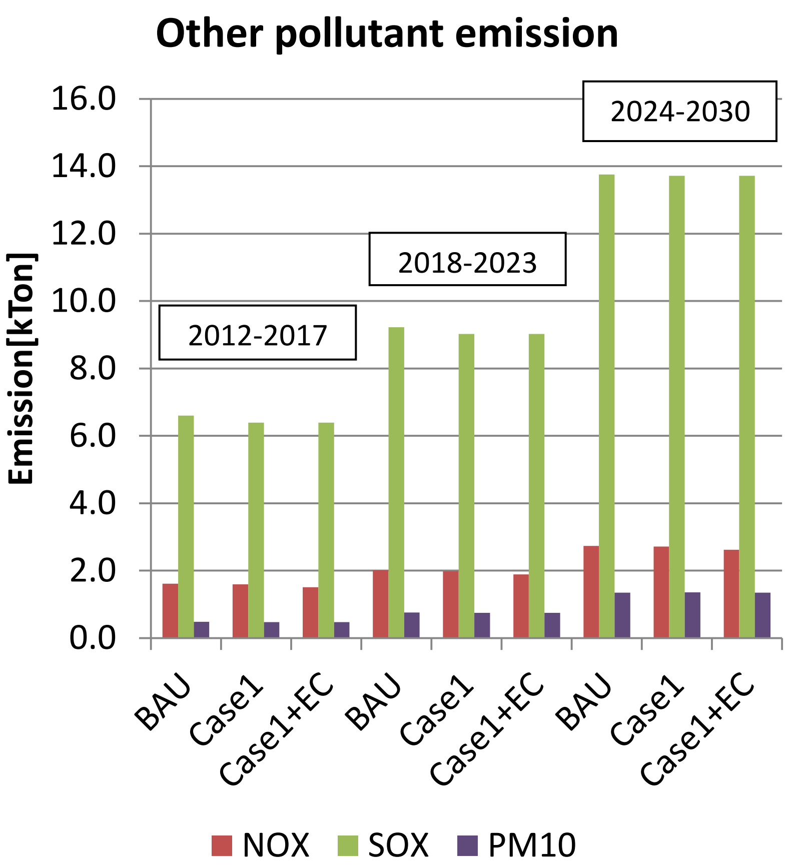


Findings and results

Costs [M. Baht]	BAU	Case1	Case1+EC
Capital investment	4,532.87	4,510.82	4,459.01
T&D investment	176.71	176.71	176.71
Feeder investment	294.37	282.12	200.38
Smart system investment	-	1,112.14	1,112.14
Generation O&M cost	3,373.04	3,362.63	3,163.06
Generation fuel cost	36,916.90	34,505.60	31,207.19
Feeder O&M cost	2,244.13	2,244.13	2,131.93
Smart system O&M cost	-	201.19	201.19
Difference		**1,343.80**	**5,649.26**

Findings and results





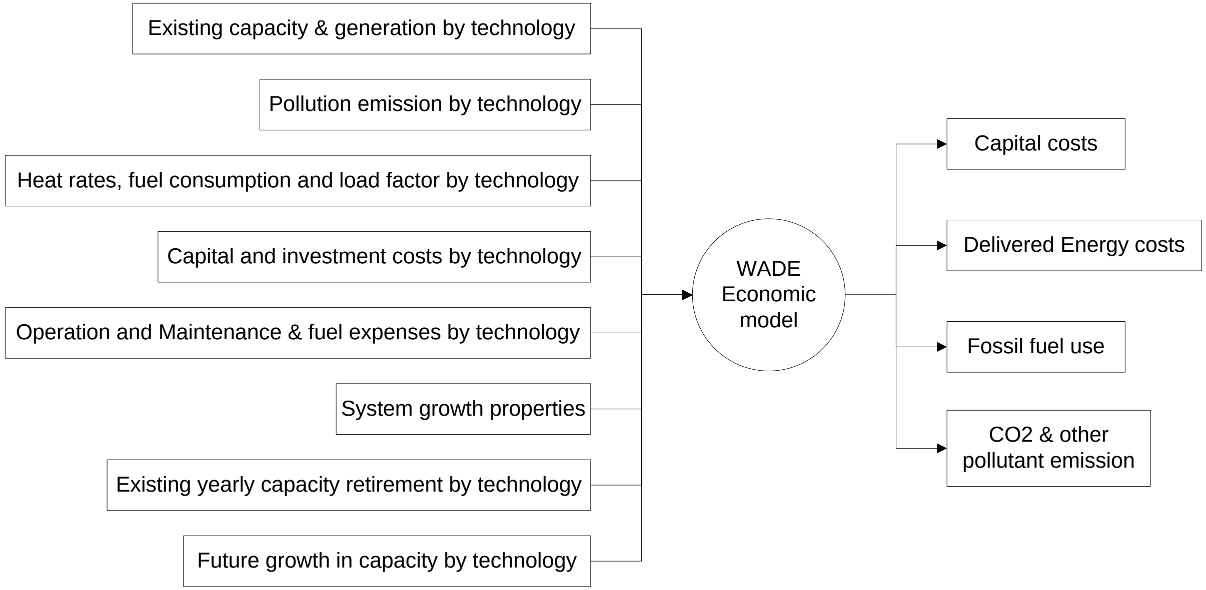
Conclusion

- The smart grid model has been simulated on Pattaya city considering dynamic load forecast.
- Three scenarios have been demonstrated with sensitivity analysis.
- Simulation results indicate that smart grid benefits including economic and environmental benefits are very attractive.

THANK YOU FOR YOUR ATTENTION

WADE Economic Model (WADE model)

WADE economic model or in short WADE model is an economic model which is a product of *World Alliance for Decentralized Energy (WADE)* mainly compares the performance of decentralized energy resource (DE) and centralized power generation (CG) in meeting future electricity demand growth. WADE model directly compares in economic and environmental terms based on extensive input data and defined assumptions.



WADE
WORLD ALLIANCE FOR DECENTRALIZED ENERGY

Source: www.localpower.org

WADE Economic Model (WADE model)

Our model utilizes input specified by WADE model and also requires several additional input such as load profile, feeder profile. Detailed description is in the methodology part.

Also our work utilizes partly some of calculation from WADE model in our generation system calculation.