13th Meeting of the Regional EST Forum in Asia
10-11 November 2020

Japan-Thailand Clean Air Partnership (JTCAP): Particulate Matter Reduction Strategy and Measures Development for Thailand

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Japan-Thailand Clean Air Partnership (JTCAP)

- JTCAP is established based on the policy dialogue between the Ministry of the Environment of Japan (MOEJ) and the Ministry of Natural Resources and Environment of the Kingdom of Thailand (MONRE) as the joint project of countermeasure for severe air pollution caused by $PM_{2.5}$ and other air pollutants in Thailand.

  Phase 1 (June 2018-March 2020), Phase 2 (April 2020-)

Open seminar of JTCAP

Planning meeting by Japanese and Thai participants

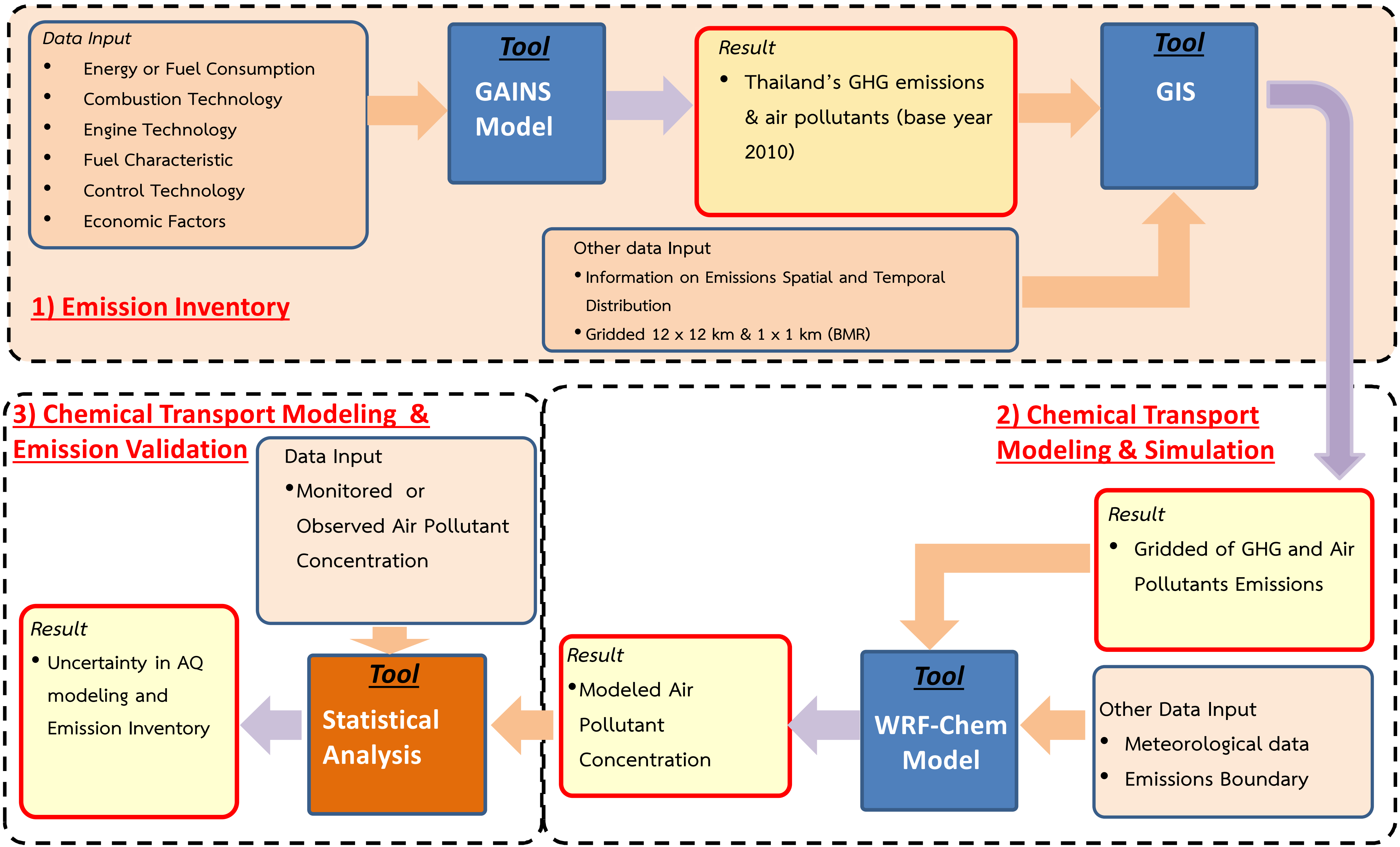
[Objectives]

(1) Identification of major $PM_{2.5}$ source sectors and regions by chemical transport model

(2) Long term observation and identification of major $PM_{2.5}$ sources by receptor model

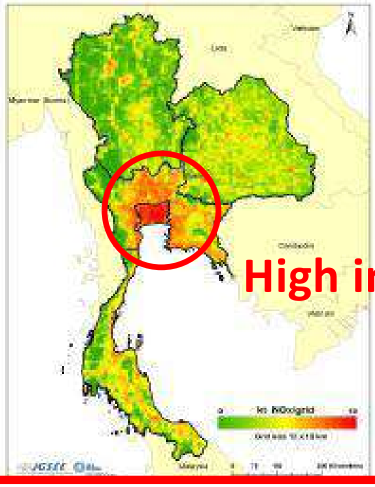
(3) Development of policy and appropriate measure along with generating stakeholder relationship

Method for the objective (1): Development of emission inventory



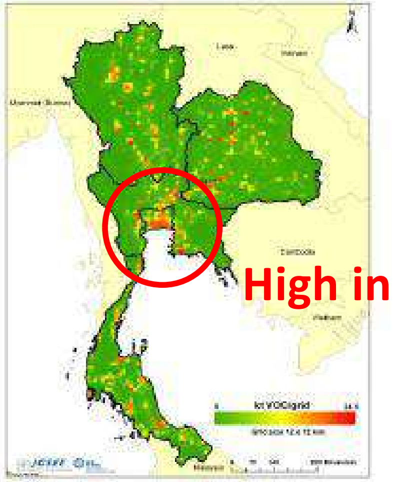
Results for the objective (1), Emission Inventory: Emission spatial distribution for important emission sectors in Thailand (Grid size: 12x12km, base year 2015)

Transport
($ktNO_x$)



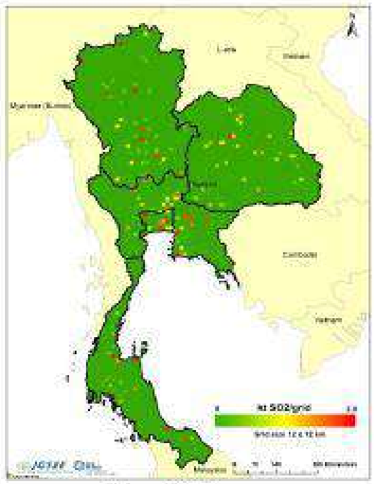
High in BMR

Industrial process
(ktVOC/grid)

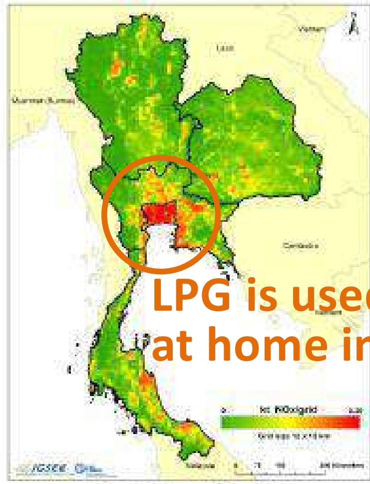


High in BMR

Power plant
($ktSO_2$/grid)

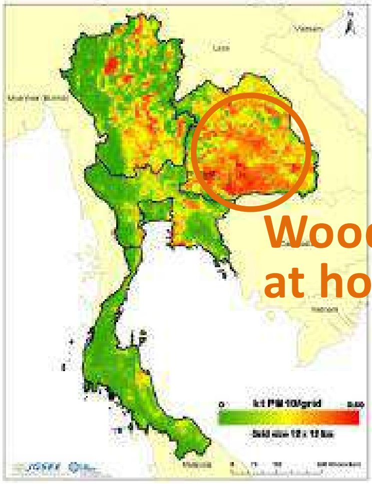


Domestics from LPG
($ktNO_x$/grid)



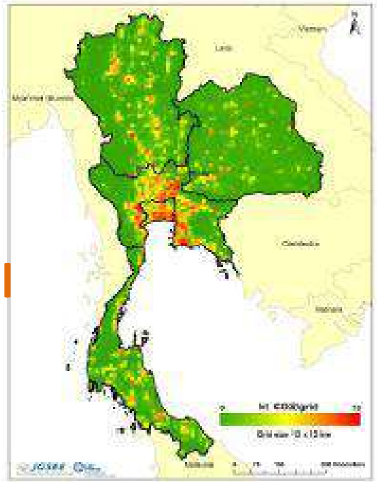
LPG is used
at home in urban

Domestic from Fuel Wood
(ktPM10/grid)

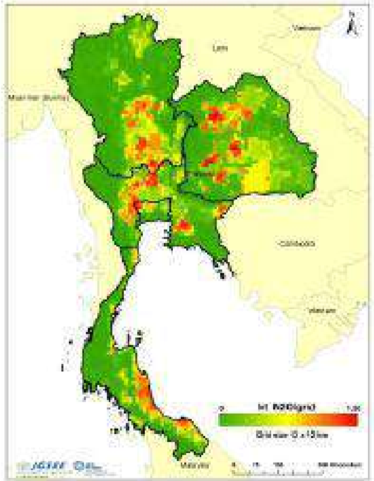


Wood is used
at home in local

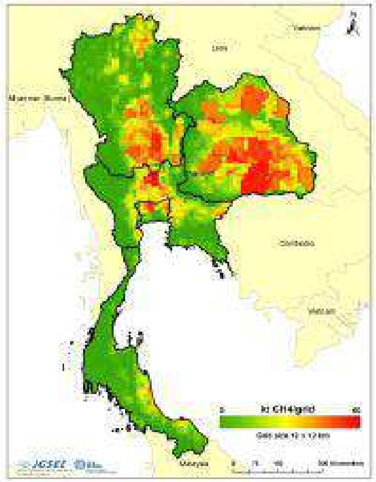
Industrial combustion
($ktCO_2$/grid)



Fertilizer
(ktN_2O/grid)

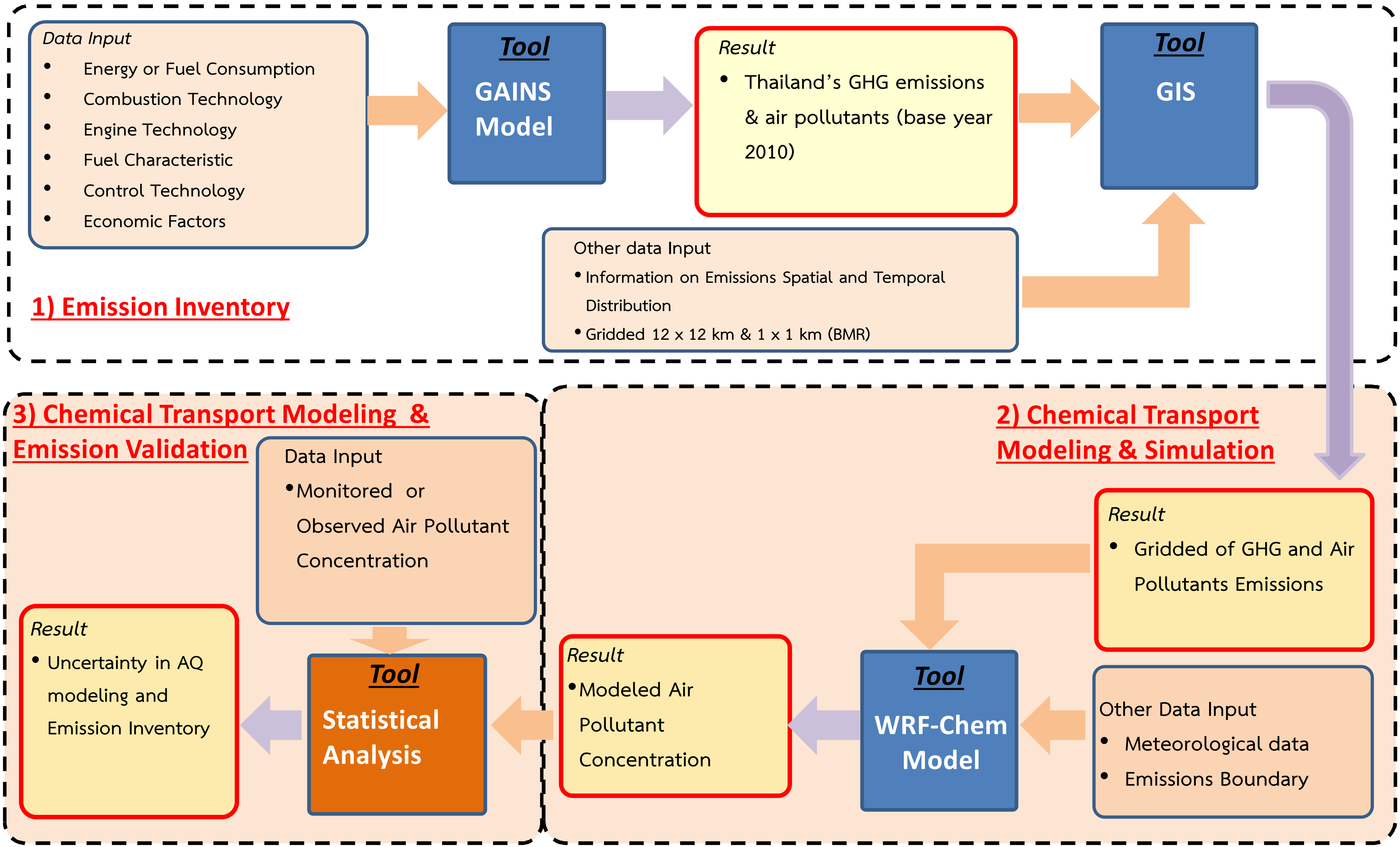


Paddy field
($ktCH_4$/grid)



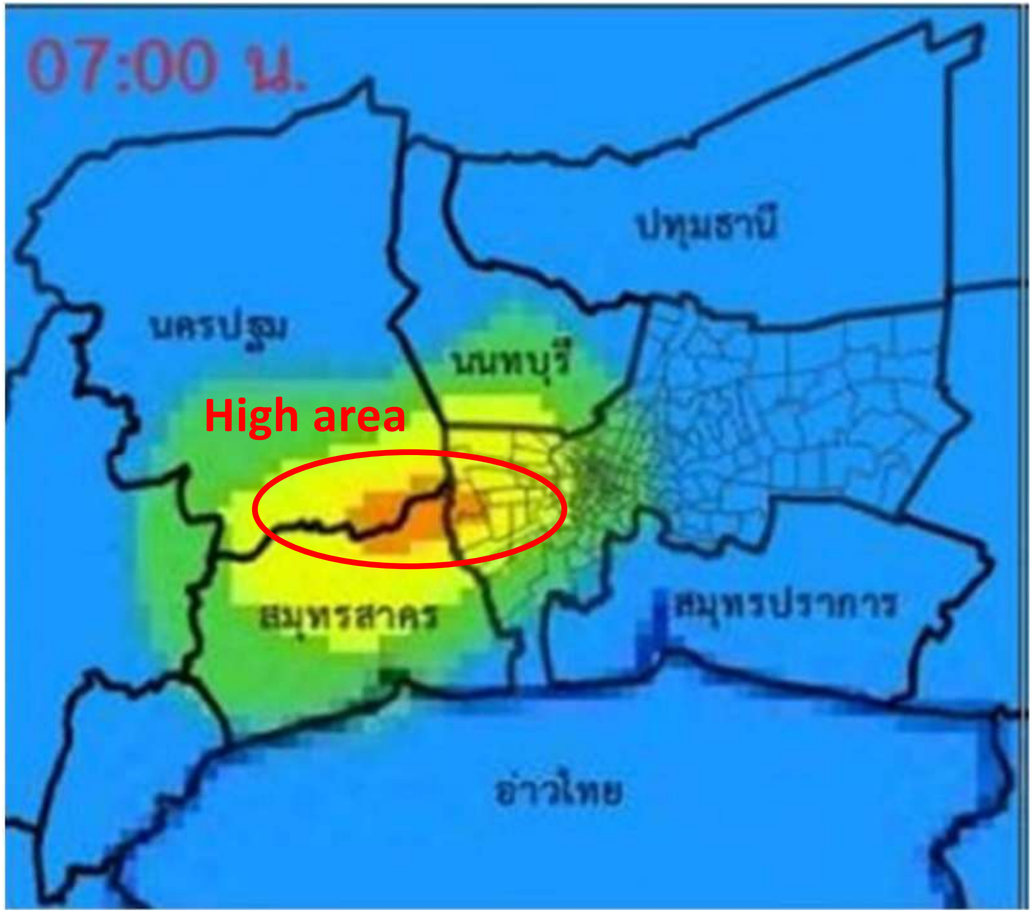
- High emission region is different depending on emission sectors and pollutants.
- These emission data will be used for Chemical Transport Model.

Method for the objective (1): Air quality assessment by chemical transport model

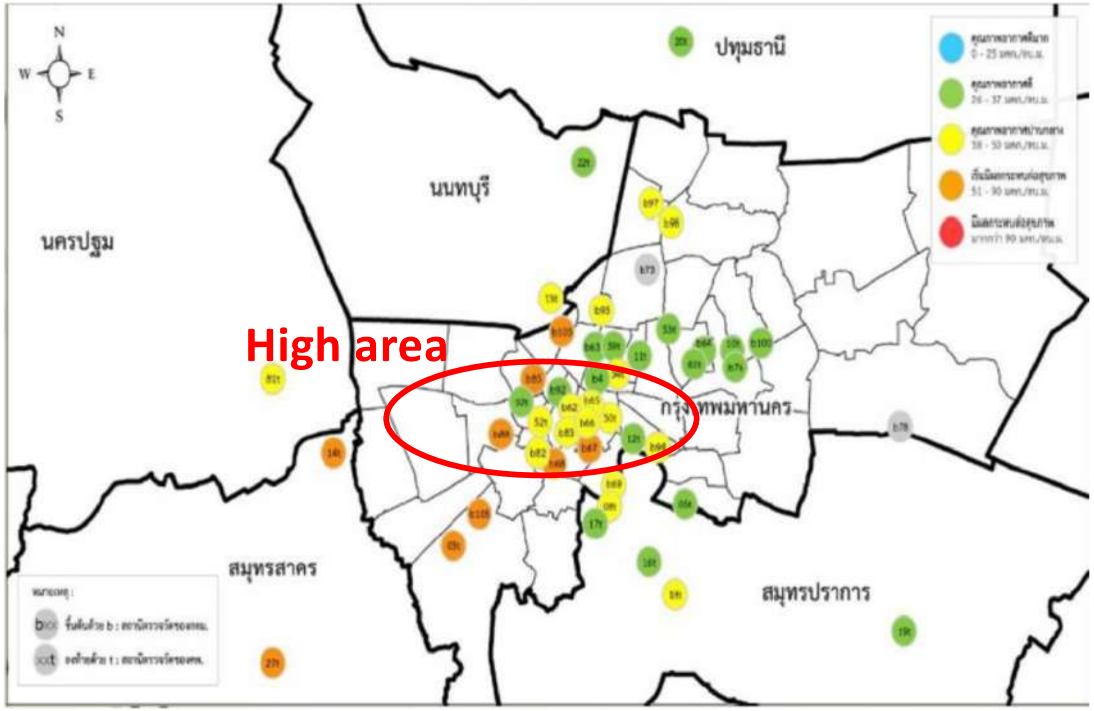


Results for the objective (1), Model simulation & validation: Spatial distribution of $PM_{2.5}$ concentrations calculated by chemical transport model (November 16, 2019)

Chemical transport model (WRF-Chem) at 7am on November 16, 2019



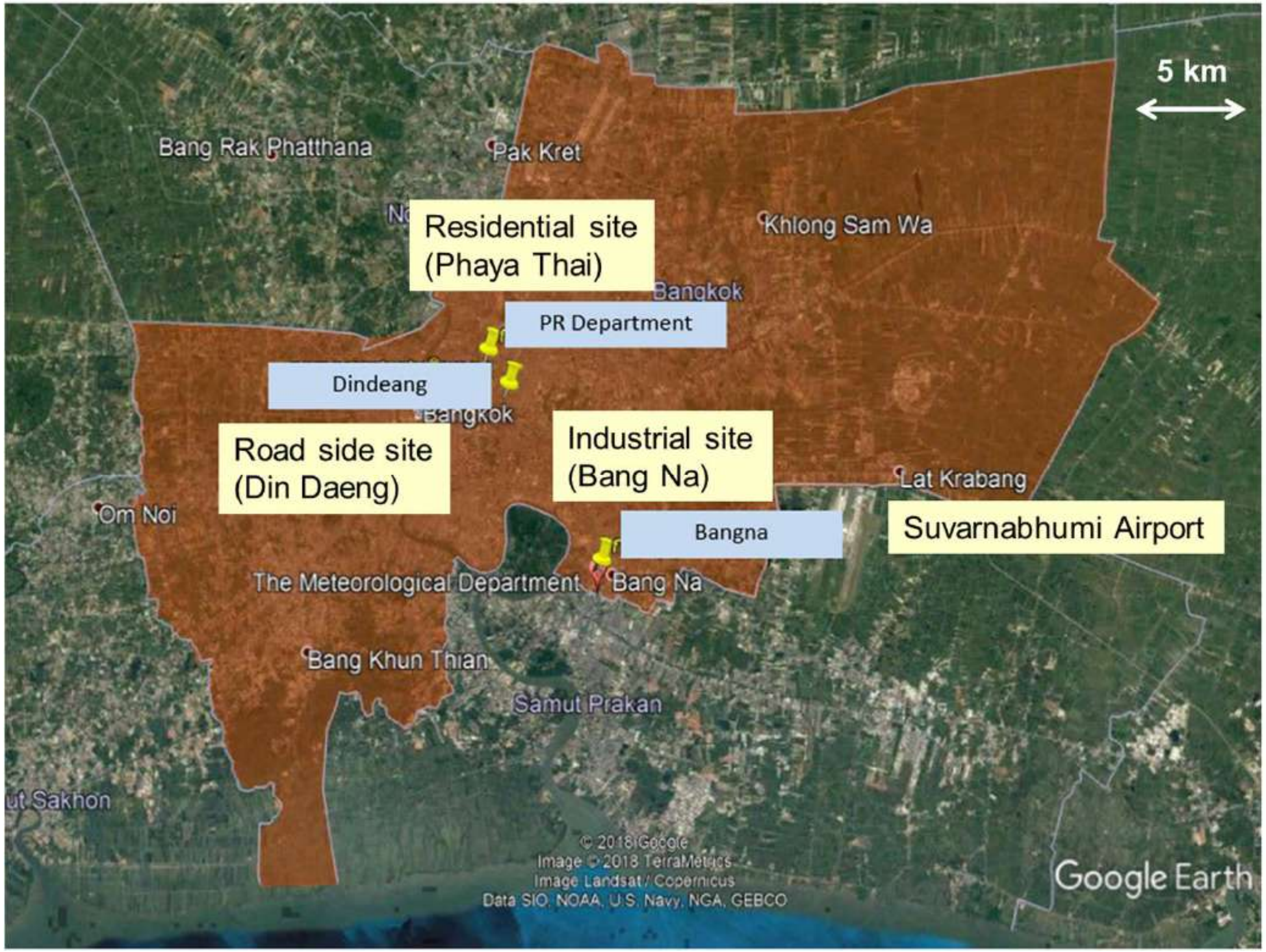
Daily average of $PM_{2.5}$ concentrations at air quality monitoring stations in Bangkok on November 16, 2019



- Spatial distribution of $PM_{2.5}$ is similar between model and observation. The results demonstrated that the model can reproduce $PM_{2.5}$ distribution in Bangkok.
- Model simulation during severe pollution period (January 2019) and normal period (March 2019) will be implemented to identify major $PM_{2.5}$ source sectors and regions .

Method for the objective (2): Long term observation of PM2.5 composition in Bangkok

Location of monitoring sites



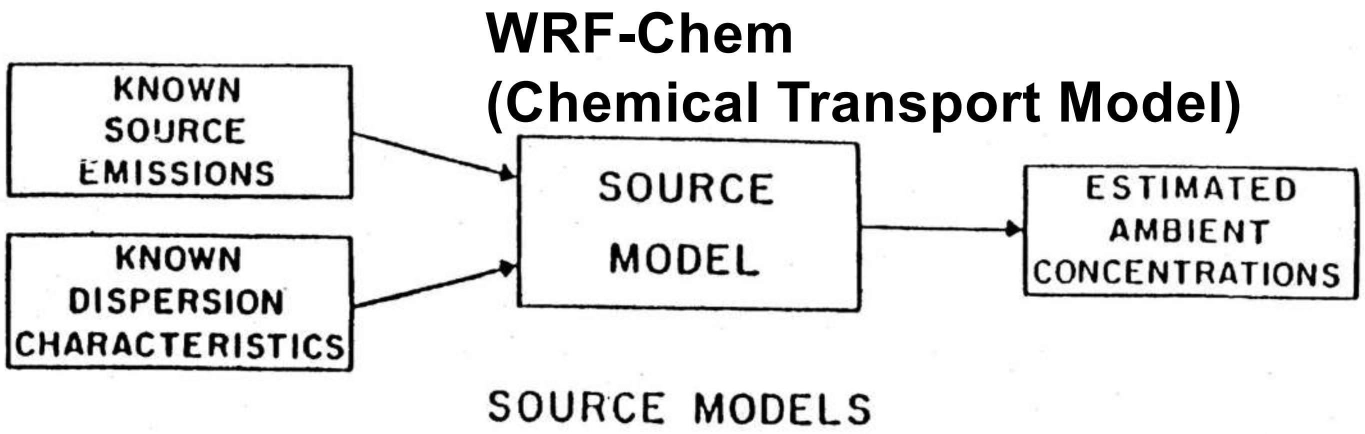
PM2.5 sampler

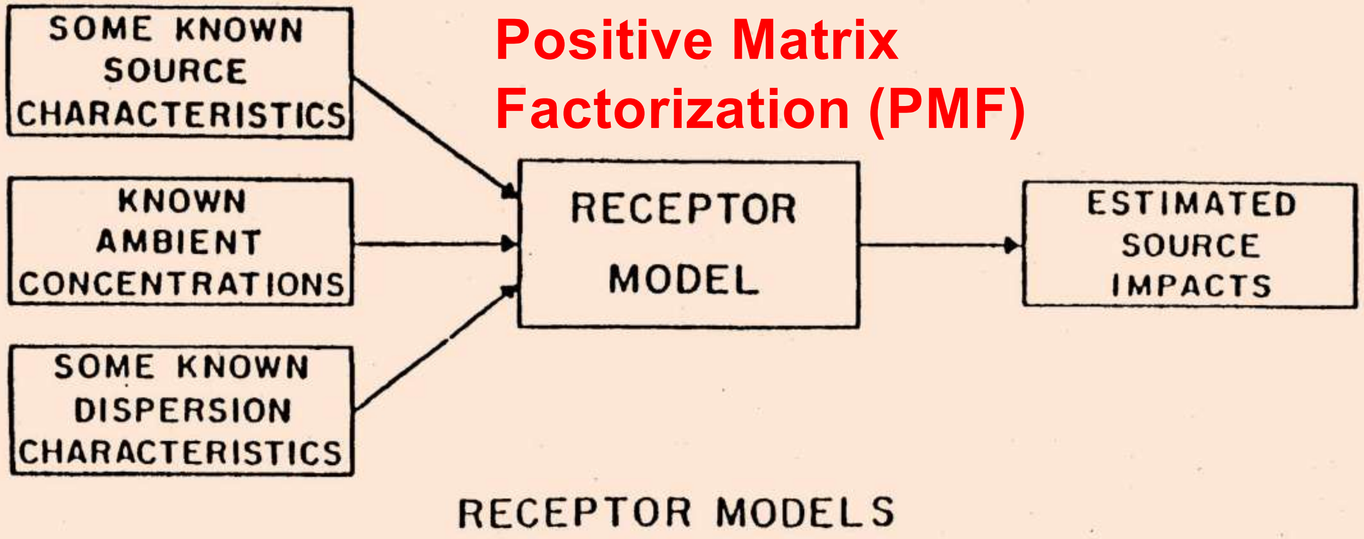
Daily PM2.5 was collected on a quartz filter at 3 sites in Bangkok from December 2018 to November 2019.

For laboratory analysis

- PM2.5 mass concentration
- Ion component (anions, cations)
- Carbonaceous component (Elementary and organic carbon)
- Metallic elements (Al, Fe, Ni, etc.)

Method for the objective (2): Source apportionment of $PM_{2.5}$ by receptor models

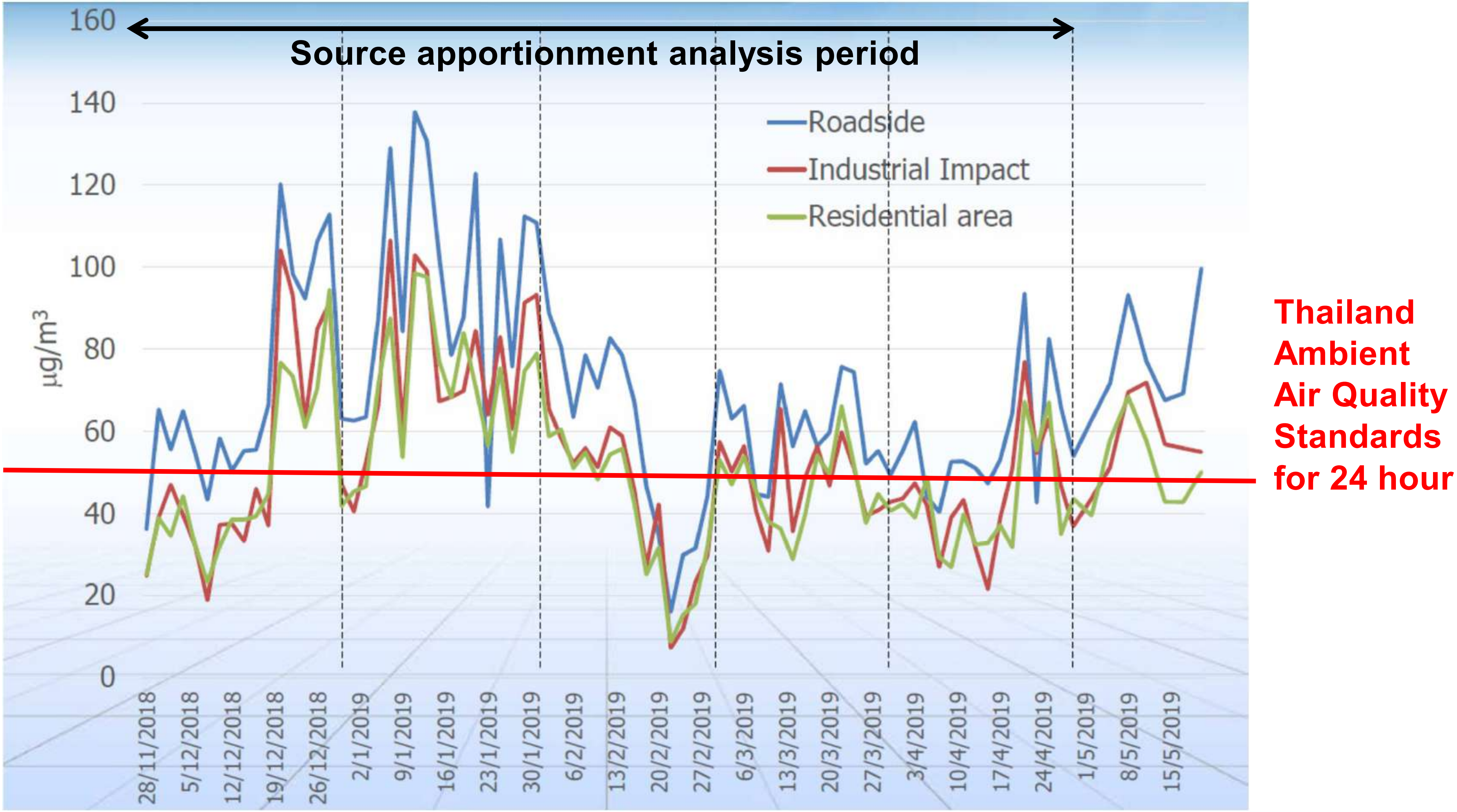




The source model uses source emissions (emission inventory) as input data and calculates ambient concentrations.
The receptor model uses ambient concentrations as inputs and calculates source contributions.

(Watson and Chow, *Air Quality Modeling*, 1979)

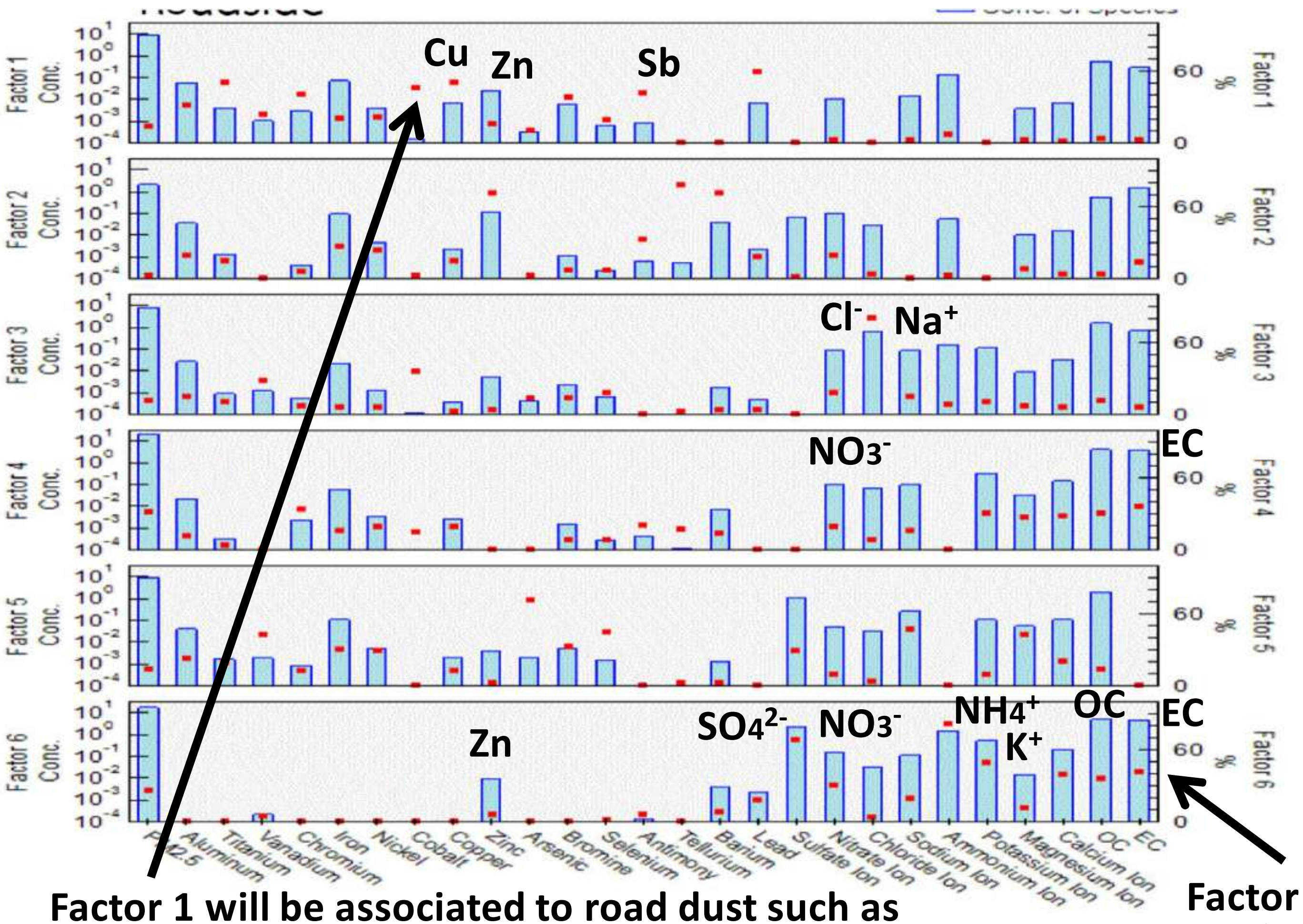
Results for the objective (2): Variations in daily mean PM2.5 concentrations at three sites in Bangkok



- PM2.5 concentrations at 3 sites exceeded the national standard from late December 2018 to late January 2019.
- In April and May 2019, air pollution caused by biomass burning in northern Thailand and neighboring countries is significant.

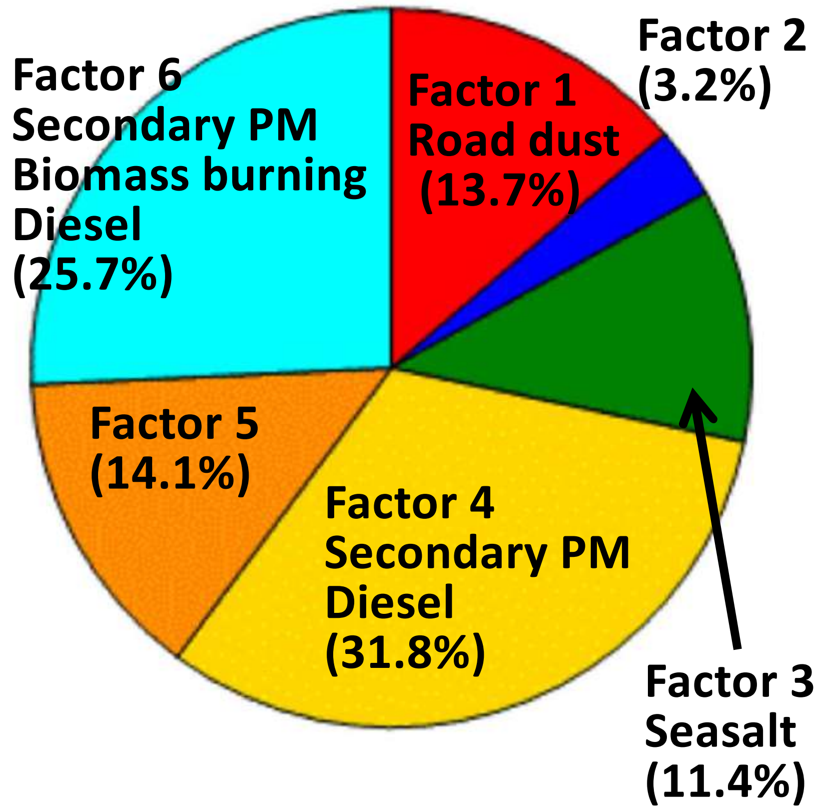
Results for the objective (2): Source apportionment results by Positive Matrix Factorization (PMF) at roadside site in Bangkok (November 2019 to April 2020)

Six factors obtained by PMF 5.0 model for each source category



Factor 1 will be associated to road dust such as break wear dust (Sb, Cu) and tire wear dust (Zn) because of high % of components.

Mean contribution of each source to PM2.5 estimated from PMF analysis



Factor 6 will be associated to Secondary PM (SO_4^{2-}, NH_4^+, NO_3^-), Biomass burning (OC, K+) and Diesel source (EC, Zn) because of high % of components.

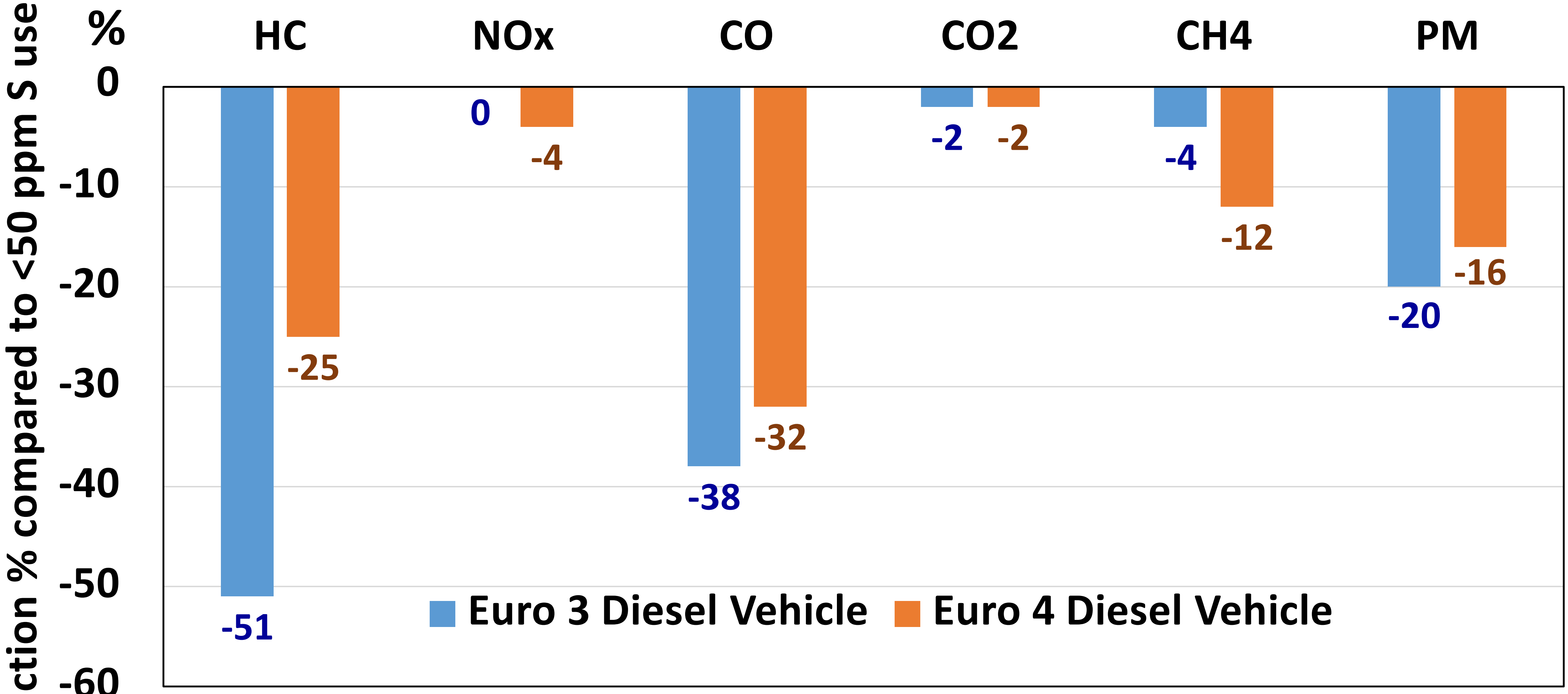
- PMF analysis indicated secondary PM, Biomass burning and Diesel exhaust particle are major sources of PM2.5.
- It was difficult to qualify contribution of each source because several sources were mixed in one factor.

Results for the objective (3): Action plan for measures against road transport recommended from JTCAP that is consistent with the National Agenda

Conceptual Measures	Measures against road transport
Positive social involvement measures	• "No My Car Day" (Car free day, Scheduled car pool day, Car sharing) • Encourage to work at home day • Promote commuting in different time ranges/day in order to improve the crowded commuting traffic • Promote non-motorized transportation
Laws and regulations	• Registration renewal fee based on used years
New Technology	• Promote soot free vehicles • Replace heavy duty vehicles by soot free vehicles
Local authority regulation/ responsibility	• Diesel vehicles entrance prohibited policy due to high EC/OC ratio data from $PM_{2.5}$ composition analysis • Schedule use of vehicles by registration number

- The National Agenda for action plans "Solving the dust pollution problem" was approved by the cabinet of Thailand in August 2019.

Effective emission reduction scenario case study (1): Emission Reduction obtained from Switching from <50 ppm Sulfur to <10 ppm Sulfur Diesel Fuel in Euro 3 and Euro 4 Diesel Vehicles

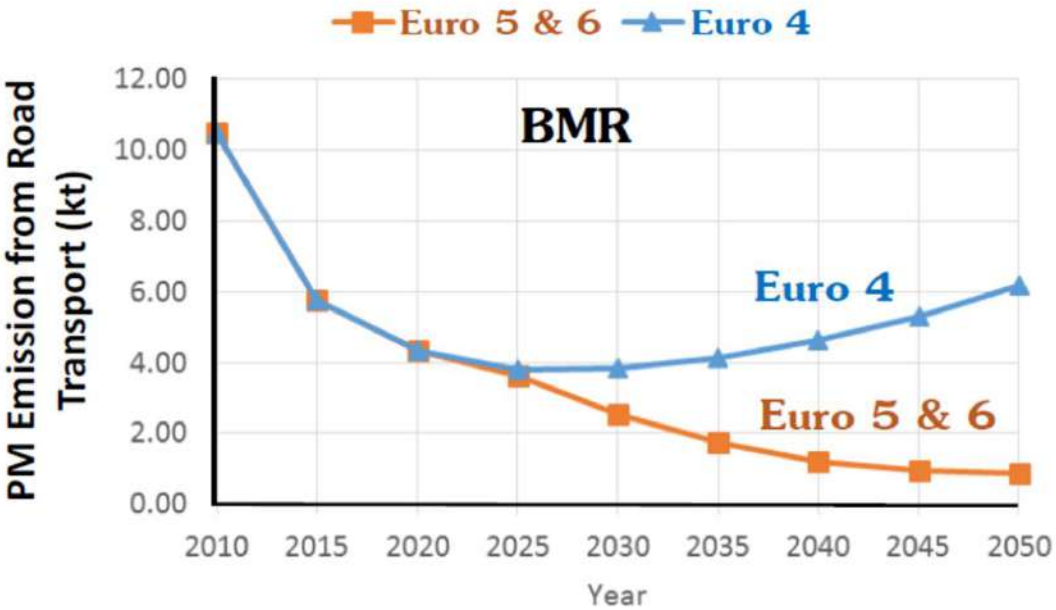


Dr. Supat Wangwongwatana, Workshop on Asian countries on the challenges of achieving cleaner and more efficient fuels and vehicles (2018)

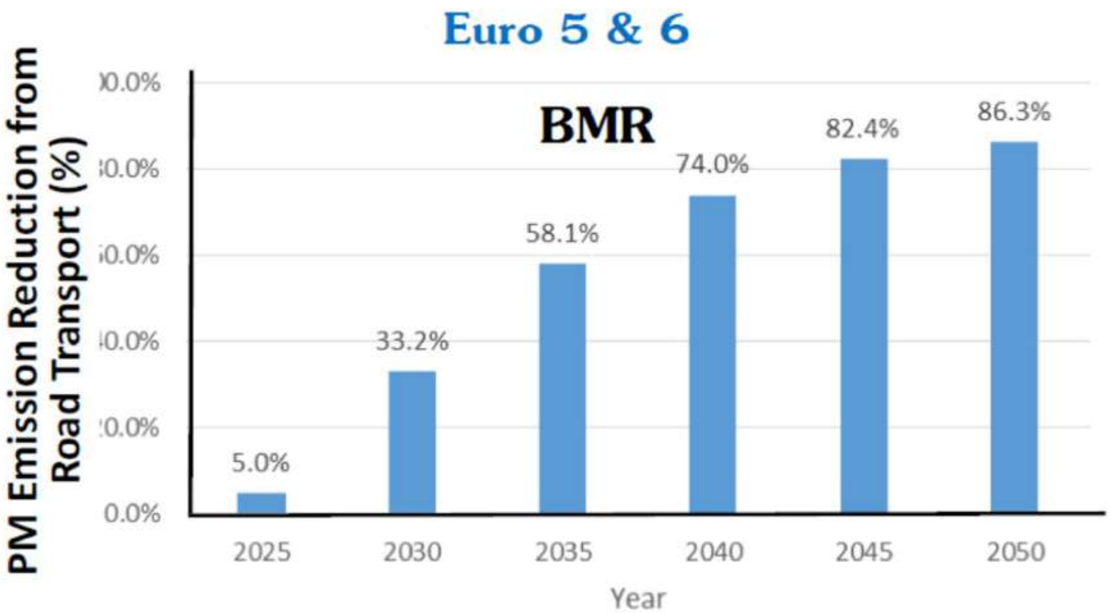
- Primary emission of particulate matter will decrease by 16-20 % for low sulfur fuel.
- HC and CO emissions will effectively decrease by 25-51 % for low sulfur fuel.

Effective emission reduction scenario case study (2): PM emission reduction in the road transport in Bangkok from the implementation of Euro 5/6 Roadmap

Future projection on PM emission from road transport implementation of Euro 4 and Euro 5-6



PM emission reduction ratio compared to Euro 4



Dr. Supat Wangwongwatana, Workshop on Asian countries on the challenges of achieving cleaner and more efficient fuels and vehicles (2018)

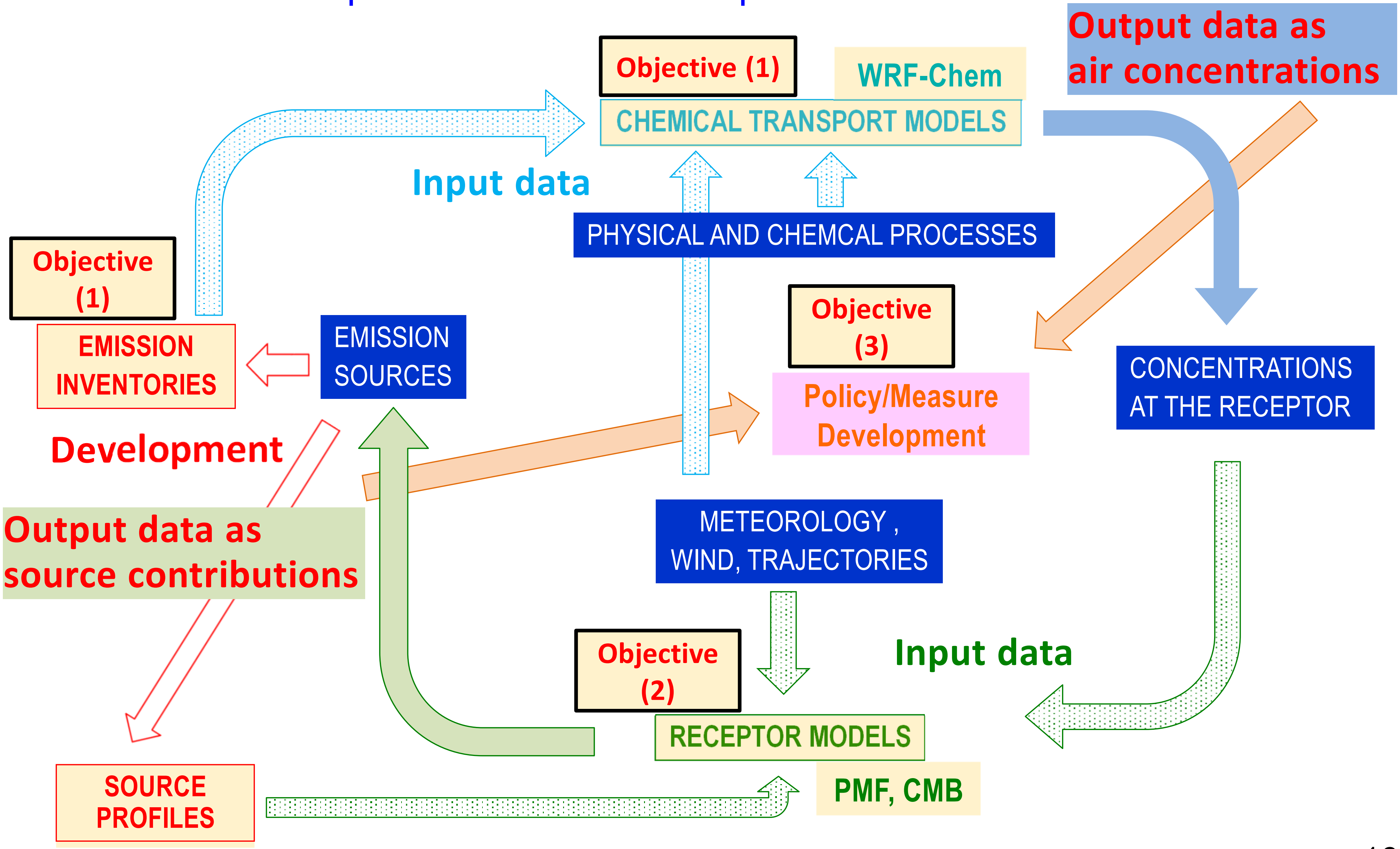
- By 2040, Primary emission of particulate matter will decrease by 74.0 % for Euro 5/6 compared to Euro 4.
- It was implied that implementation on Euro 5/6 is effective for automobile emission reduction.

Summary

1. Emission inventories of anthropogenic and biogenic sources used for air quality model were prepared, and the future prospects for the development of emission inventory guidelines and its role of government were summarized. The summarized results will be used to create a framework for the continued development of Thailand's national emission inventory in the future.
2. Trial calculations of the chemical transport model in the Bangkok Metropolitan Region showed that the model has generally good reproducibility during the period when the impact of biomass burning is small. The air quality model was used to analyze the characteristics of $PM_{2.5}$ concentration distribution in the high-pollution period in the Bangkok metropolitan area.
3. The major sources of $PM_{2.5}$ were identified by the receptor model analysis. The results will provide information that can be compared with the results of the air quality model simulation, and will also help to identify the sources of $PM_{2.5}$ that we need to take countermeasures in the future.
4. Policy recommendations based on the air pollution control measures listed in the National Agenda, and a technical action plan based on the results of the monitoring and modeling analysis conducted by the JTCAP were compiled. In the future, it is necessary to review/improve existing laws, environmental standards, and guidelines, measures against wildfires, and prepare data on pollutant emission factors by vehicle type and age, and consider emission controls for end-of-life and used vehicles based on the results.

Supplement

Interactions between the objectives of JTCAP: Emission inventories, Chemical Transport models and Receptor models



Activities to attain the objectives of Japan-Thailand Clean Air Partnership (JTCAP)

(1) Identification of major PM2.5 source sectors and regions by chemical transport model

- Development newest emission inventory of anthropogenic and biogenic sources
- Establishment of model simulation system (WRF-Chem) and test calculation
- Identification of polluted area during severe pollution period (January 2019) and normal period (March 2019)

(2) Long term observation and identification of major PM2.5 sources by receptor model

- Observation of PM2.5 chemical components at 3 sites in Bangkok
- Trend analysis of PM2.5 concentrations in residential, industrial and roadside sites
- Source apportionment of PM2.5 by Positive Matrix Factorization (PMF) and Chemical mass balance (CMB) methods

(3) Development of policy and appropriate measure along with generating stakeholder relationship

- Review of existing air pollution control policy in Japan and Thailand
- Consideration on action plan recommended from JTCAP

Method for the objective (1): Process flow of developing emission inventory

Defining scope and structure

↓

Designing methodology

↓

Collecting necessary data/information and settings
(Activity data, emission factors, reduction rates, technologies, ...)

↓

Calculating emissions and creating final products

↓

Emissions of detailed source categories and activities in target countries or administrative regions

Gridded emissions of major source categories in target area

Method for the objective (1): Emission estimation of air pollutants from road transport

$$EM_{i,j,y} = NV_{i,j,y} \times VKT_{i,j,y} \times EF_{i,j,y}$$

Emissions from running exhaust

i	Fuel types
j	Vehicle types
y	Target years

Traffic Volume

Number of Vehicles

Vehicles in operation with ratios of vehicle age

Type of vehicles:
Passenger car, Taxi, Jeep, Light trucks, Heavy Trucks, Buses, Motorcycles, Rural vehicles

Fuels:
Motor gasoline, Diesel, LPG, CNG, Biogasoline, Biodiesel

Vehicles Kilometers Travelled

Annual mileage for each vehicle type, age and road condition while running

National/International statistics and literatures for road transport

Emission Factors

Amounts of emissions per traffic volume of each vehicle type

Function of
- Vehicle speed
- Deterioration <- Vehicle age
- Temperature/Humidity

Emissions from road other than running exhaust

- Cold start emissions during transient thermal engine operation
- Road dust and Brake/Tire wear (PM emissions)
- Diurnal breathing loss, Running loss and Hot soak loss (NMVOC emissions)

Method for the objective (2): Detailed information on long term observation of $PM_{2.5}$ composition in Bangkok

- $PM_{2.5}$ is collected on a 47mm quartz filter at 3 sites in Bangkok [Bang Na (Industrial), Phaya Thai (Residential), Din Daeng (Roadside) District] from December 2018 to November 2019.

↓ Bring to laboratory

【$PM_{2.5}$ mass concentration】

The sample filters are determined gravimetrically with the use of an electronic microbalance with 1 μg sensitivity under controlled temperature (20–23 °C) and relative humidity (RH at 35–45%).

【Ion component】

Three anions (Cl^-, NO_3^- and SO_4^{2-}) and five cations (Na^+, NH_4^+, K^+, Mg^{2+} and Ca^{2+}) are determined by ion chromatography.

【Carbonaceous component】

Organic carbon (OC) and elemental carbon (EC) are analyzed using the thermal optical reflectance method.

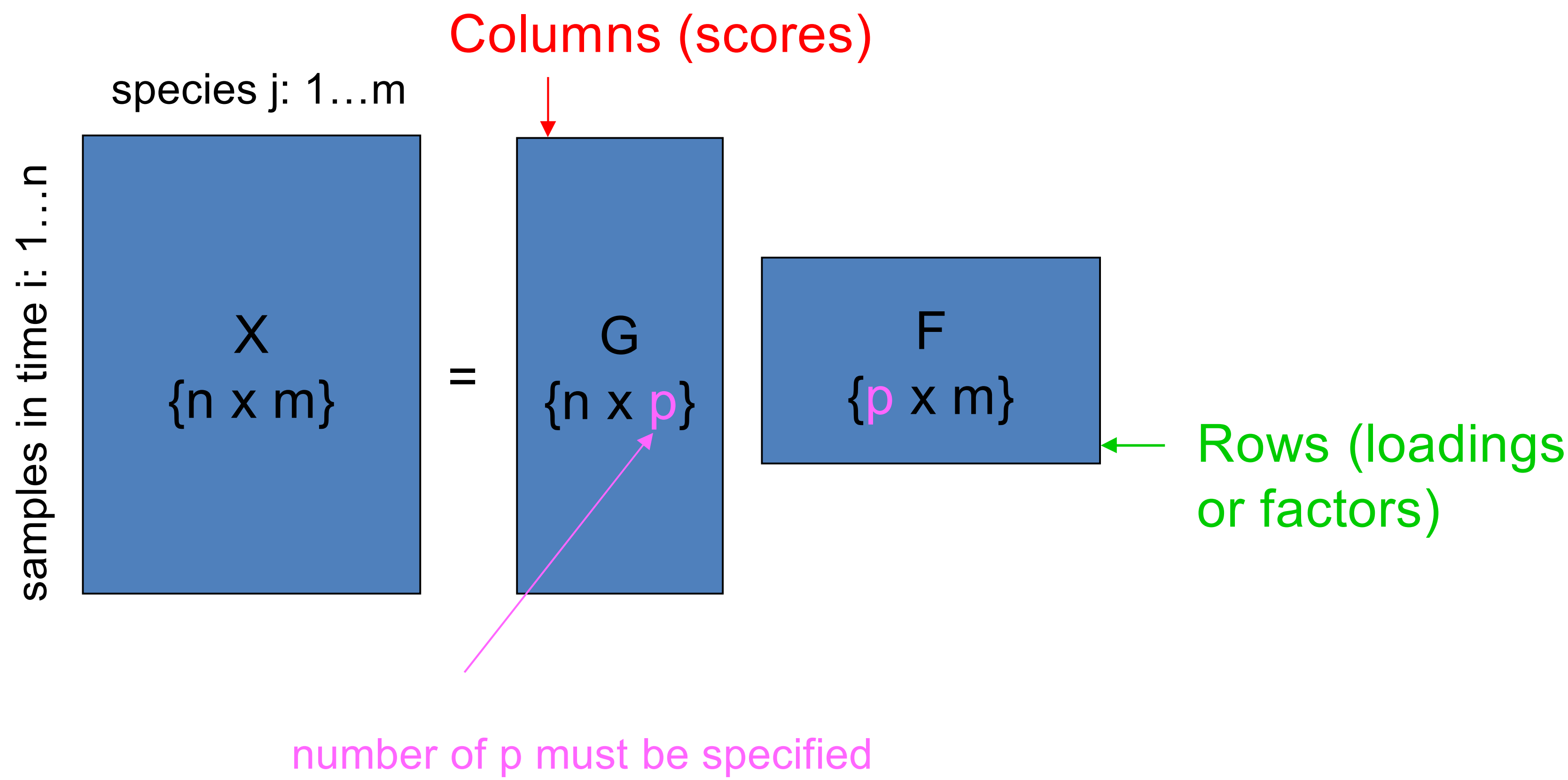
【Metallic elements】

ICP-MS (Inductively coupled plasma mass spectrometry) is used to determine the concentrations of major elements (Al, Fe), and 15 trace elements (As, Ba, Br, Co, Cr, Cu, Ni, Pb, Se, Si, Sb, Ti, Te, V, Zn).

Method for the objective (2): Principal of Positive Matrix Factorization (PMF)

X(Ambient Conc.) = **G(Source contribution)** x F(Conc. for each factor) + e(uncertainty)

Obtained by long term observation



- non-negativity of **G** and **F**
- algorithm accounts for uncertainty in **X** (weighted least squares)

(Hueglin et al., AMS User's meeting, 2006)

Results for the objective (3): Recommended technical action plans for PM2.5 countermeasures from automobiles based on the results of JTCAP

- Classify emission from automobile sources by type of vehicles, fuel usage, used mileage (VKT) and age of vehicle for improving PM2.5 reduction strategy from automobile
- Review the diesel vehicle exhaust gas inspection program and regulation for improving PM2.5 reduction strategy from automobile
- JTCAP recommends the governmental agency to review the current inspection or supervising system specifically on exhaust emission of automobile inspection center to improve quality of the system
- JTCAP recommends to limit heavy duty diesel vehicles entering into the BMR municipal area on specific time based on the PM2.5 condition (labeling or other signs)
- Promote the use of low sulfur fuel (10 ppm) in BMR by provide incentive and subsidy during transition and/or critical period

Effective emission reduction scenario case study (3): On-road transport sector in BMR

Scenario Description

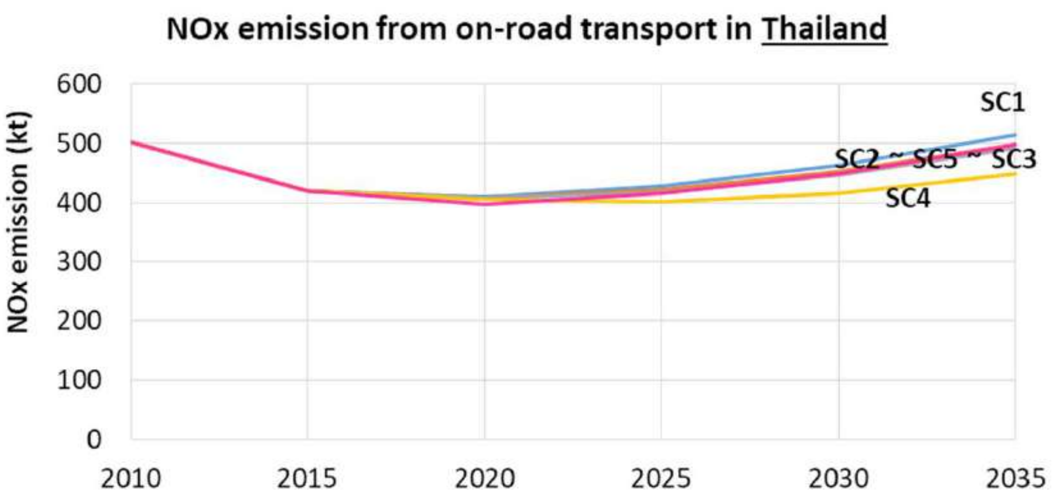
Dr. Savitri Garivait, 6th ICGSI Conference (2016)

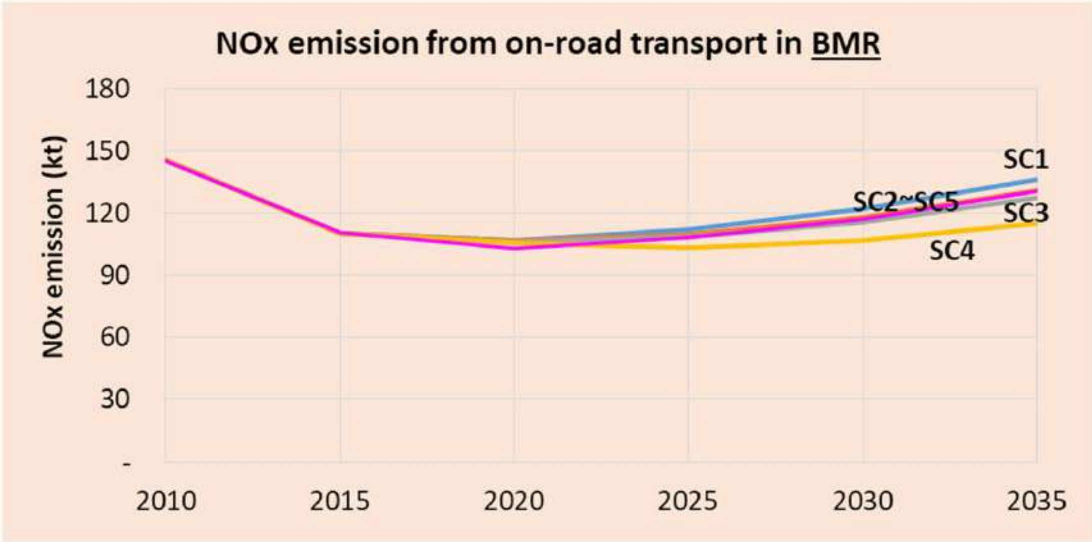
Scenarios	2015	2020	2025	2035
SC1	LDT & LDC/Gasoline and Diesel Car (Euro 4), Fuel (Euro 4)			
SC2	LDT & LDC/Gasoline and Diesel Car (Euro 4), Fuel (Euro 4)	LDT & LDC/Gasoline and Diesel Car (Euro 5), Fuel (Euro 5)		
SC3	LDT & LDC/Gasoline and Diesel Car (Euro 4), Fuel (Euro 4)	LDT & LDC/Gasoline: Car (Euro 6), (Euro 6) Diesel: Car (Euro 5), (Euro 5)		
SC4	LDT & LDC/Gasoline and Diesel Car (Euro 4), Fuel (Euro 4)	LDT & LDC/Gasoline and Diesel Car (Euro 6), Fuel (Euro 5)		
SC5	LDT & LDC/Gasoline and Diesel Car (Euro 4), Fuel (Euro 4)	LDT & LDC/Gasoline and Diesel Car (Euro 4), Fuel (Euro 4) Phased out LDC at 16 years, and LDT at 21 years		

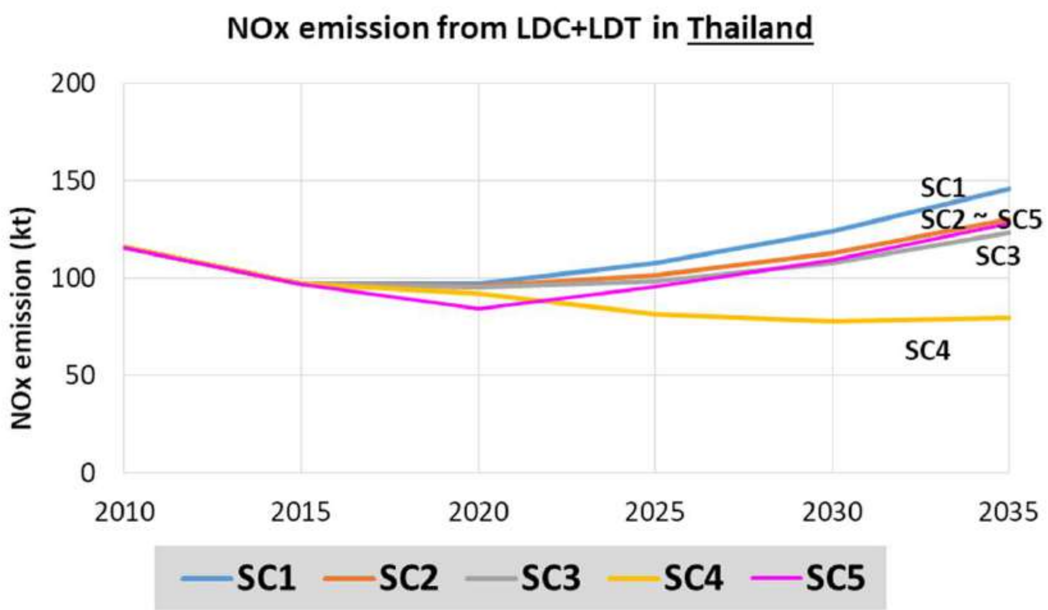
Note: Euro 4 has been effectively implemented since 2013

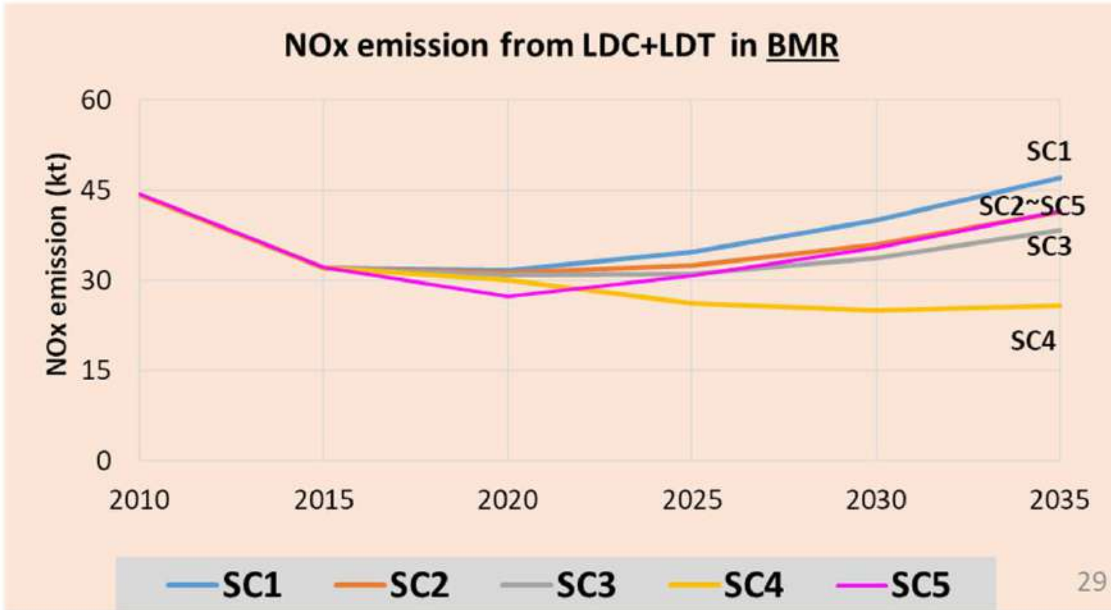
NOx emission projection 2010-2035 under various reduction scenarios (SC1 to SC5)

Dr. Savitri Garivait, 6th ICGSI Conference (2016)





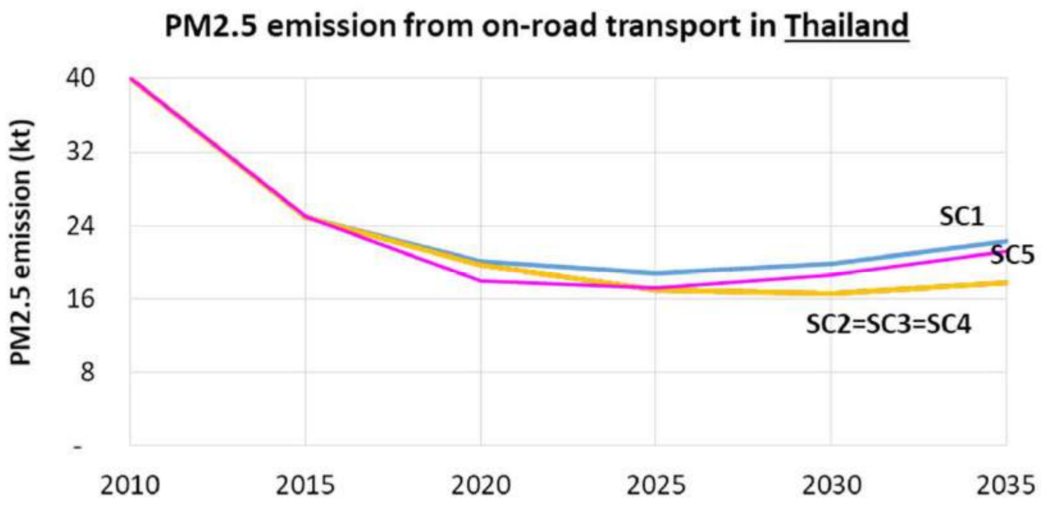


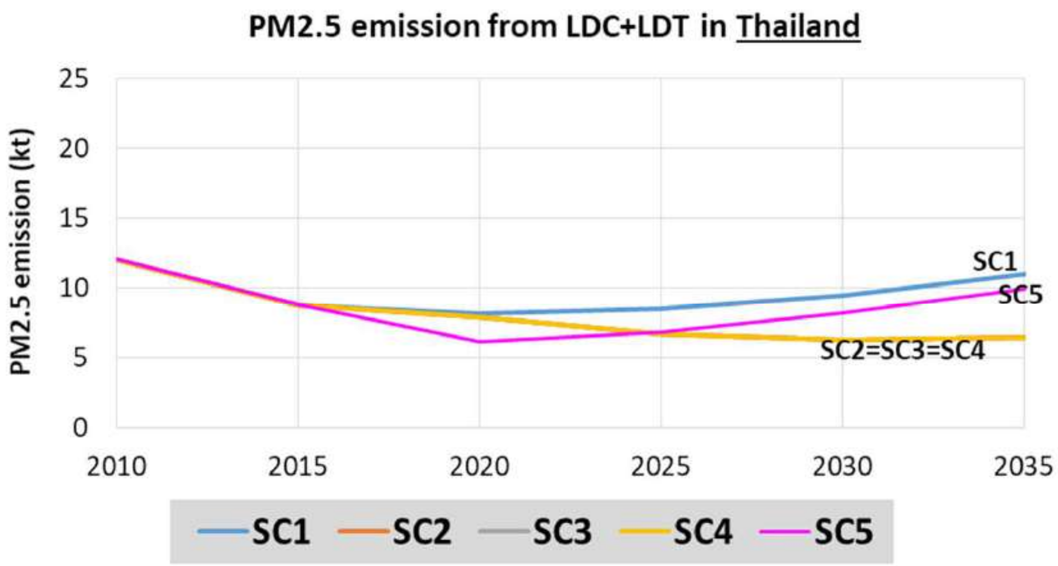


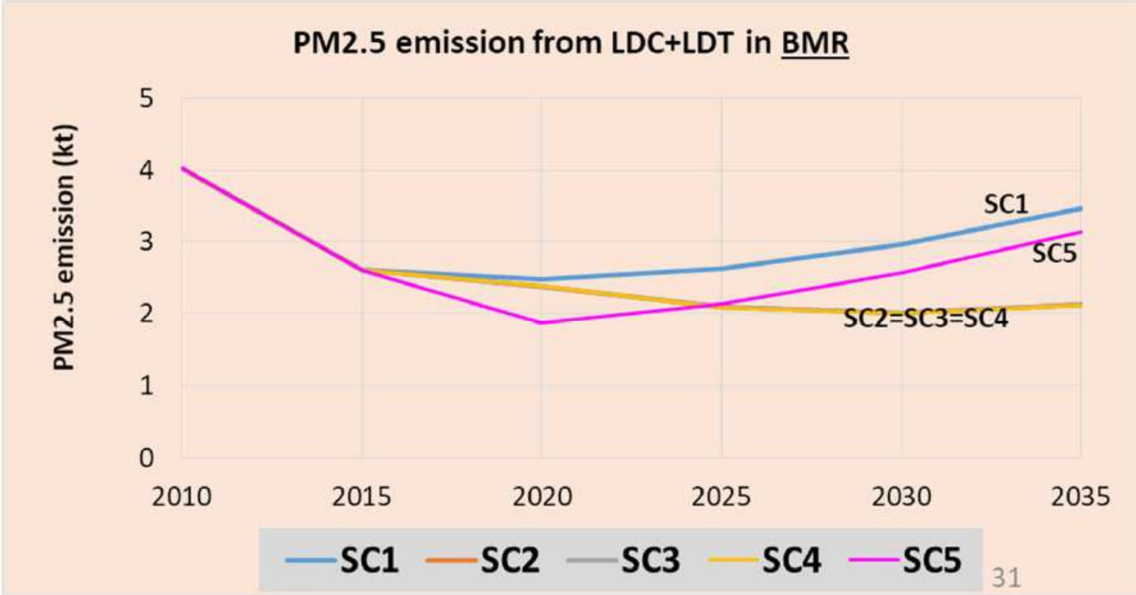
- SC4 is the most effective for NOx reduction from Light Duty Car (LDC) and Light Duty Truck (LDT).
- For scenarios except SC4, NOx will increase after 2020 mainly due to emission from High Duty Truck (HDT).

PM2.5 emission projection 2010-2035 under various reduction scenarios (SC1 to SC5)

Dr. Savitri Garivait, 6th ICGSI Conference (2016)







- SC2, SC3 and SC4 are effective for PM2.5 reduction from on road transport.
- For SC1 and SC5, PM2.5 will slightly increase after 2020.