Introduction to FEW research framework in Thailand

Assoc. Prof. Dr. Sucharit Koontanakulvong
Dr. Pongsak Suttinon
Faculty of Engineering, Chulalongkorn University

Presented at International Workshop on Food Energy Water Nexus

5 September 2016, Taipei, Taiwan

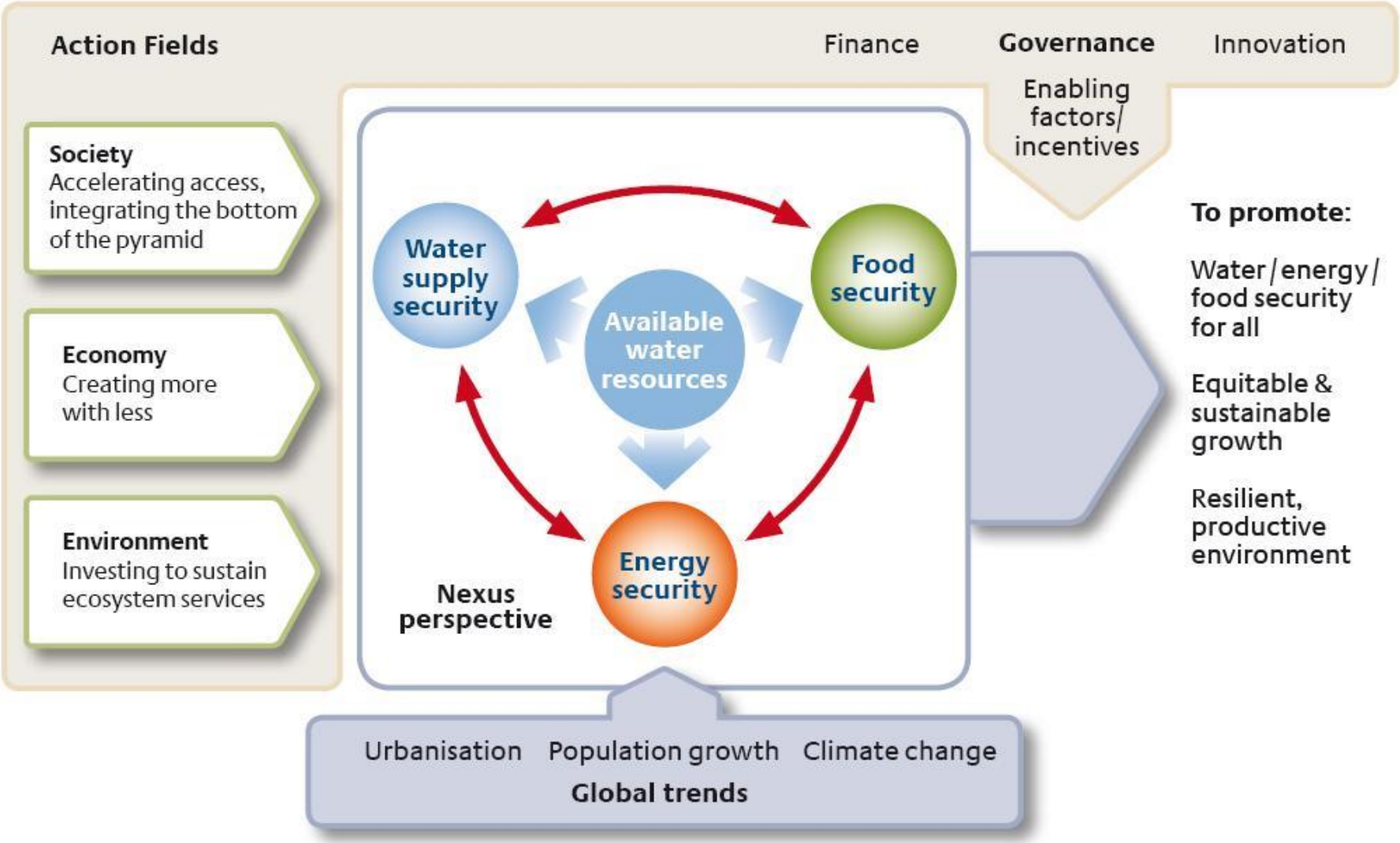
Topics

- WEF Nexus concept development
- Previous studies
- Objectives
- Study Approach

- I/O Table at national level and at each sector
- Water, Energy & Food and I/O
- linkage and interrelations with I/O

- Possible applications
- Preliminary conclusions

Water-Energy-Food NEXUS for Socio-Economic Dev.



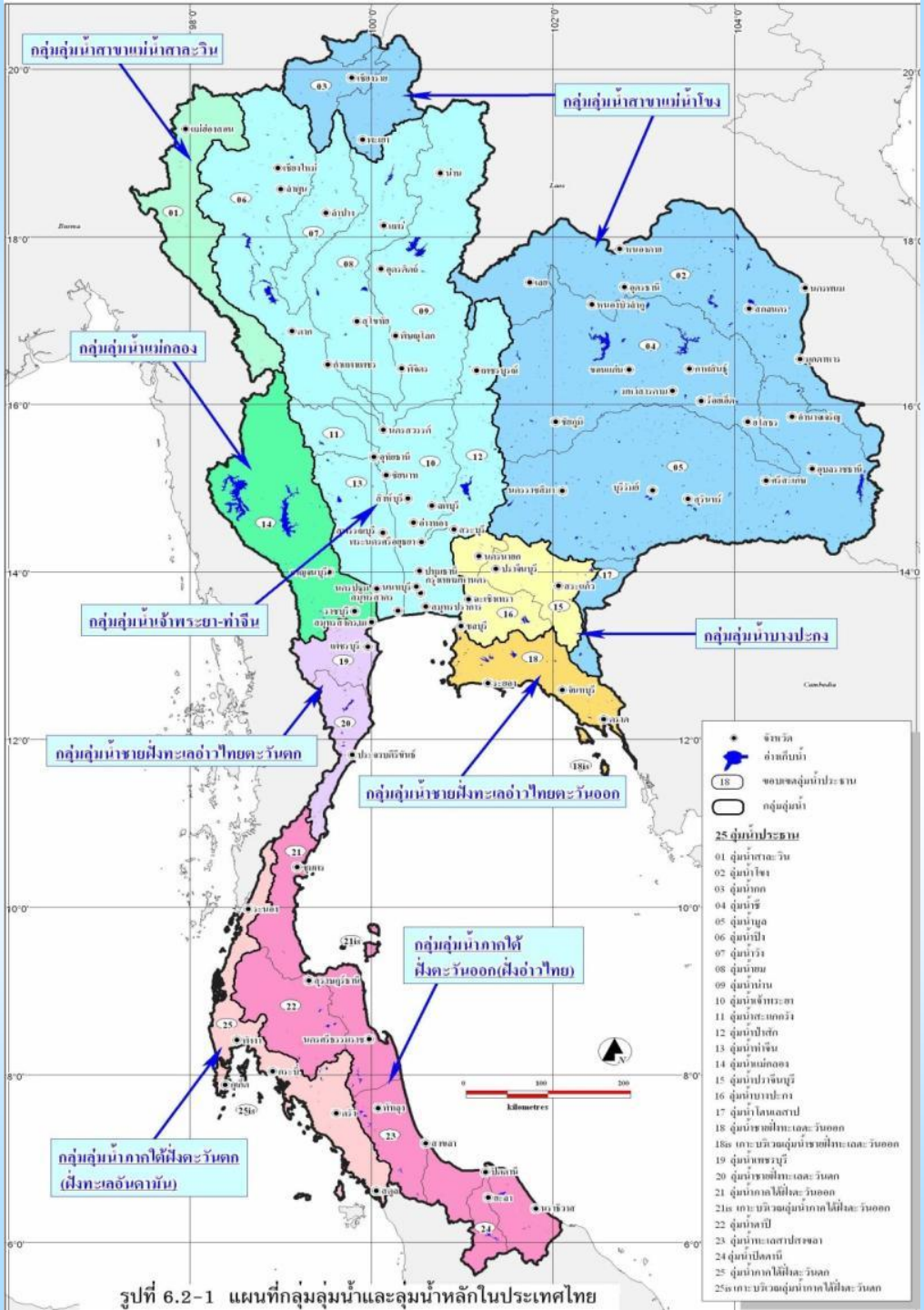
(source: In Focus: Water, Energy, Food Nexus – Report, https://climatecommercial.wordpress.com/2011/11/09/in-focus-water-energy-food-nexus-report/)

Previous studies-1

- ADB(2013) Thinking about water differently proposed idea of water resources planning under the concepts of water for food, energy.
- OECD (2014) proposed WEF towards sustainable growth and integrating with national planning
- Aiko Endo et. al (2015) summarized the methods WEF nexus.

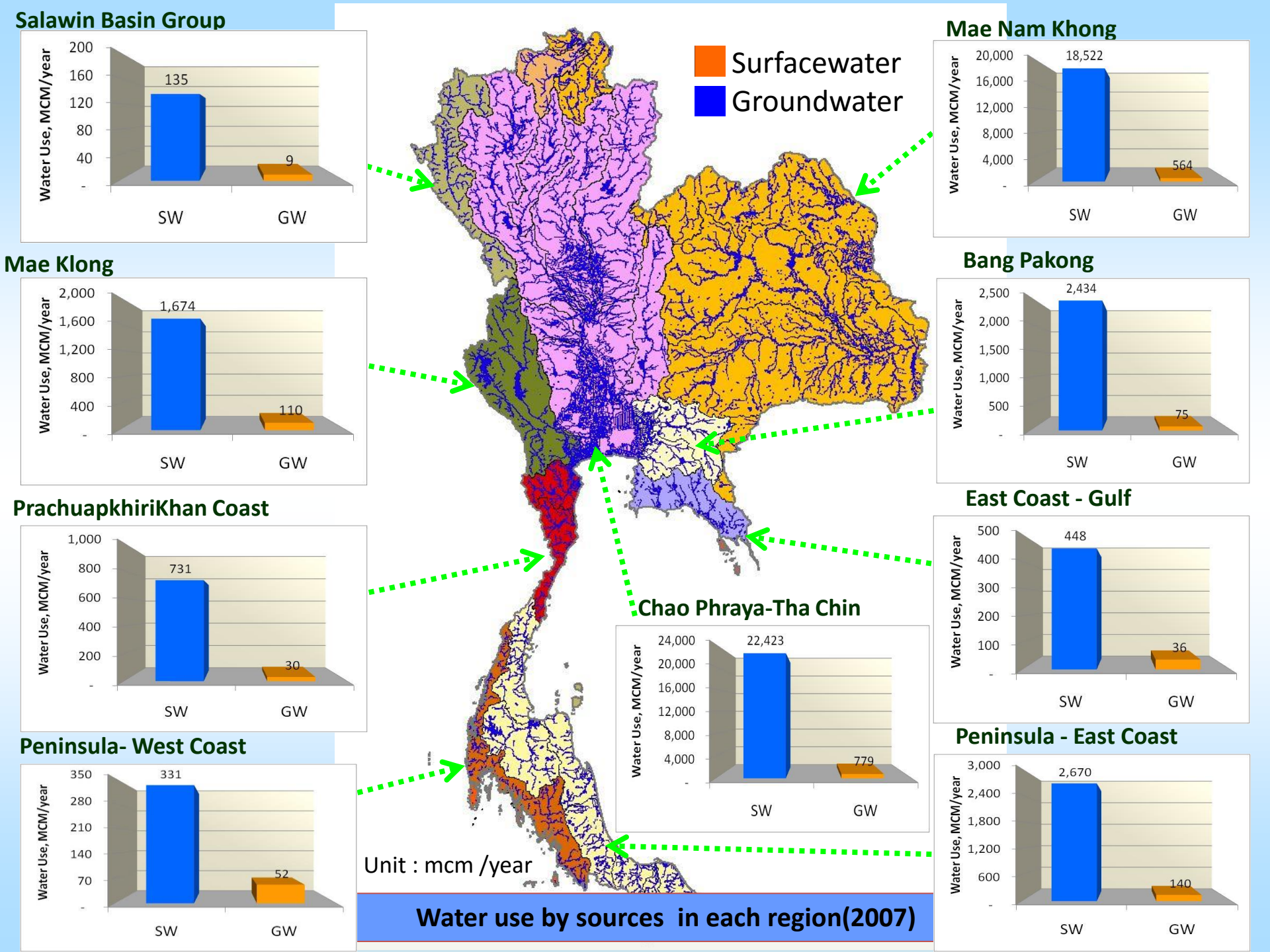
Previous Studies-2

- Sectorial studies on alternative energy under the National Energy Plan, food security and water security under climate change (2010)
- Biomass production planning and Climate Change impacts (2012)
- Thailand's Water Security Situation in the context of world and ASEAN (2014)
- Vulnerability Assessment under Climate Change and National Water Management Strategy (2016)

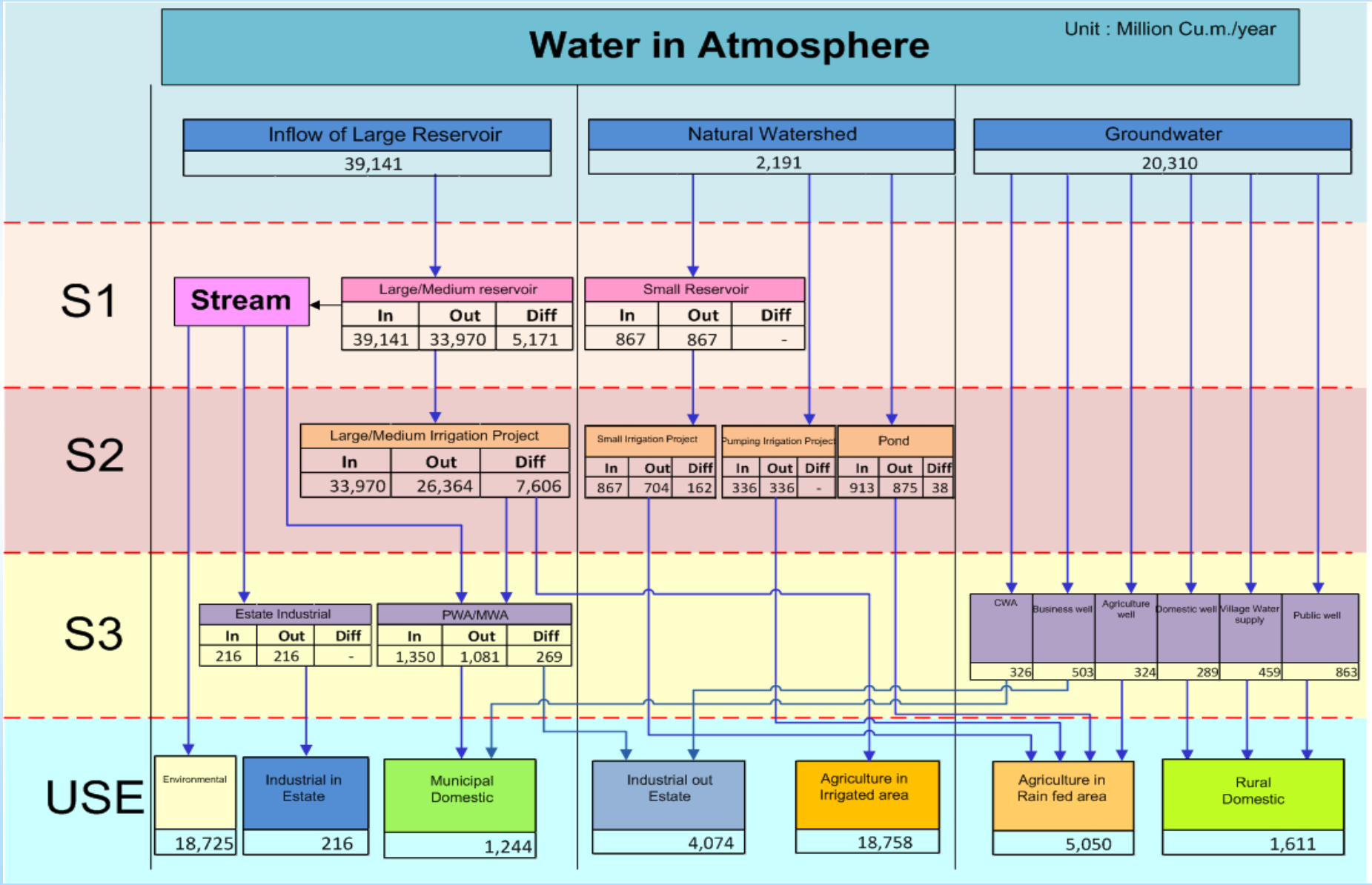


รูปที่ 6.2-1 แผนที่กลุ่มลุ่มน้ำและลุ่มน้ำหลักในประเทศไทย

Surface Water Basin Group	Area (SQ.KM)
1. Mae Khong	188,645
2. Salawin	17,918
3. Chao Phraya - Tha Chin	157,925
4. Mae Klong	30,836
5. Bang Pakong	18,458
6. East Coast – Gulf	13,829
7. PrachuapkhiriKhun Coast	12,347
8. Peninsula - East Coast	50,930
9. Peninsula - West Coast	20,473
Total	511,361


Salawin Basin Group
Water Use, MCM/year
200
160
120
80
40
-
135
9
SW
GW
Mae Nam Khong
Water Use, MCM/year
20,000
16,000
12,000
8,000
4,000
-
18,522
564
SW
GW
Surfacewater
Groundwater
Mae Klong
Water Use, MCM/year
2,000
1,600
1,200
800
400
-
1,674
110
SW
GW
Bang Pakong
Water Use, MCM/year
2,500
2,000
1,500
1,000
500
-
2,434
75
SW
GW
PrachuapkhiriKhan Coast
Water Use, MCM/year
1,000
800
600
400
200
-
731
30
SW
GW
East Coast - Gulf
Water Use, MCM/year
500
400
300
200
100
-
448
36
SW
GW
Chao Phraya-Tha Chin
Water Use, MCM/year
24,000
20,000
16,000
12,000
8,000
4,000
-
22,423
779
SW
GW
Peninsula- West Coast
Water Use, MCM/year
350
280
210
140
70
-
331
52
SW
GW
Unit : mcm /year
Peninsula - East Coast
Water Use, MCM/year
3,000
2,400
1,800
1,200
600
-
2,670
140
SW
GW
Water use by sources in each region(2007)

Thai Water Balance

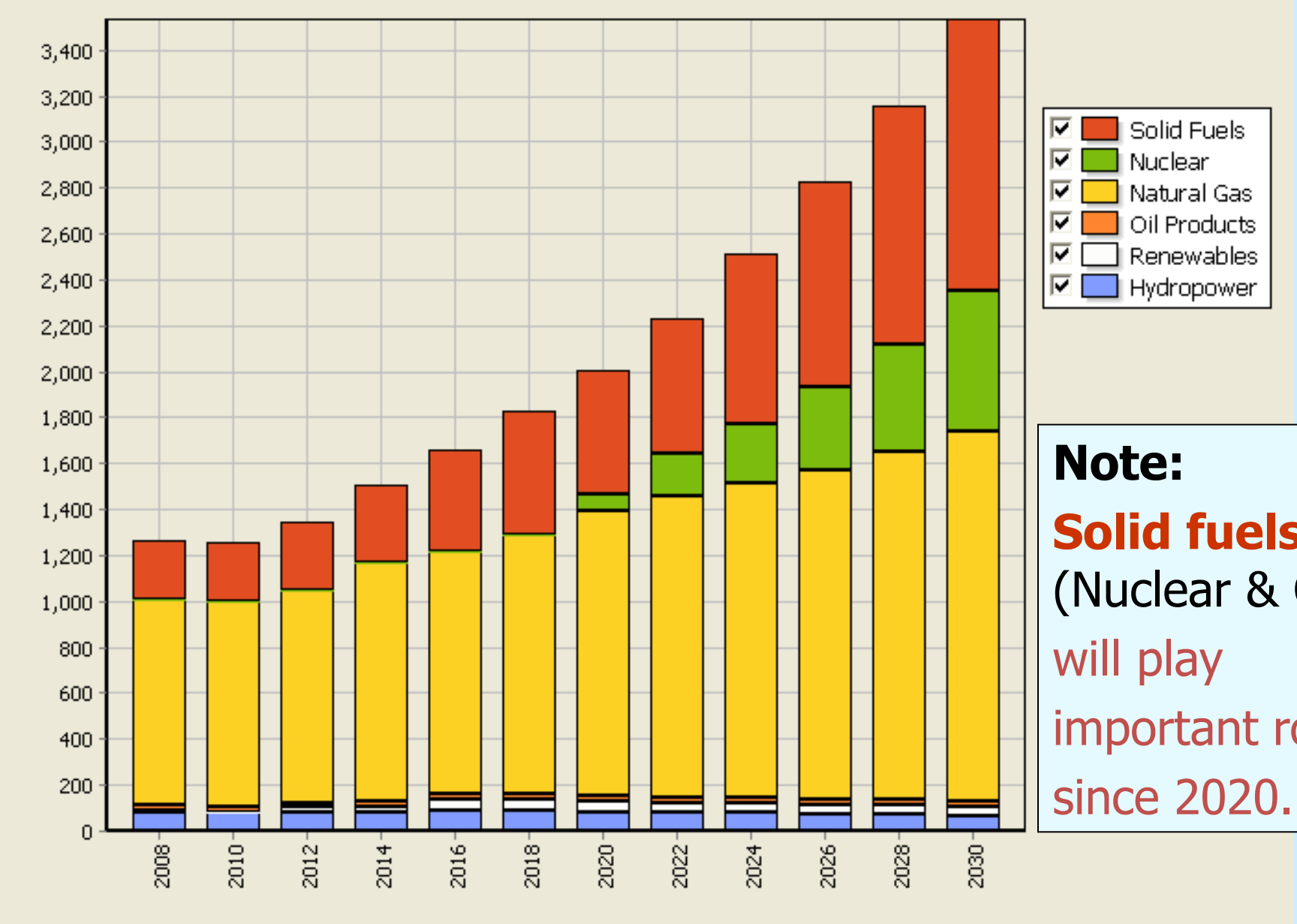


Water Security Index

Dimension	Elements	World		Asia		ASEAN		Thailand
		average	ranking	average	ranking	average	ranking	
Basic water	1. fresh water renewable (cu.m per capita)	22,167	79	10,854	15	19,205	8	6,382
	2. water supply (cu.m per capita)	84	46	84	9	85	3	98
	3. sanitation water (cu.m per capita)	67	15	70	6	71	2	96
Sufficient water	1. water use per capita (cu.m./capita)	511	12	842	9	531	7	1,391
	2. house holds (cu.m/capita)	84	46	84	9	85	3	98
	3. agricultural water (cu.m/capita)	354	159	712	7	424	1	1,322
Water for development	1.irrigation area (%)	19	49	41	30	18	3	25
	2.industrial water (cu.m/capita)	97	68	60	18	49	4	34
	3.water for energy (%)	31	89	20	23	14	6	4
	4. water for fresh water aquaculture (cu.m/capita)	346,734	4	1,241,323	4	582,458	2	1,385,801
Water disaster	1.flood damage (US$)	3,543,108	3	8,670,092	2	6,002,888	1	41,051,592
	2.drought damage (US$)	1,261,531	22	1,896,770	5	239,512	2	424,300
Water for future	1.population growth (%)	1.3	137	1.43	38	1.31	10	0.43
	2.urban population growth (%)	63	147	59	30	59	7	42
	3.water footprint (cu.m/capita)	1,338	7	1,304	2	1,697	2	2,223
Water productivity	1.GDP (million US$)	343,530	29	445,799	7	151,224	2	318,907
	2.productivity(US$ / cu.m. water)	81	132	41.3	132	117.3	6	3.6
	3.agricultural productivity (US$ /cu.m. water)	392	124	33.8	18	162.5	7	0.32
	4.industrial productivity(US$ / cu.m. water)	169.1	63	69.5	8	121.6	4	51.2

กระทรวงพลังงาน
MINISTRY OF ENERGY

Fuel Mix under PDP2010



Note:

Solid fuels (Nuclear & Coal) will play important role since 2020.

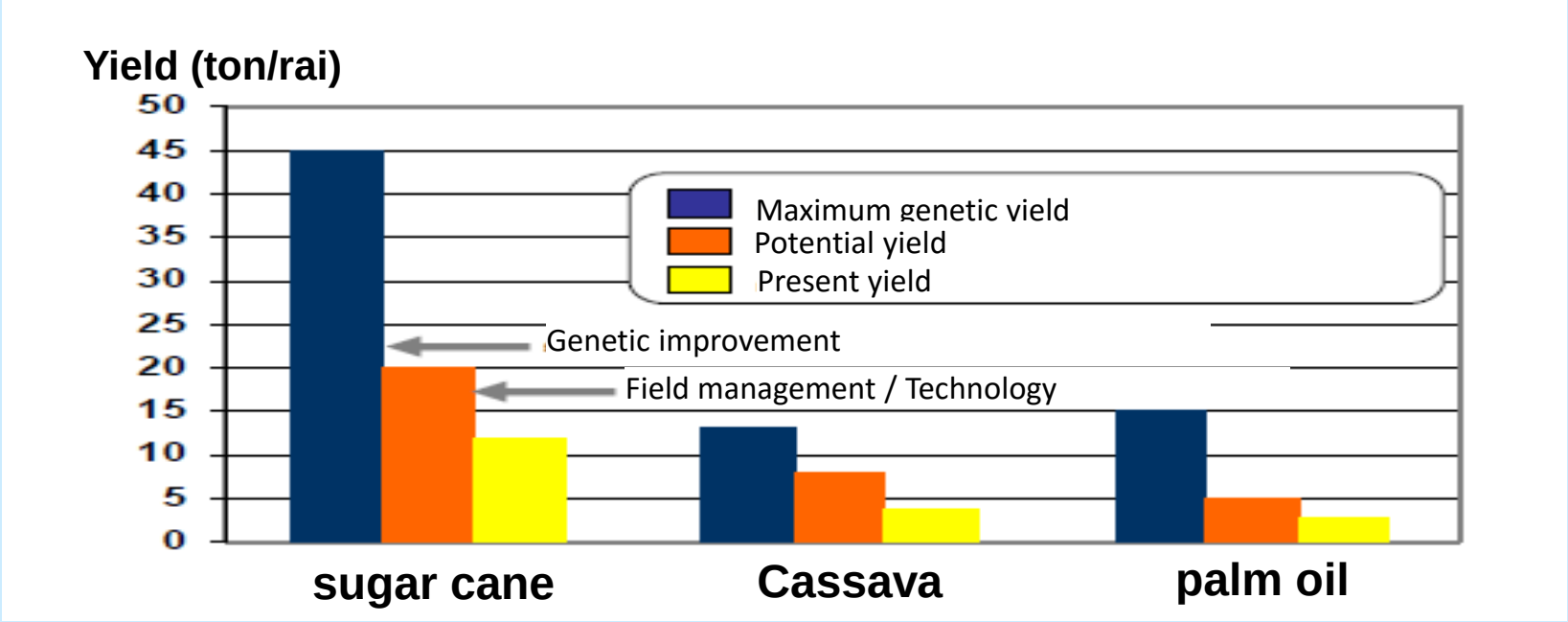
Department of Alternative Energy Development and Efficiency
MINISTRY OF ENERGY

RE Potential and Target

Type of Energy	Potential	existing	2008 - 2011		2012 - 2016		2017 - 2022	
Electricity	**MW**	**MW**	**MW**	ktoe	**MW**	ktoe	**MW**	ktoe
Solar	50,000	**32**	**55**	6	**95**	11	**500**	56
Wind Energy	1,600	**1**	**115**	13	**375**	42	**800**	89
Hydro Power	700	**56**	**165**	43	**281**	73	**324**	85
Biomass	4,400	**1,610**	**2,800**	1,463	**3,220**	1,682	**3,700**	1,933
Biogas	190	**46**	**60**	27	**90**	40	**120**	54
Municipal Solid Waste	400	**5**	**78**	35	**130**	58	**160**	72
Hydrogen			**0**	0	**0**	0	**3.5**	1
Total		**1,750**	**3,273**	1,587	**4,191**	1,907	**5,608**	2,290
Thermal	**ktoe**	**ktoe**		**ktoe**		**ktoe**		**ktoe**
Solar Thermal	154	**1**		**5**		**17.5**		**38**
Bimass	7,400	**2,781**		**3,660**		**5,000**		**6,760**
Biogas	600	**224**		**470**		**540**		**600**
Municipal Solid Waste		**1**		**15**		**24**		**35**
Total		**3,007**		**4,150**		**5,582**		**7,433**
Biofuel	**m lt/d**	**m lt/d**	**m lt/d**	ktoe	**m lt/d**	ktoe	**m lt/d**	ktoe
Ethanol	3.00	**1.24**	**3.00**	805	**6.20**	1,686	**9.00**	2,447
Biodiesel	4.20	**1.56**	**3.00**	950	**3.64**	1,145	**4.50**	1,415
Hydrogen			**0**	0	**0**	0	01 mill kg	124
Total			**6.00**	1,755	**9.84**	2,831	**13.50**	3,986
Total Energy Consumption		66,248		70,300		81,500		97,300
Total Energy from R E (ktoe)		4,237		7,492		10,319		13,709
Renewable Energy Ratio		**6.4%**		**10.6%**		**12.7%**		**14.1%**
NGV (mmscfd - ktoe)		108.1	393.0	3,469	596	5,260	690	6,090
Total Energy from RE + NGV (ktoe)				10,961		15,579		19,799
Alternative Energy Ratio				**15.6%**		**19.1%**		**20.3%**

Assumptions for cultivation area estimation

	Cassava		sugar cane		palm oil	
Yield in 2008 (ton/rai)	**3.4**		**11.2**		**2.6**	
Reference , planned yield	4.5 (2012)	4.5 (2030)	15 (2012)	15 (2030)	2.9 (2012)	2.9 (2030)
Yield increase case	4.5 (2012) →	8.0 (2030)	15 (2012) →	20 (2030)	2.9 (2012) →	5.0 (2030)

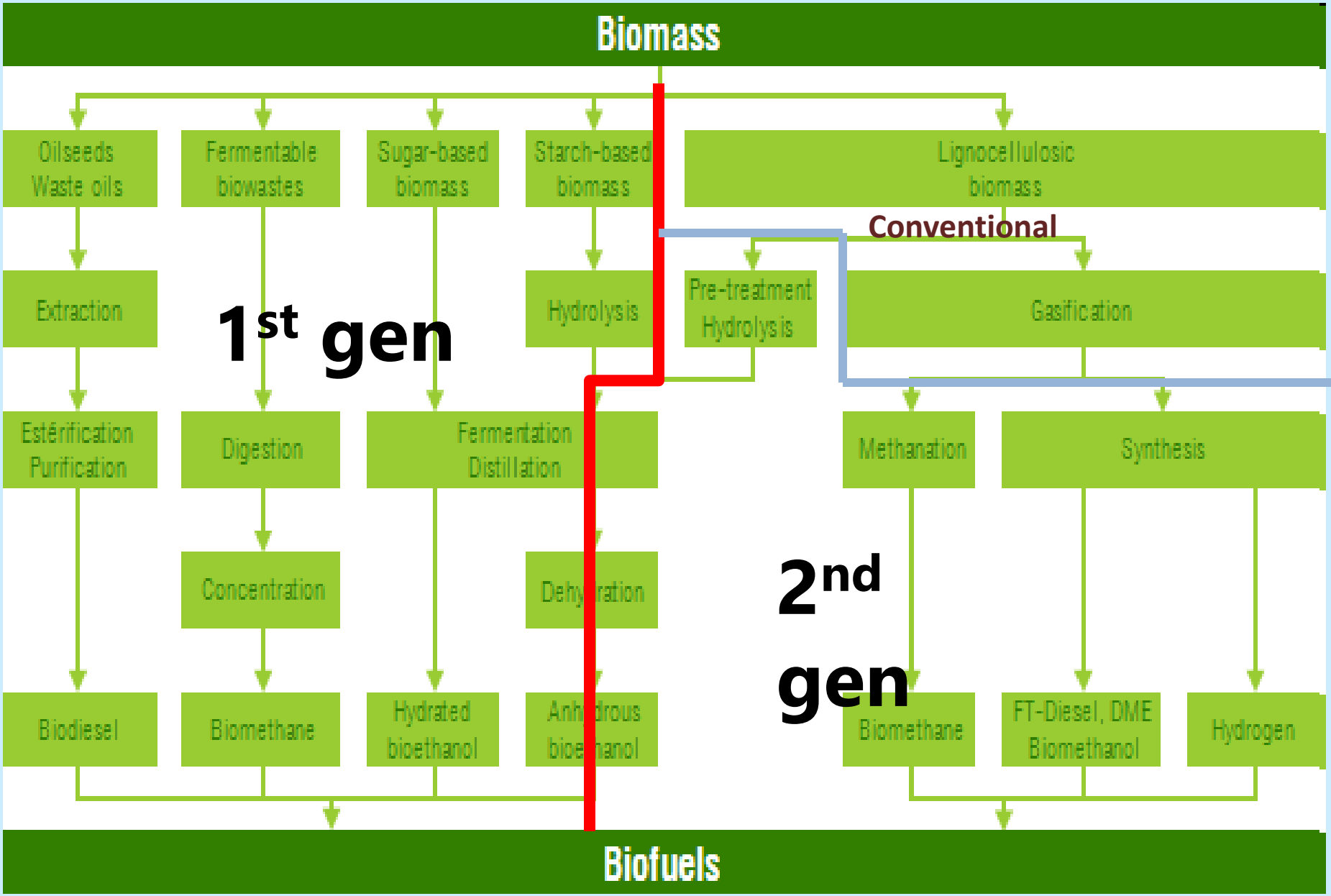


Plantation area

biomass plant	Production demand in 2022 (M ton)[1)]	Potential production in 2022 (M ton)[2)]	Demand plantation area (M rai)[1)]	Planned plantation area (M rai)[3)]
Cassava	38.2	60 – 80	12	7.4
sugar cane	109.7	80 – 90	7	6.0
oil palm	17.2	8 - 10	10	5.5

Remarks

- projected by energy study team (NESDB, 2010)
- projected by agriculture study team (NESDB, 2010)
- national plan (REDP, 2010)



http://www.plateforme-biocarburants.ch/en/infos/index.php

Objectives

1. To review past studies on W/E/F,
2. To see the possibility on their linkage,
3. To see the possibility on their interrelationship,
4. To investigate possible applications,
5. To set the framework for future study.

Approach

- Central Plain/Northeast

  (overall, sample of dam, pilot area)

- Climate Change : bias corrected climate data of present (1979-2012) , near future (2015-2039) and far future (2075-2099) periods (using MRI-GCM , scenario A1B).

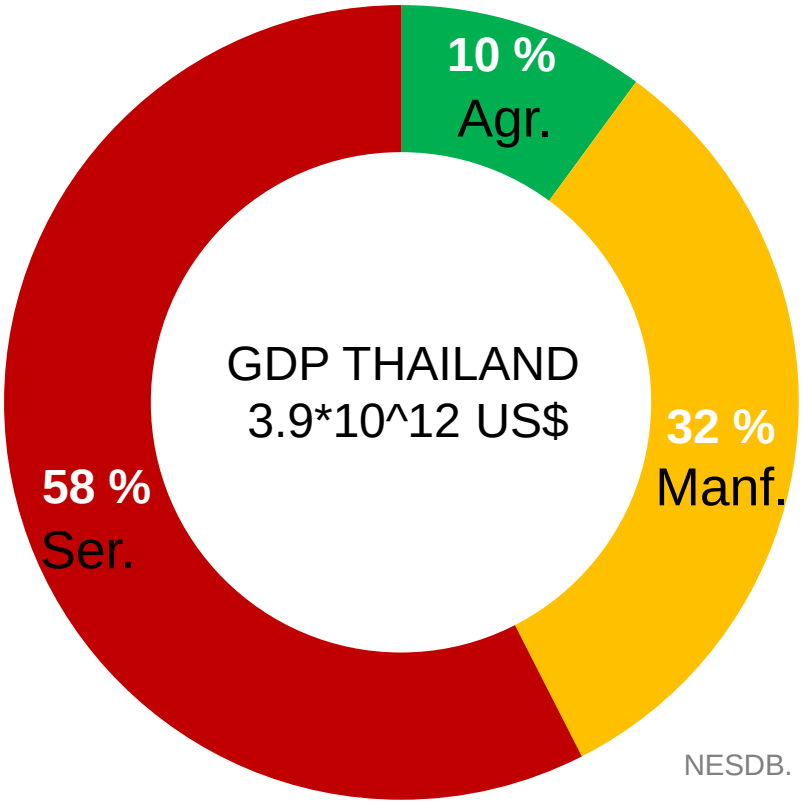
Water-Energy-Food NEXUS

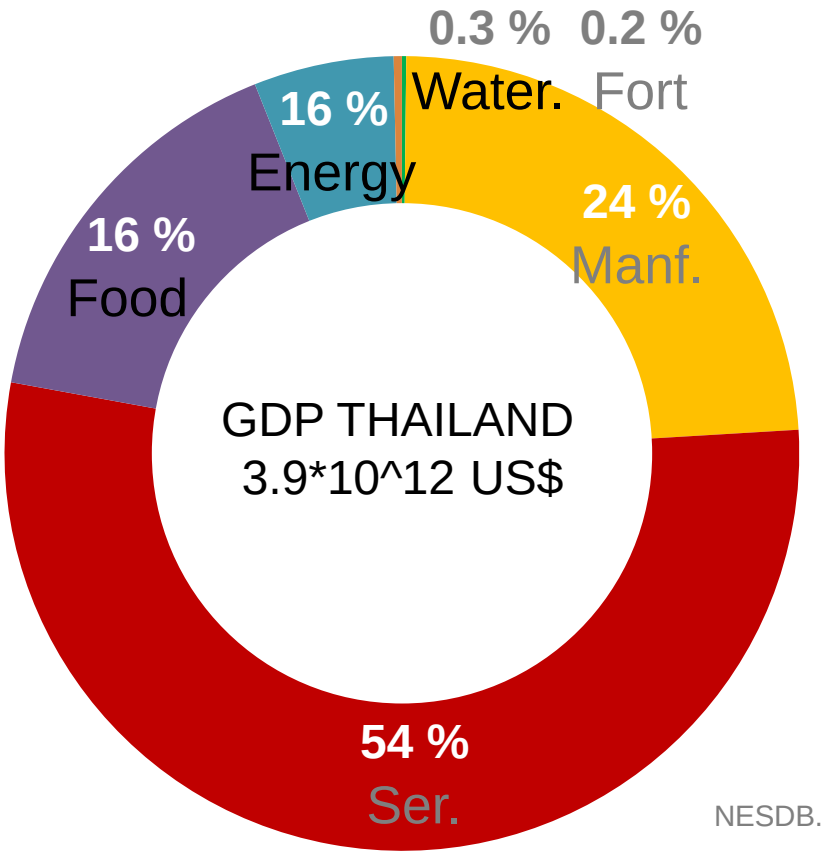
for Socio-Economic Development.

--- Existing Information ---

(National I/O Table, Water and I/O, Energy and I/O, Food and I/O)

GDP of Thailand





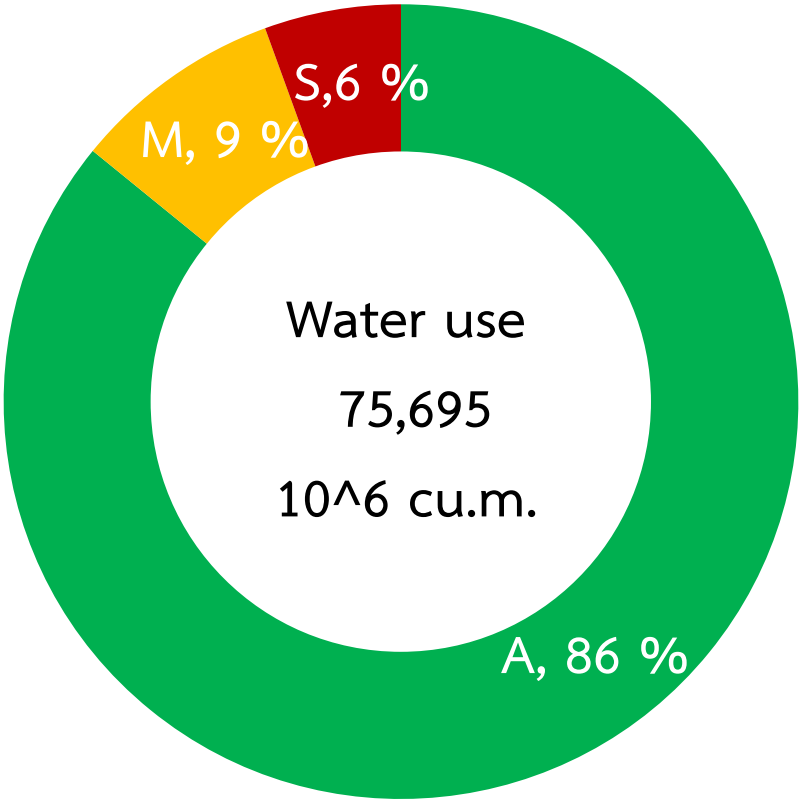
Note: data from IO table (NESDB), AGR = Agriculture, FORT = Forestry, MFG = Mining, Manufacturing, SER = Services, COAL = Coal and Lignite, PETO = Petroleum and Natural Gas, ELEC = Electricity, GAS = GAS-Pipe Line, FOOD = Crops + Livestock + Fishery + Food Manufacturing + Beverages Products, ENER = Energy, WATR = Water Supply System

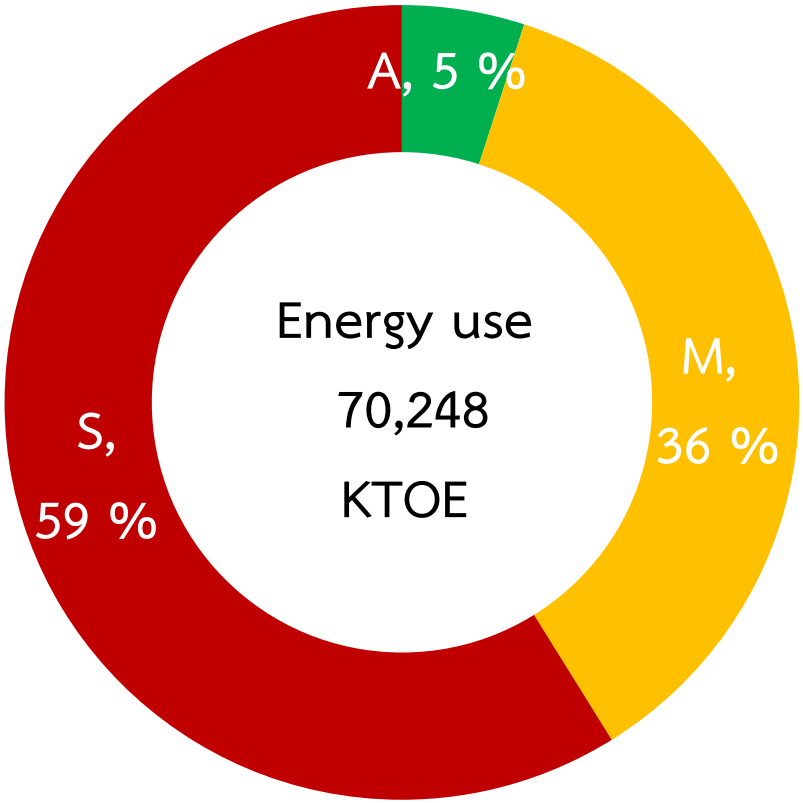
Water-Energy-Food NEXUS in socio-economic development (IO table based)

Sector	Definition in IO table	GDP, M.US$
Water	• Water Supply System (137)	12,829
Energy	• Coal and Lignite (030) • Petroleum and Natural Gas (031) • Electricity (135) • GAS-Pipe Line (136)	220,558
Food	• Crops (001-017 024) • Livestock (018-023) • Fishery (028-029) • Food Manufacturing (042-061) • Beverages Products (062-066)	622,976

NESDB.

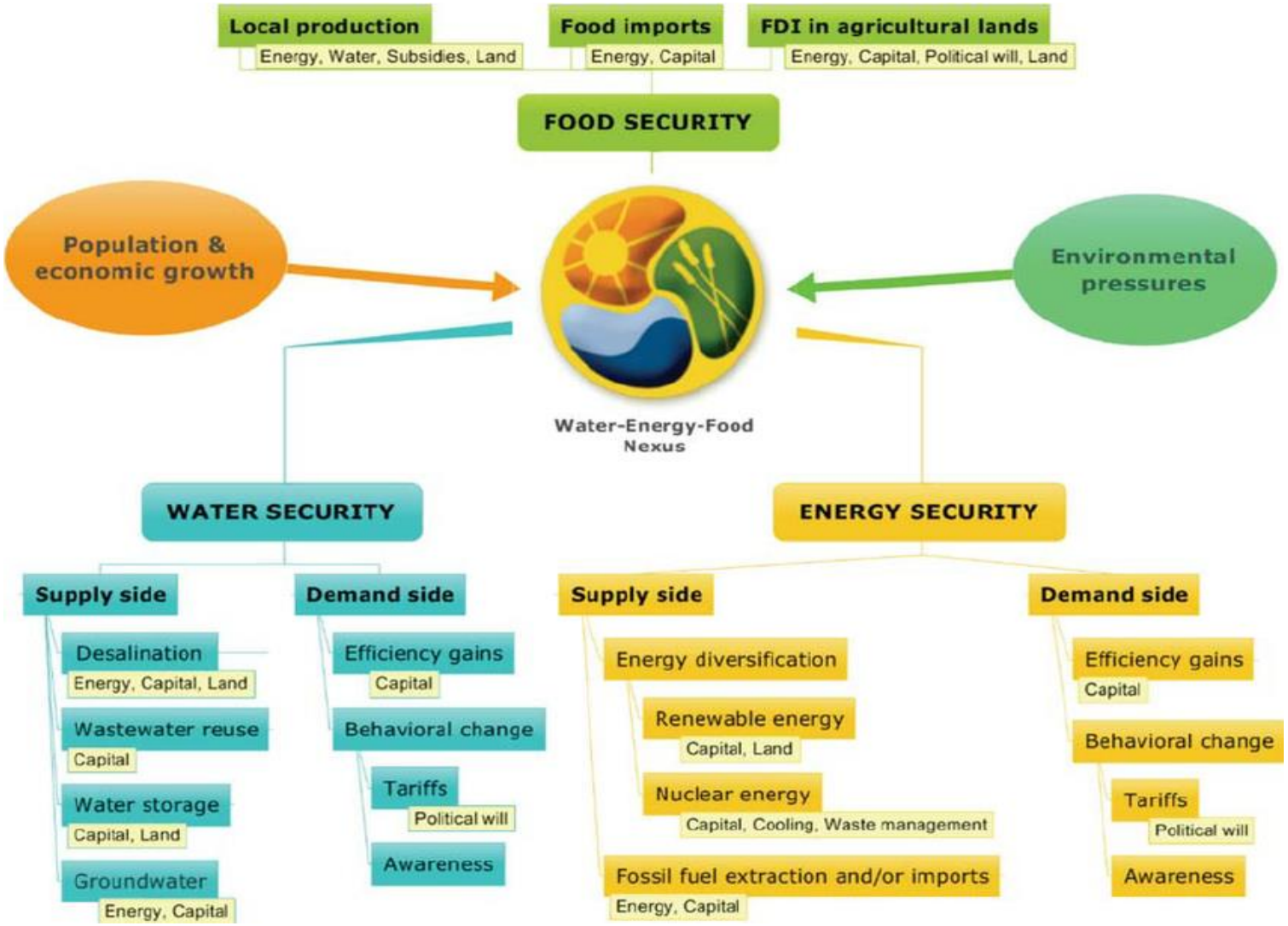
Water and Energy Use in Thailand (Physical Unit)





Note: A = Agriculture, M = Mining, Manufacturing, S = Services, KTOE = kilo ton of oil equivalent
Source: Water information from Thailand Water Management Strategy
Energy information from Thailand 20-Year Energy Efficiency Development Plan (2011 – 2030)

Water-Energy-Food NEXUS for Socio-Economic Dev.



Source: Water security in the GCC countries: challenges and opportunities

CHULA ΣNGINEERING
Foundation toward Innovation

Water-Energy-Food Linkage (M.US$)

Intermediate transaction

	FORT	MFG	SER	FOOD	ENER	WATR
FORT	349	12,276	2,723	367	83	
MFG	1,203	2,428,873	750,646	170,276	56,054	1,660
SER	335	154,017	500,080	50,517	43,358	2,201
FOOD	220	77,775	156,651	578,915	528	
ENER	10	435,275	88,736	20,142	208,823	3,148
WATR	1	3,379	4,620	1,350	133	639

Export, Import

	305+306	409
FORT	2,915	- 2,081
MFG	1,867,360	- 1,708,534
SER	273,079	- 185,322
FOOD	337,512	- 129,321
ENER	16,854	- 346,955
WATR	0	

Value added

201	3,530	243,653	751,425	155,832	65,273	4,619
202	2,885	415,867	943,464	363,441	77,050	4,754
203	224	130,866	308,103	33,894	57,597	3,140
204	154	133,354	79,336	69,810	20,639	316

Note: data from IO table (NESDB), AGR = Agriculture, FORT = Forestry, MFG = Mining, Manufacturing, SER = Services, COAL = Coal and Lignite, PETO = Petroleum and Natural Gas, ELEC = Electricity, GAS = GAS-Pipe Line, FOOD = Crops + Livestock + Fishery + Food Manufacturing + Beverages Products, ENER = Energy, WATR = Water Supply System, 201 Wages and Salaries, 202 Operating Surplus, 203 Depreciation, 204 Indirect Taxes less Subsidies, 305 Exports (F.O.B.), 306 Special Exports, 409 Total Imports

CHULA ΣNGINEERING
Foundation toward Innovation

Water-Energy-Food Linkage (M.US$)

Water for Food
Water for Energy

Energy for Food
Energy for Water

Food for Energy

Intermediate transaction

	FORT	MFG	SER	FOOD	ENER	WATR
FORT	349	12,276	2,723	367	83	
MFG	1,203	2,428,873	750,646	170,276	56,054	1,660
SER	335	154,017	500,080	50,517	43,358	2,201
FOOD	220	77,775	156,651	578,915	**528**	
ENER	10	435,275	88,736	**20,142**	208,823	**3,148**
WATR	1	3,379	4,620	**1,350**	**133**	639

Export, Import

305+306	409
2,915	- 2,081
1,867,360	- 1,708,534
273,079	- 185,322
337,512	- 129,321
16,854	**- 346,955**
0	0

Domestic

World Market

Note: data from IO table (NESDB), AGR = Agriculture, FORT = Forestry, MFG = Mining, Manufacturing, SER = Services, COAL = Coal and Lignite, PETO = Petroleum and Natural Gas, ELEC = Electricity, GAS = GAS-Pipe Line, FOOD = Crops + Livestock + Fishery + Food Manufacturing + Beverages Products, ENER = Energy, WATR = Water Supply System, 201 Wages and Salaries, 202 Operating Surplus, 203 Depreciation, 204 Indirect Taxes less Subsidies, 305 Exports (F.O.B.), 306 Special Exports, 409 Total Imports

Linkage

- How to link the GDP growth (esp in food production) with the use of water, energy and what will be the food production quantity ?
- How to link the security of water and energy with the growth ?
- How to link the sustainability of WEF with the long term growth ?

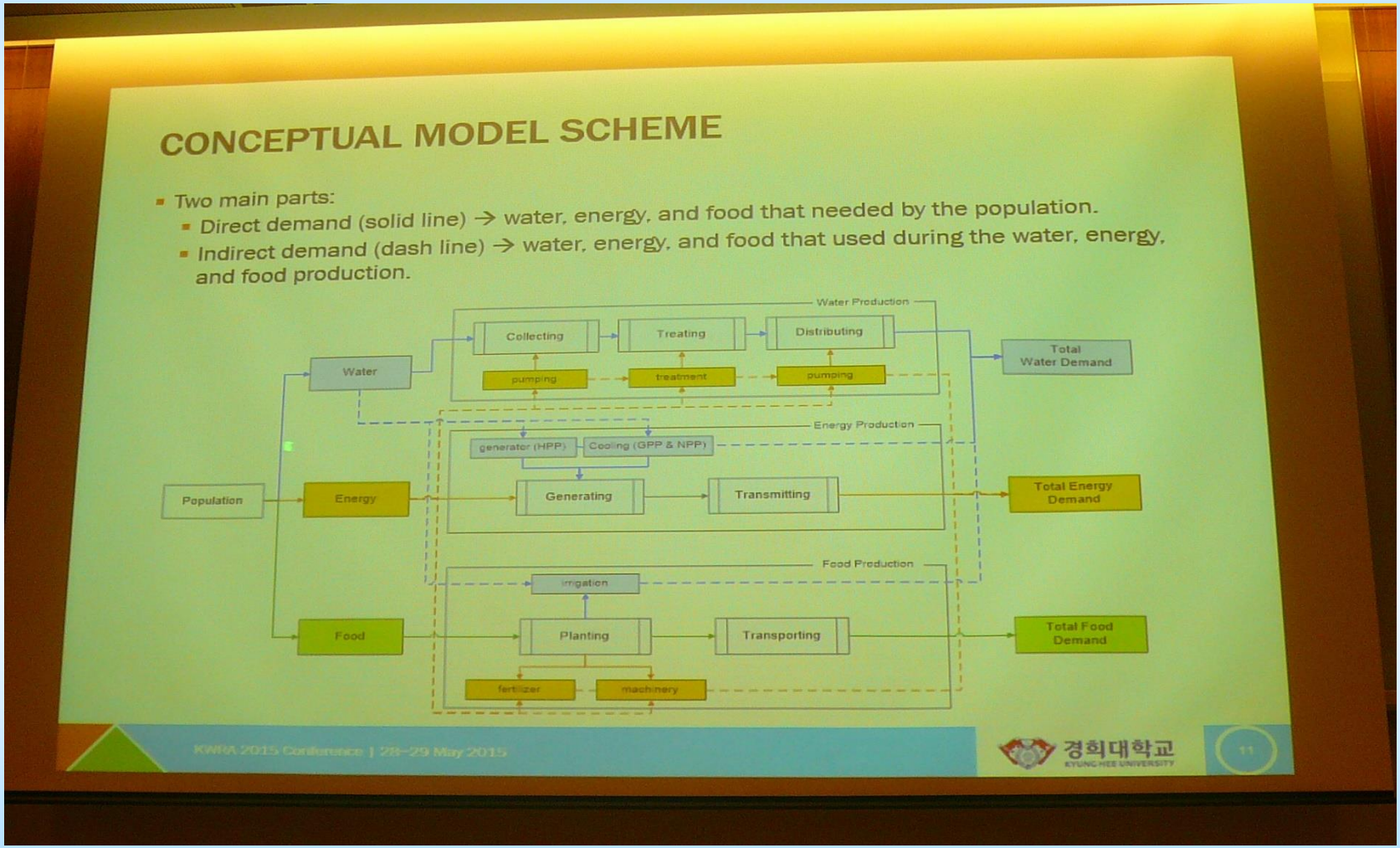
Interrelationships

- What is the unit use of water for food unit ?

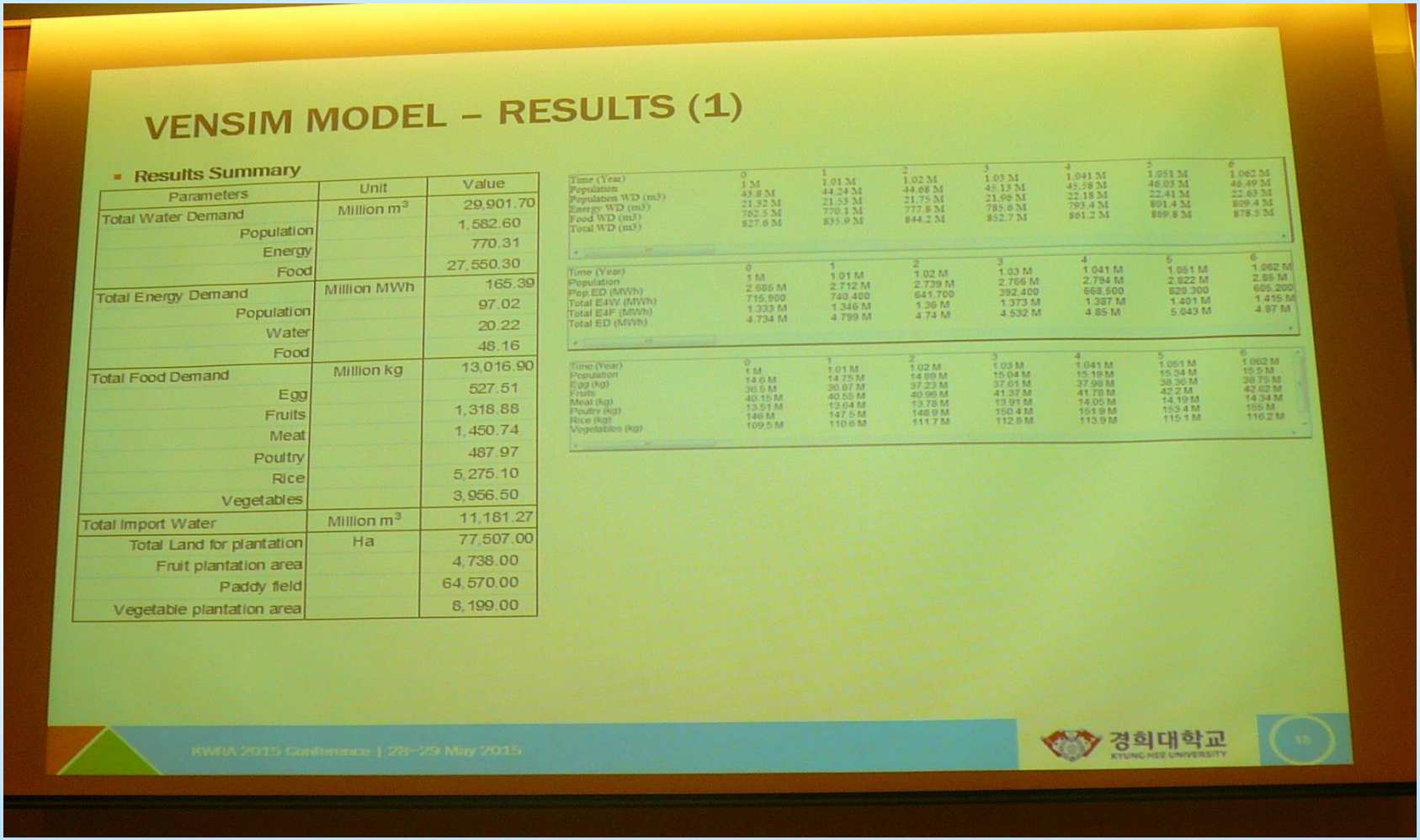
  (input, process, post harvest, distribution)
- What is the use unit of water for (alternative) energy unit ?

  (input, process, storage, distribution)
- What is the unit use of energy for food unit ?
- What is the unit use of energy for (alternative) energy unit ?

Sample of framework-1



Sample of framework-2



VENSIM MODEL – RESULTS (1)

- **Results Summary**

Parameters	Unit	Value
Total Water Demand	Million m^3	29,901.70
Population		1,582.60
Energy		770.31
Food		27,550.30
Total Energy Demand	Million MWh	165.39
Population		97.02
Water		20.22
Food		48.16
Total Food Demand	Million kg	13,016.90
Egg		527.51
Fruits		1,318.88
Meat		1,450.74
Poultry		487.97
Rice		5,275.10
Vegetables		3,956.50
Total Import Water	Million m^3	11,181.27
Total Land for plantation	Ha	77,507.00
Fruit plantation area		4,738.00
Paddy field		64,570.00
Vegetable plantation area		8,199.00

Time (Year)	0	1	2	3	4	5	6
Population	1 M	1.01 M	1.02 M	1.03 M	1.041 M	1.051 M	1.062 M
Population WD (m3)	43.8 M	44.24 M	44.68 M	45.13 M	45.58 M	46.03 M	46.49 M
Energy WD (m3)	21.32 M	21.53 M	21.75 M	21.96 M	22.18 M	22.41 M	22.63 M
Food WD (m3)	762.5 M	770.1 M	777.8 M	785.6 M	793.4 M	801.4 M	809.4 M
Total WD (m3)	827.6 M	835.9 M	844.2 M	852.7 M	861.2 M	869.8 M	878.5 M

Time (Year)	0	1	2	3	4	5	6
Population	1 M	1.01 M	1.02 M	1.03 M	1.041 M	1.051 M	1.062 M
Pop ED (MWh)	2.686 M	2.712 M	2.739 M	2.766 M	2.794 M	2.822 M	2.85 M
Total E4W (MWh)	715.900	740.400	641.700	392.400	668.500	829.300	605.200
Total E4F (MWh)	1.333 M	1.346 M	1.36 M	1.373 M	1.387 M	1.401 M	1.415 M
Total ED (MWh)	4.734 M	4.799 M	4.74 M	4.532 M	4.85 M	5.043 M	4.87 M

Time (Year)	0	1	2	3	4	5	6
Population	1 M	1.01 M	1.02 M	1.03 M	1.041 M	1.051 M	1.062 M
Egg (kg)	14.6 M	14.75 M	14.89 M	15.04 M	15.19 M	15.34 M	15.5 M
Fruits	36.5 M	36.87 M	37.23 M	37.61 M	37.98 M	38.36 M	38.75 M
Meat (kg)	40.15 M	40.55 M	40.96 M	41.37 M	41.78 M	42.2 M	42.62 M
Poultry (kg)	13.51 M	13.64 M	13.78 M	13.91 M	14.05 M	14.19 M	14.34 M
Rice (kg)	146 M	147.5 M	148.9 M	150.4 M	151.9 M	153.4 M	155 M
Vegetables (kg)	109.5 M	110.6 M	111.7 M	112.8 M	113.9 M	115.1 M	116.2 M

Possible applications

- appropriate policies, strategies and investments, to explore and exploit synergies, and to identify and mitigate trade-offs among the development goals related to water, energy and food security.

Macro view

- If we want to have growth xx % of GDP, how much water, energy needed ?
- If we want to have growth xx % of food sector, how much water, energy needed ?
- Will there be sustainable (compared with national plan, or long term sustained) ?
- What are impacts among various water use in these situations (water allocation conflicts) ?

Micro view

- In the specific area (like a province), can we measure security level and sustainable level from the use of WFE and their balances ?
- If we want to develop an irrigation project to produce foods, how much we will use water and energy ? And will it be sustainable compared with other project ?

SDG objectives and targets within 2030

1. safe drinking water availability (population percentage available)
2. water quality upgrading (water treated area and good water quality natural water sources)
3. water use efficiency (w/u efficiency upgrade, concerned with environment water)
4. IWRM in all levels (IWRM level)

SDG objectives and targets within 2030

5. rehabilitate water ecological situations (percentage of change)
6. International collaborations to improve coping capacity (projects involved including national budget)
7. community participations (number of local autho. with community participation policy)

Questions

- The framework of WFE Nexus
- The possibilities of development
- Their interlink and interrelationships
- Its merits and applications
- How to link WFE Nexus with SDG

References-1

1. Aiko Endo, et al., Methods of the Water-Energy-Food Nexus, Water 2015, 7, 5806-5830; doi:10.3390/w7105806.

2. ADB, Thinking about water differently -managing NEF nexus-, ISBN 978-92-9254-252-8, 2013.

3. Albert W. et. al., VENSIM model and NEXUS, Proc. KWRA 2015, Korea, May 2015.

4. Albert W. et. al., WEF Nexus simulation considering Interbasin Trade, Proc. KWRA 2016, Korea, May 2016.

Chulalongkorn, Master Plan to cope with Climate Change, Energy and Food Crisis, submitted to NESDB, September 2010 (in Thai).

5. Chulalongkorn, National Account of Thailand including Water Resources Cost, submitted to National Economic and Social Development Board, September 2010 (in Thai).

References-2

6. OECD, New Perspectives on the Water-Energy-Food Nexus, Forum Background Note, Global Forum for Environment, Nov 2014, OECD H/Q, Paris, 2014.

7. Sucharit K., Biomass production planning and Climate Change impacts, Report on 6th International Conference of UN-CECAR on Renewable Energy, Saranitade Conference Room, Chulalongkorn University, Thailand, May 22-23, 2012.

8. Sucharit K., Piamchan D., Piyatida H., Thailand's Water Security Situation in the context of world and ASEAN, Hydrological Sciences and Water Security: Past, Present and Future (Proceedings of the 11th Kovacs Colloquium, Paris, France, June 2014), IAHS Publ. 366, 2014.

References-3

9. Sucharit K., Climate Change and Water Resources Management Planning in Thailand, Textbook on Climate Change and Water Resources Planning, Chulalongkorn University, September 2015 (in Thai: http://project-wre.eng.chula.ac.th/watercu_eng/sites/default/files/publication/cc_mgt_th/cc_mgt_th.pdf).

10. Sucharit K., Pongsak S., Vulnerability Assessment under Climate Change and National Water Management Strategy, Proc. 2016 Korea Water Resources Association (KWRA) Annual Conference, May 26-27, 2016, Korea.