
THE ASSESSMENT OF RENEWABLE ENERGY SCENARIOS FOR NAN, RAYONG, AND PHUKET

Results of energy system modelling



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Seminar on Provincial Renewable
Energy Scenarios and its implication
for National and Regional Energy
Planning

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Energy system modelling

Objectives

- Identify the technically feasible and most cost-effective structure of the province electricity system for given boundary conditions (scenarios)
- Calculate costs and CO₂ emissions of the different scenarios
- Develop recommendations for each of the 3 provinces

Energy scenarios were modelled for following boundary conditions:

Provinces	Target years	Demand scenarios	Shares of RES
Nan	2025 2036	Business as usual (BAU)	20%
Phuket		Energy efficiency (EE)	40%
Rayong		Energy efficiency plus (EE+)	60%
			80%
			100%

Nan modelling results

- Inhabitants: 478,264
- Area: 11,472 km²
- Electricity demand per year: 283 GWh/a
- Electricity demand per inh.: 591 kWh/(inh*a)
- Electricity supply: most of electricity imported

Nan Province



Source: maps-thailand.com

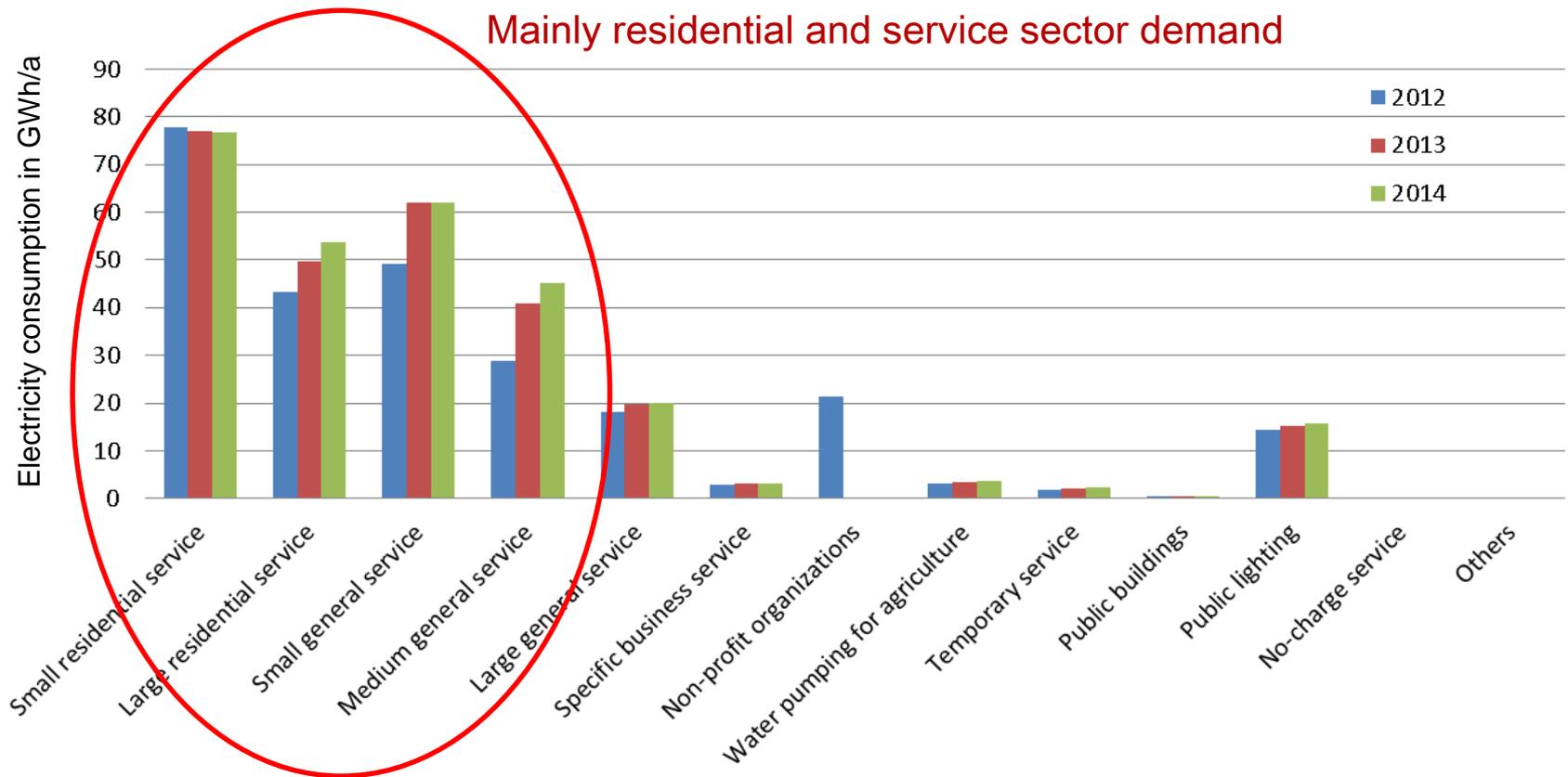
RES potential NAN



Source: "Nan z doi phuka 2006 1003" by Takeaway – Own work. Licensed under CC BY-SA 3.0

	Source	Potential
	Wind	Very low potential
	Solar	Very high potential Good solar radiation (1,600 kWh/m ² a) High potential on roof space for PV installations (41 m ² /inh.)
	Biomass	High potential 1) Solid biomass (corn, ...): 2,891 GWh 2) Waste (municipal and animal waste): 637 GWh 3) Liquid biofuels: 19 GWh

Annual electricity consumption Nan 2012 – 2014



Data on annual electricity consumption in Nan are available for 2012, 2013 and 2014, divided into 13 consumer categories. A continuous increase of electricity consumption is observed from 2012 to 2014 in most sectors. For modeling, 2014 data are used.

Modelling results Nan

2025 scenarios BAU

Electricity in GWh	PV	Wind	hydro	Bio energy	Waste	Fossil fuels	Batteries (MWh)	Total produced
Ref	0	0	48	0	0	345	0	393
20% RES	0	0	48	8	23	314	0	393
40% RES	0	0	48	75	35	236	0	393
Cost optimum (77%)	0	0	48	220	35	90	0	393
Recommended 50% RES incl. 10% PV	39	0	48	75	35	196	0	393

The results for EE scenarios differs only slightly

Modelling results Nan

Recommended 2025 scenario BAU, 50% RES incl. 10% PV

Detailed data of scenario

	Unit	PV	Hydro	Bio energy	Waste	Fossil fuels
Installed capacity	MW	32.6	5.5	9.3	4.3	66.7
Electr. generated	GWh	39.3	48.0	74.6	34.6	196.5
Share	%	10.0	12.2	19.0	8.8	50.0
LCOE	Baht/kWh	3.2	1.0	1.8	1.7	3.2
LCOE	€ct/kWh	7.9	2.6	4.6	4.2	7.9
PV modules area	km ²	0.16				
Full load hours	h/a	1,206	8,760	8,000	8,000	
Used potential	%	1.4	100	8.5	36.2	

Modelling results Nan

2036 scenarios BAU, electricity generation by fuels

Electricity in GWh	PV	Wind	hydro	Bio energy	Waste	Fossil fuels	Bat-teries (MWh)	Total produced
Ref	0	0	48	0	0	504	0	552
20%	0	0	48	14	49	441	0	552
40%	0	0	48	124	49	331	0	552
60%	0	0	48	234	49	221	0	552
80%	0	0	48	350	43	110	34	552
Cost Optimum (86%)	0	0	48	379	47	77	53	552
100%	0	0	48	463	41	0	166	552
Recommended 100% incl. PV	110	0	48	357	37	0	193	552

Modelling results Nan

2036 scenarios EE, electricity generation by fuels

Electricity in GWh	PV	Wind	hydro	Bio energy	Waste	Fossil fuels	Bat-teries (MWh)	Total pro-duced
Reference	0	0	48	0	0	409	0	457
20% RES	0	0	48	8	36	366	0	457
40% RES	0	0	48	95	40	274	0	457
60% RES	0	0	48	186	40	183	0	457
80% RES	0	0	48	282	36	91	27	457
86% RES cost optimum	0	0	48	305	39	65	44	457
100% RES	0	0	48	375	34	0	138	457
Recommended 100% incl. PV	91	0	48	287	31	0	160	457

Modelling results Nan

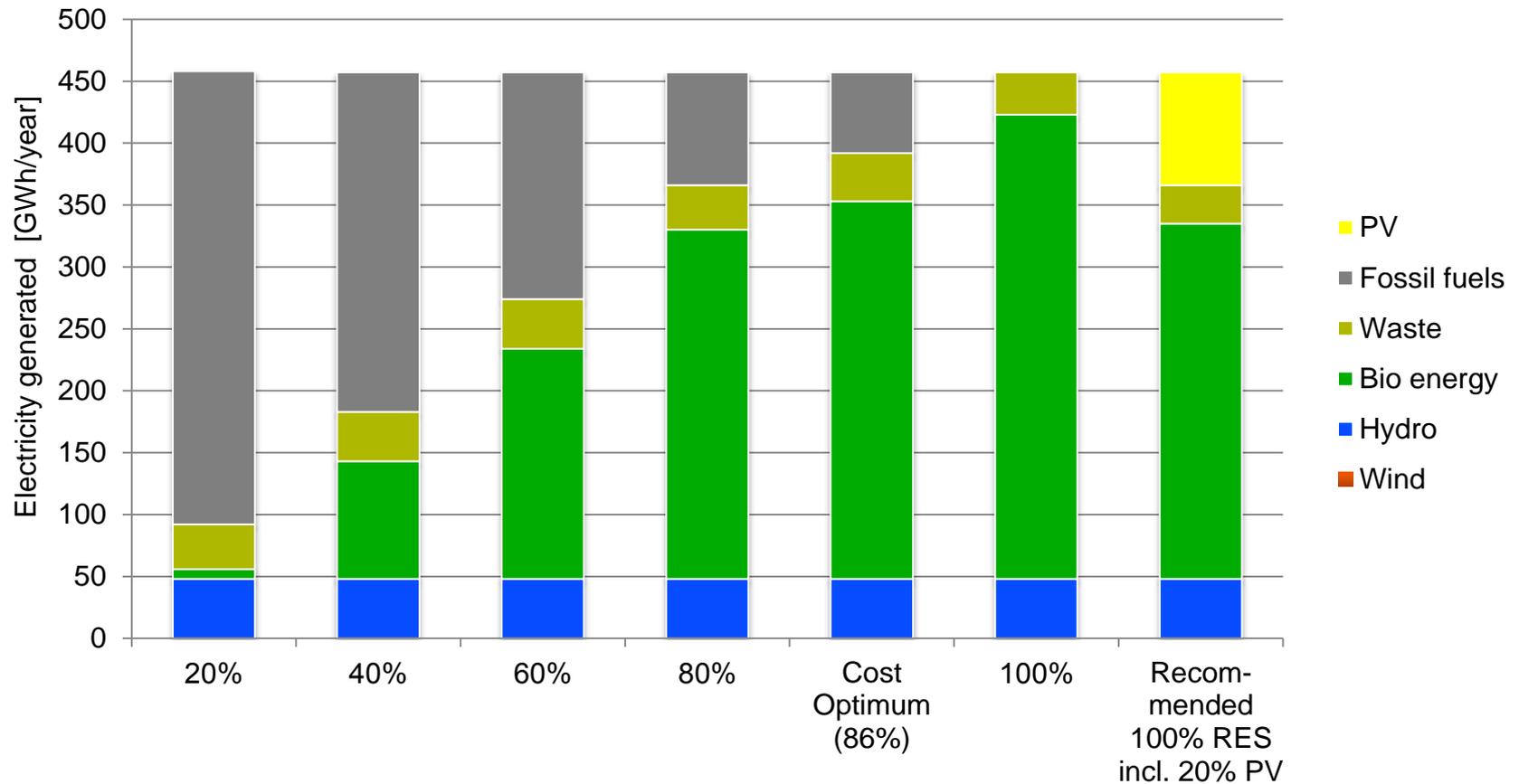
Recommended 2036 scenario 100% RES incl. 20% PV

Detailed data of scenario

	Unit	PV	Hydro	Bio energy	Waste	Batteries
Installed capacity	MW	75.8	5.5	55.3	3.8	160 MWh
Electr. generated	GWh	91	48.0	287	31	
Share	%	20	10.5	63	6.8	
LCOE	Baht/kWh	2.6	1.1	2.5	1.7	
LCOE	€ct/kWh	6.4	2.7	6.2	4.3	
PV modules area	km ²	0.38				
Full load hours	h/a	1,206	8,760	5,912	8,000	
Used potential	%	3.14	100	43.2	38.6	

Modelling results Nan

Overview 2036 scenarios EE



Conclusions Nan

- **Nan can reach 100 % renewable energy generation (RES) on electricity demand in 2036**
- **Recommended scenario 2036: 100% RES incl. 20% PV**
 - **Hydro power** has the least LCOE, potential would be fully used
 - **Bio energy and waste** are the second cheapest RES option, about 40% of the potential would be used
 - **PV** is slightly more expensive than biomass (2.6 instead of 2.5 Baht/kWh), it is recommended to aim for a 20% share of PV in the 100% RES scenario, then 3% of the potential would be used

Recommendations

- **Target setting and development of implementation roadmap**
- **Improve data basis on RES potential: wind, waste and hydro**
- **Pilot projects: focus on bio energy / waste as well as PV rooftop**

Phuket modelling results

- Inhabitants: 378,364
- Tourists per year: 12,000,000
- Area: 576 km²
- Electricity demand (2014): 2,311 GWh/a
- Electricity demand per inh.: 6,108 kWh/(inh*a)
- Electricity generation in Phuket:
1 waste power plant (16,5 MW)
Share on electricity demand: appr. 6%



RES potential Phuket

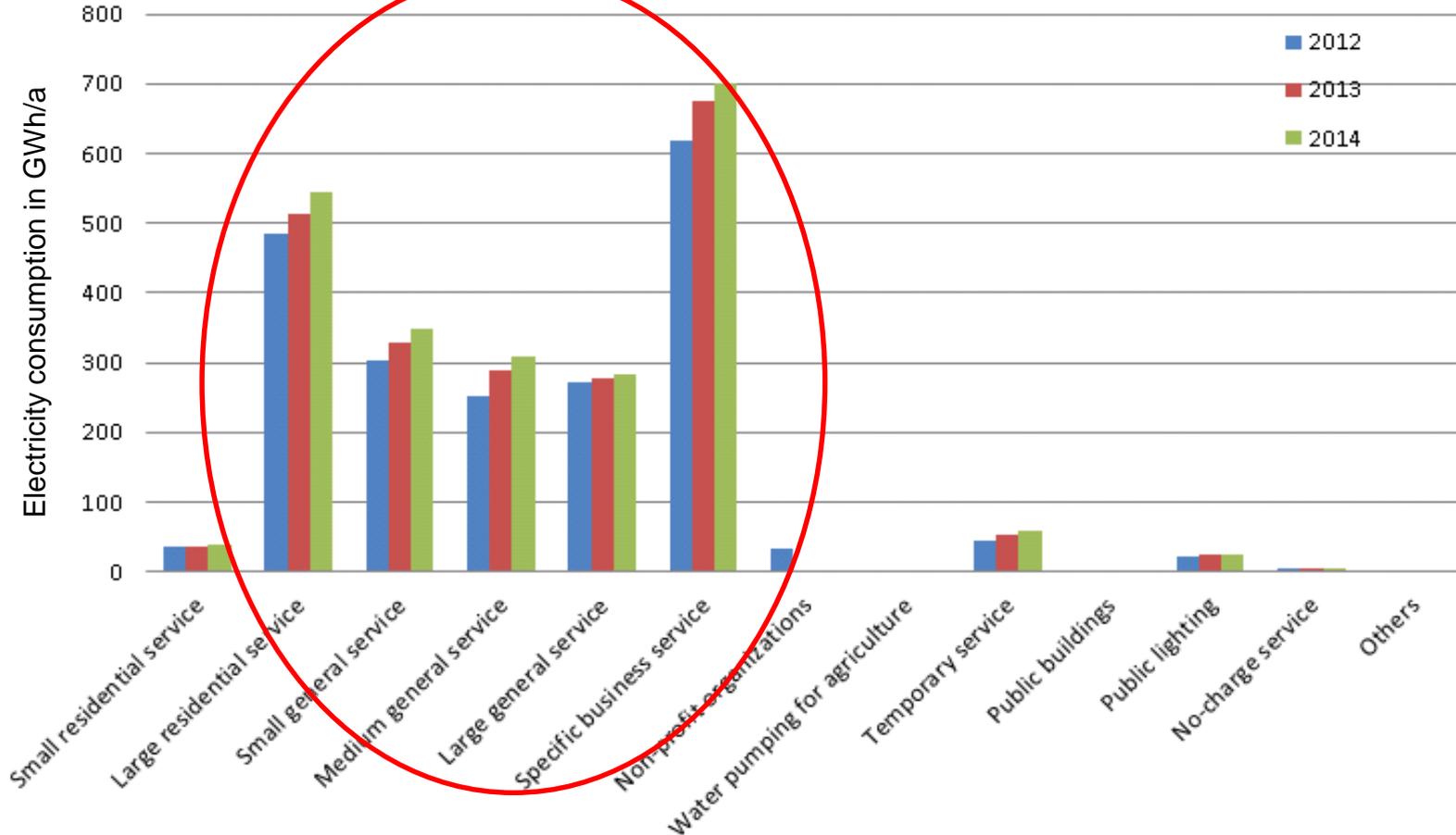


PHUKET MUNICIPAL SOLID WASTE INCINERATION POWER PLANT

	Source	Potential
	Wind	Low to medium wind speed Almost no area to install wind turbines
	Solar	High potential Good solar radiation (1,750 kWh/m ² a) Limited roof space for PV installations (22 m ² /inh.)
	Biomass	Low potential 1) Solid biomass (pineapple, coconut, ...): 142 GWh 2) Waste (municipal and animal waste): 477 GWh 3) Liquid biofuels: 4 GWh

Annual electricity consumption Phuket 2012 – 2014

Mainly large residential and service sector demand



Data on annual electricity consumption in Phuket are available for 2012, 2013 and 2014, divided into 13 consumer categories. A continuous increase of electricity consumption is observed from 2012 to 2014. For modeling, 2014 data are used.

Modelling results Phuket 2025 scenarios BAU

Electricity in GWh	PV	Wind	hydro	Bio energy	Waste	Fossil fuels	Batteries (MWh)	Total produced
Reference	0	0	0	0	80	3,164	0	3244
20% RES Recommended	524	0	0	44	80	2,596	0	3244
40% RES	1,389	19	0	44	80	1,947	156	3479

Remarks: The results for EE scenarios differs only slightly. The use of batteries in the 40% RES scenario is increasing the electricity demand, due to losses by charging, storing, and discharging the batteries.

Modelling results Phuket

2025 recommended BAU scenario 20% RES

Detailed data of scenario

	Unit	PV	Wind	Hydro	Bio energy	Waste	Fossil fuels
Installed capacity	MW	404	0	0	5.5	10	
Electr. generated	GWh	524	0	0	44	80	2,596
LCOE	Baht/kWh	3.0			1.7	1.7	2.8
LCOE	€ct/kWh	7.4			4.2	4.2	7.0
PV modules area	km ²	2.0					
Full load hours	h/a	1,297			8,000	8,000	
Used potential	%	24			100	100	

Modelling results Phuket

2036 scenarios BAU, electricity generation by fuels

In BAU scenario, 40% RES is possible with RES resources from the island

Electricity in GWh	PV	Wind	Bio energy	Waste	Fossil fuels	Batteries (MWh)	Total produced
Reference	0	0	0	80	4,409	0	4489
10 % RES cost optimum	335	0	44	80	4,030	0	4489
20% RES	773	0	44	80	3,592	0	4489
40% RES	1,838	19	44	80	2,694	724	4675

Modelling results Phuket

2036 scenarios EE, electricity generation by fuels

In EE scenario, 60% RES is possible with RES resources from the island

Electricity in GWh	PV	Wind	Bio energy	Waste	Fossil fuels	Batteries (MWh)	Total produced
Reference	0	0	0	80	3,642	0	3,722
12% RES cost optimum	335	0	44	80	3,262	0	3,722
20% RES	620	0	44	80	2,977	0	3,722
40% RES Recommended	1,507	19	44	80	2,233	495	3,883
60% RES	2,090	19	44	80	1,490	5,909	3,723

Modelling results Phuket

Recommended 2036 BAU scenario 40% RES

Detailed data of scenario

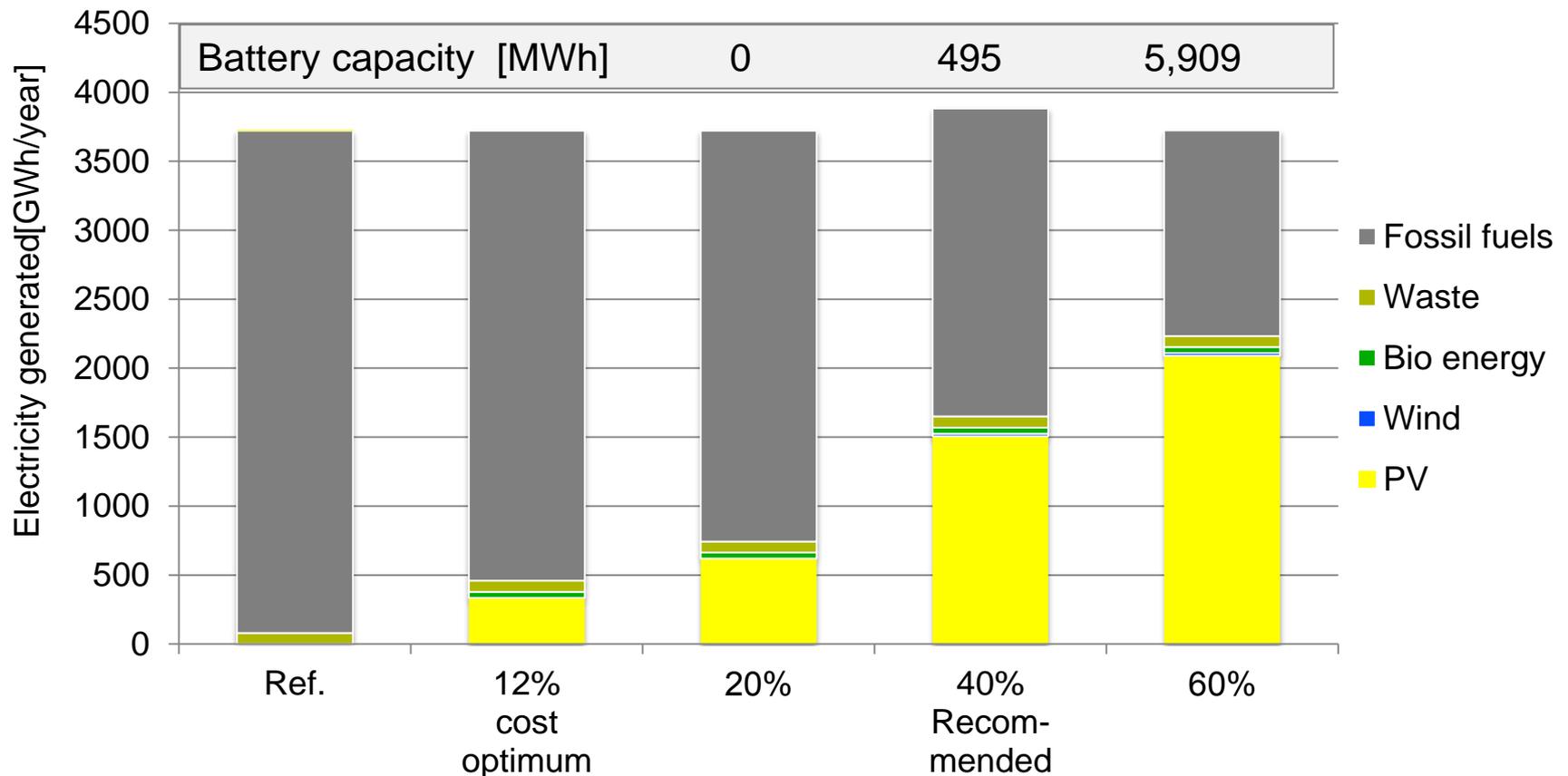
Batteries are necessary, if RES electricity is not imported/exported

	Unit	PV	Wind	Bio energy	Waste	Fossil fuels	<i>Bat- teries</i>
Installed capacity	MW	1,473	10	6.0	10	589	<i>724 MWh</i>
Electr. generated	GWh	1,838	19	44	80	2,694	
LCOE	Baht/kWh	2.6	3.7	1.9	1.8	3.0	
LCOE	€ct/kWh	6.4	9.4	4.7	4.4	7.5	
PV modules area	km ²	7.4					
Full load hours	h/a	1,217	1,947	7,360	7,865		
Used potential	%	86	100	100	100		

Modelling results Phuket

Overview 2036 scenarios EE

In the 40% and 60% scenarios the installation of batteries is necessary, if import/export of RES energy with other regions is not established



Conclusions Phuket

- In 2036, **Phuket maximum share on RES** is 40 % in BAU scenario, 60% in EE scenario and 90% in EE+ scenario
- ➔ **Actions in energy efficiency should be taken**
since energy efficiency has a strong influence on the RES share
- **Recommended scenario 2036: 40% RES**
 - **Bio energy, waste** are cheapest RES option, but their potential is limited
 - **Wind:** medium wind velocity, but hardly any place to install wind turbines
 - **Rooftop PV** is the main RES potential

Recommendations

- **Target setting and development of implementation roadmap**
- **Improve data basis on RES potential:** solar, wind, and biomass
- **Pilot projects:** focus on PV rooftop systems
(tourism resorts, public and commercial buildings)
- **Cooperation with neighbourhood provinces** on the mainland on generating RES and import it to Phuket

Results for Rayong



Source: mappery.com

- Inhabitants: 674,393
- Area: 3552 km²
- Electricity demand (2014): 9,101 GWh/a
- Electricity demand per inh.: 13,495 kWh/(inh*a)

Installed electricity generation capacities:

Natural gas (2,501 MW), Coal (2,578 MW), PV (1.6 MW), Waste (1.0 MW)

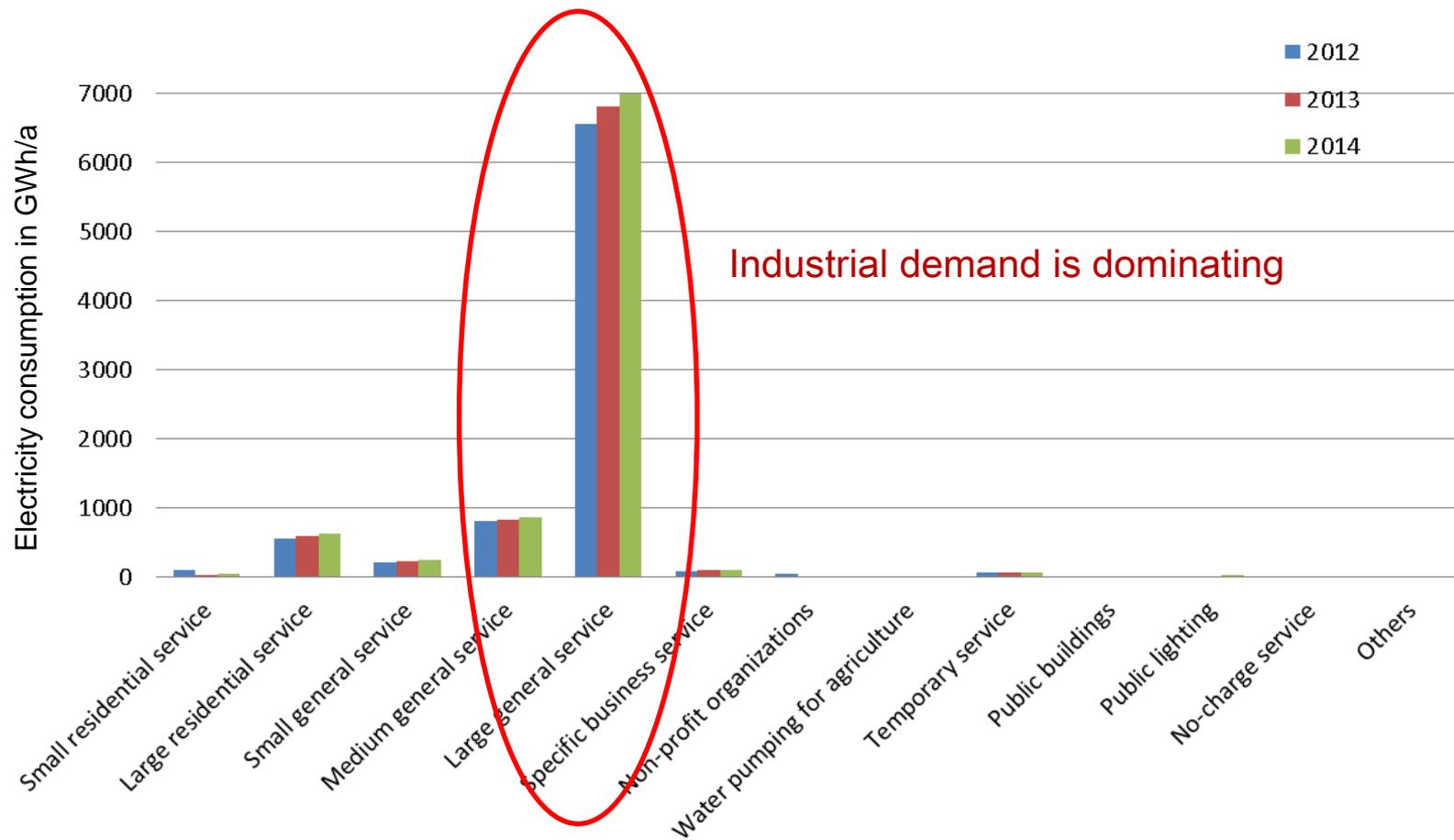
RES potential Rayong



Coal fired power plant in Rayong

	Source	Potential
	Wind	Limited potential, which should be further evaluated
	Solar	High potential Good solar radiation (1,800 kWh/m ² a) Limited roof space for PV installations (24 m ² /inh.)
	Biomass	Medium potential 1) Solid biomass (pineapple, coconut, ...): 2,652 GWh 2) Waste (municipal and animal waste): 1,057 GWh 3) Liquid biofuels: 322 GWh

Annual electricity consumption Rayong 2012 – 2014



Data on annual electricity consumption in Rayong are available for 2012, 2013 and 2014, divided into 13 consumer categories. A continuous increase of electricity consumption is observed from 2012 to 2014. For modeling, 2014 data are used.

Modelling results Rayong

2025 scenarios BAU

Electricity in GWh	PV	Wind	Bio energy	Waste	Fossil fuels	Batteries (MWh)	Total produced
Reference	0	0	79	28	14,185	0	14,292
8% RES cost optimum	0	0	917	203	13,173	0	14,292
20% RES	1,739	0	917	203	11,434	0	14,292
30% incl. 4% Wind recommended	2,576	600	917	203	10,005	0	14,292
40% RES	4,242	601	917	203	8,576	0	14,292

Remarks: The results for EE scenarios differs only slightly. The model would not choose wind in the 30% scenario, however, it is expected, that the provincial government will find economic solutions

Modelling results Rayong

Recommended **2025** scenario BAU:

30% RES incl. 4% Wind

Detailed data of scenario

	Unit	PV	Wind	Bio energy	Waste	Fossil fuels
Installed capacity	MW	1,973	442	114	25	
Electr. generated	GWh	2,576	600	917	203	10,005
<i>Share</i>	%	<i>18.0</i>	<i>4.2</i>	<i>6.4</i>	<i>1.4</i>	<i>70.0</i>
LCOE	Baht/kWh	3.0	5.0	1.7	1.7	2.4
LCOE	€ct/kWh	7.4	12.4	4.3	4.2	6.0
PV modules area	km ²	9.9				
Full load hours	h/a	1,298	1,357	8,000	8,000	
<i>Used potential</i>	%	<i>58</i>	<i>5</i>	<i>100</i>	<i>100</i>	

Modelling results Rayong

2036 scenarios EE, electricity generation by fuels

Electricity in GWh	PV	Wind	Bio energy	Waste	Fossil fuels	Bat-teries (MWh)	Total pro-duced
Reference	0	0	79	28	18,172	0	18,279
20% RES cost optimum	2536	0	917	203	14,624	0	18,279
40% RES recommended	4,242	2,167	917	203	10,968	751	19,248
60% RES	4,242	8,654	917	203	7,314	10000	21,330

Modelling results Rayong

Recommended 2036 EE scenario 40% RES

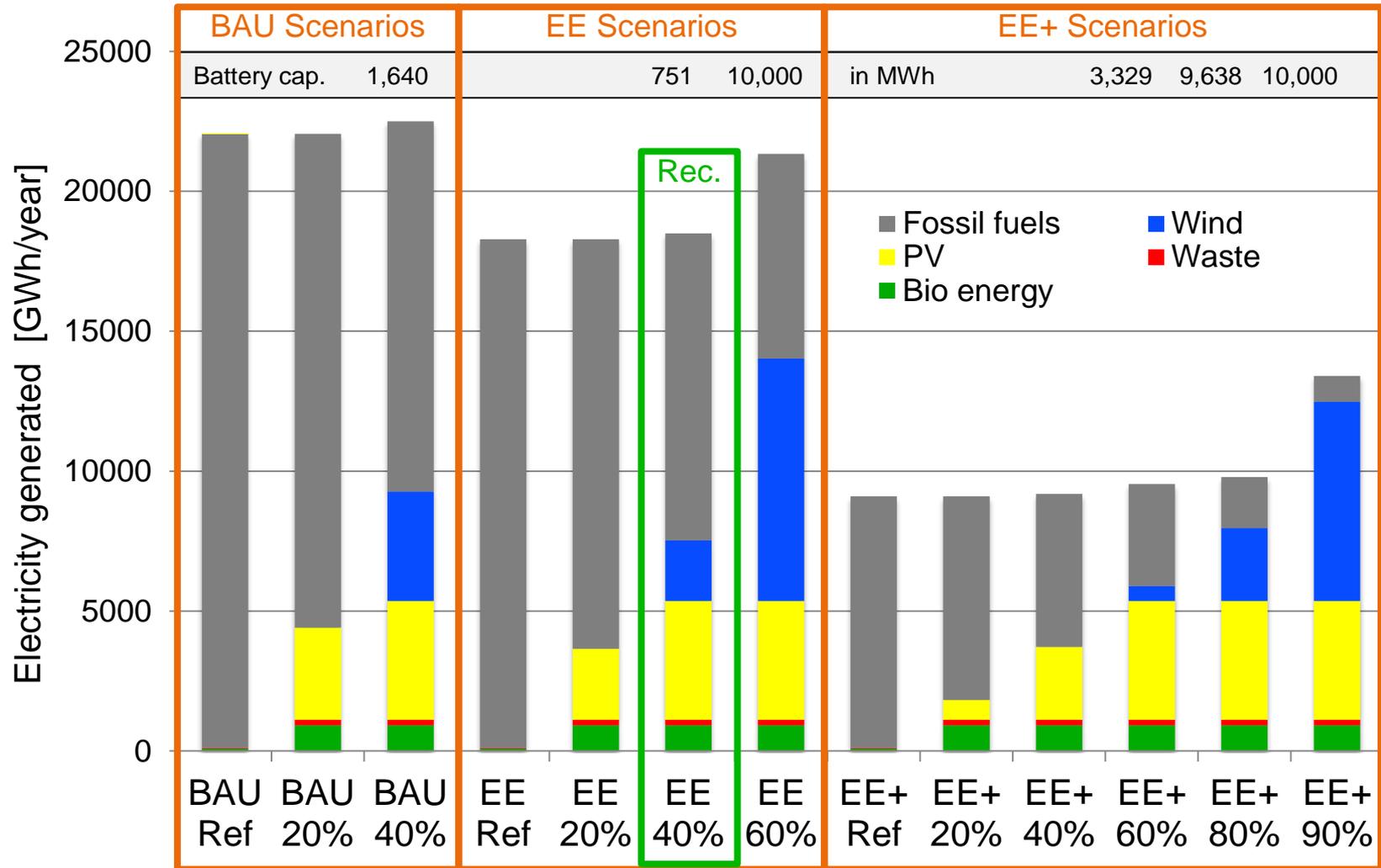
Detailed data of scenario

Batteries are necessary, if RES electricity is not imported/exported

	Unit	PV	Wind	Bio energy	Waste	Fossil fuels	Bat-teries
Installed capacity	MW	3,380	1,597	123	25		751 MWh
Electr. generated	GWh	4,242	2,167	917	203	10,968	
Share	%	22.9	11.7	5.0	1.1	59.3	
LCOE	Baht/kWh	2.5	5.1	1.8	1.7	2.6	
LCOE	€ct/kWh	6.3	12.8	4.6	4.3	6.4	
PV modules area	km ²	16.9					
Full load hours	h/a	1,250	1,357	7,625	8,000		
Used potential	%	100	18	100	100		

Modelling results Rayong

Electricity source mix of 2036 scenarios BAU, EE, and EE+



Conclusions Rayong

- Rayong possible RES share depends on the demand scenarios: 40% for BAU, 60% for EE and 90% for EE+
- ➔ Actions in energy efficiency should be taken since energy efficiency has a strong influence on the RES share
- Recommended scenario 2036: 40% RES
 - Bio energy, waste are cheapest RES option, but potential is limited
 - PV: significant, but limited potential, cheaper than fossil fuels
 - Wind: medium wind velocity, more costly than PV, potential to be evaluated
- Rayong is today the powerhouse of Thailand, it doesn't make sense to aim for 100% of this energy amount to be delivered by RES from the Rayong province, electricity generation in Thailand will be more decentralized with RES

Recommendations

- Target setting and development of implementation roadmap
- Improve data basis on RES potential: solar, wind, and waste

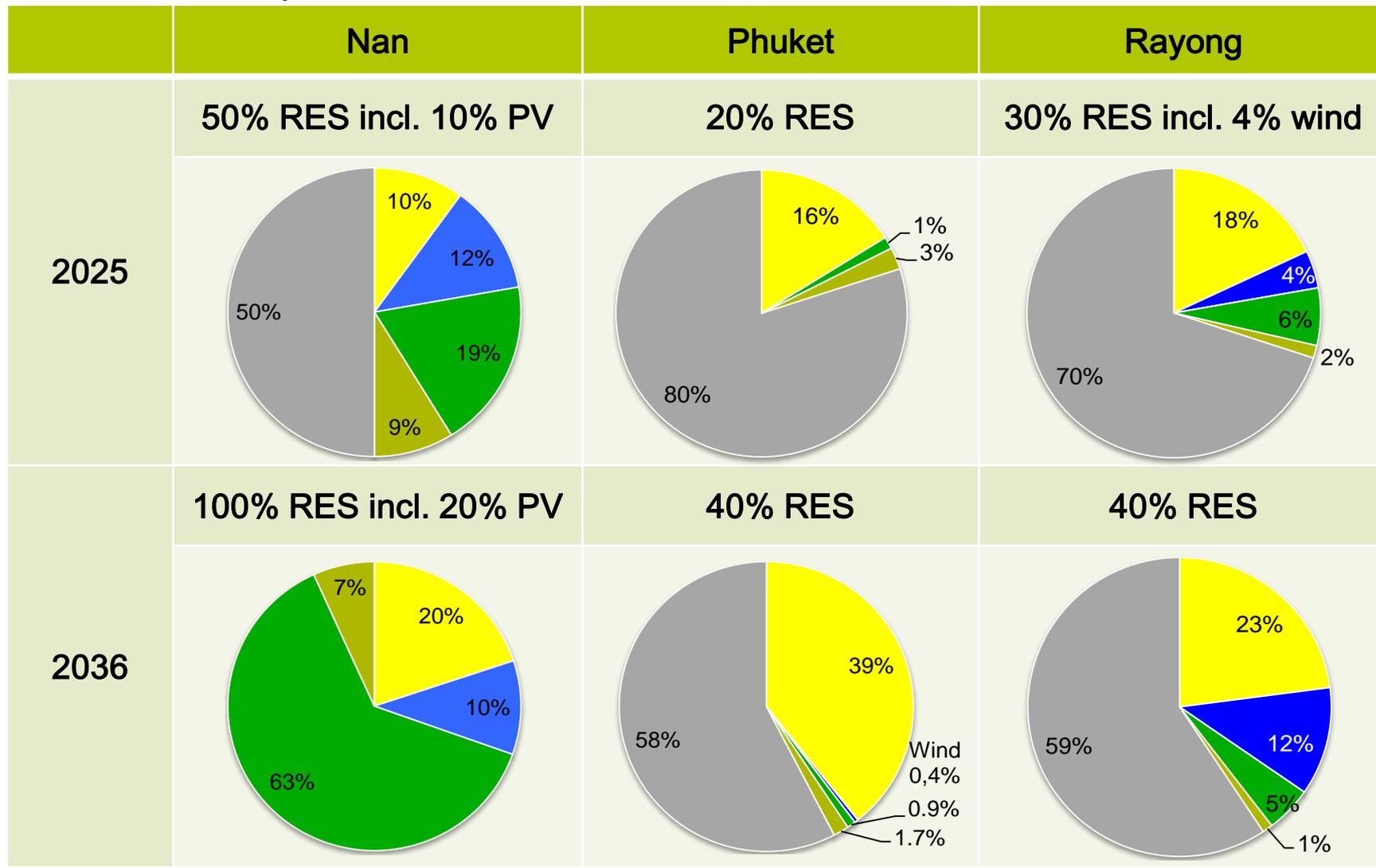
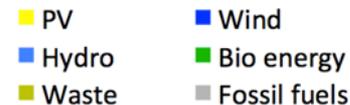
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General conclusions and recommendations

- **Following work was done within the project RES4THAI for each of the 3 provinces Nan, Phuket, and Rayong:**
 - Identification of today's electricity demand profiles
 - Calculation of expected electricity demand in 2025 and 2036
 - Identification of renewable energy resource (RES) potentials
 - Modelling of optimized electricity system structures for 2025 and 2036, for demand profiles BAU, EE, and EE+ and for different RES shares
 - Recommendations for target energy scenarios for 2025 and 2036
- **Next steps recommended:**
 - **Target setting by national and provincial actors**
based on discussion of results and recommended target energy scenarios
 - **Development of implementation roadmaps over 3-5 years**
describing the first steps to achieve long-term targets

Recommended target scenarios overview

with related electricity source mix, based on EE demand scenarios



Recommendations 1

- **Target setting on provincial level**
- **Target setting on municipal level**
- **Development of implementation roadmaps (3-5 years)**
 - **Nan:** focus on biomass / waste to energy and PV rooftop pilot plants
 - **Phuket:** focus on PV rooftop systems
 - **Rayong:** focus on PV rooftop and identification of wind potential
- **Identification of energy efficiency potential and measures**
 - Appropriate measures to be defined on national, provincial and local level
- **Capacity building on provincial and municipal level**
 - Building up know-how (training, technical support,...)
 - Realizing lighthouse projects to gather experiences

Recommendations 2

■ Realizing lighthouse projects to

- raise awareness and motivate local actors and investors
- developing and demonstrate solutions and overcome barriers:
 - Technical design (e.g. roof top installation, connection to grid)
 - Administrative issues (necessary permissions,...)
 - Financing and business models for investors

■ Improve data on RES potentials

- Potentials must be assessed more in detail for implementation plans

■ Implement Monitoring

- Annual reporting on energy balances and progress in efficiency and renewable energies is necessary for sound political decisions

■ Building up a market for decentralized PV roof top systems

- PV will be cheaper than electricity from fossil power plants in future, therefore a PV market should be systematically built up

Thank you very much for your attention!



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Annex

Investment costs of power plant types used for LCOE calculations

	Investment costs in 2015 [THB ₂₀₁₅ /kW] / [THB ₂₀₁₅ /kWh]	Investment costs in 2025 [THB ₂₀₁₅ /kW] / [THB ₂₀₁₅ /kWh]	Investment costs in 2036 [THB ₂₀₁₅ /kW] / [THB ₂₀₁₅ /kWh]
Battery	53913	23951	9804
bioenergy power plant	87679	90286	93245
waster power plant	123123	126785	130940
liquid biofuels power plant	55965	57630	59518
Photovoltaic modules	49622	34549	28094
wind power plant	49622	51098	52773
coal power plant	61562	63393	65470
natural gas power plant	37310	38420	39679
water power plant	123123	126785	130940

Annex

Fuel costs for different kind of biomass used for LCOE calculations

in THB/kWh fuel	Low	High	Default
Rice husk	0.06553	0.26211	0.21842
Rice straw	0.15290	0.34948	0.27303
Bagasse	0.05461	0.10921	0.07645
field rest	0.06553	0.26211	0.16382
empty fruit bunch EFB	0.00874	0.01747	0.05461
oil palm fibre	0.06553	0.15290	0.10921
oil palm shells	0.32764	0.48053	0.37132
wood chips (para rubber)	0.08737	0.21842	0.15290