APEC Workshop on Filling the Gap to Reach the Goal of Doubling Renewable Energy in the APEC Region

DISCUSSION 1:

Setting a Vision for APEC Renewables Doubling Goal

Alexey KABALINSKIY
Korea, Jeju 27-28 March, 2017

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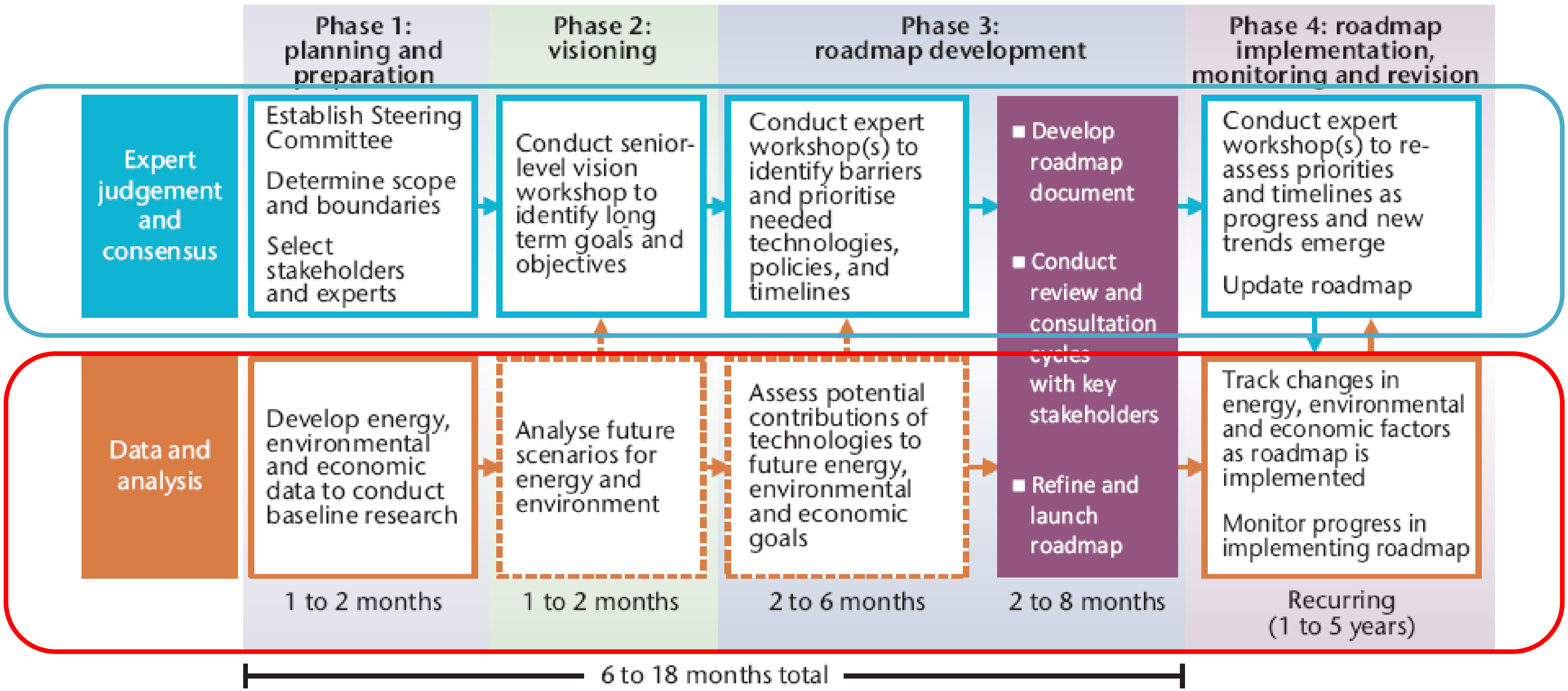
ABOUT TECHNOLOGY ROADMAPS

IEA Roadmap Definition

"A technology roadmap is a dynamic set of technical, policy, legal, financial, market & organizational requirements identified by all stakeholders involved in its development. The effort shall lead to improved and enhanced sharing and collaboration of all related technology-specific RDD&D information among participants.

The goal is to accelerate the overall RDD&D process in order to deliver an earlier uptake of the specific energy technology into the marketplace".

Roadmap process outline



Note: dotted lines indicate optional steps, based on analysis capabilities and resources.

The IEA roadmap approach

- Engage cross-section of stakeholders
- **Identify a baseline – where is technology today?**
- **Use *ETP* 2 degree scenario (2DS) results for deployment pathway to 2050**
- Identify barriers – technical, regulatory, policy, financial, public acceptance
- Develop implementation action items for stakeholders

Roadmap logic

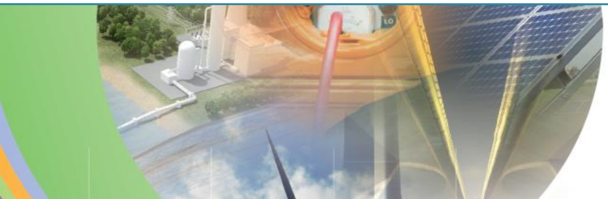
- Goal to achieve
- Milestones to be met
- Gaps to be filled
- Actions to overcome gaps and barriers
- What and when things need to be achieved

Visioning

- **What is the status of the technology today?**
- **What data are needed to establish baseline conditions, set goals and targets, and prepare forecasts?**
- Are essential analytic capabilities and tools available to evaluate alternative scenarios?
- What technical expertise is needed to evaluate technology performance and limitations?
- **Will goals and milestones include date-based, quantitative targets?**

Expert judgment and consensus: roadmap workshops

- Structured vision and technology roadmap workshops can:
  - **Build consensus on goals and targets**
  - **Evaluate and verify assumptions**
  - Identify technical and institutional barriers
  - Define alternative technology pathways
  - Develop implementation strategies and priorities



Baseline data

Situation analysis of key factors:

- **Technologies:**
  - Current status of costs and performance
  - Technology readiness
  - Market penetration and limitations
- **Markets:**
  - Suppliers, distributors and customers
  - Energy characteristics (production, delivery, storage and consumption)
  - Environmental impacts (air, water and land impacts)
- **Public policies:**
  - Current status and requirements of relevant, existing laws and regulations

Setting the Vision for APEC Renewable Energy Target

- What is the status of the Renewables in APEC today?
- Establishing baseline conditions for economies and sectors:
  - RE technologies: costs, performance, limitations,
  - RE markets: suppliers, distributors and customers,
  - Current Renewable Energy policy status,
- Understanding set RE goals and targets,
- Preparing forecasts (APEC Energy Outlook by APERC),
- Identifying (date-based, quantitative) goals and milestones.

APERC's 7th Outlook timeline (draft)

Expert Economy Review of model results	Oct 2017
EWG review of Vol II	Sept 2018
EWG review of Vol I	Oct 2018
Outlook 7th edition released	April 2019

Thank you!

http://aperc.ieej.or.jp/

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Appendix

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Modelling changes for the 7th edition

- Extend forecast to 2050
- Reduce alternative scenarios from three to two
  - High renewables + improved efficiency
  - 2-degree rise in temperature
- Use OECD GDP forecasts
- Make buildings model activity driven
- Start to change industrial model from top-down to bottom up
- Add buses and light trucks to the transportation model
- Distribute renewables to demand and electricity models
- Add a supply model
- Add an integrating module

Seminar on Conducting APEC Renewable Energy Roadmap

Renewable Energy Modelling for APEC Energy Demand and Supply Outlook 7th Edition

Alexey KABALINSKIY

3 March 2017

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Structure

- ✓ RE Model improvements
- ✓ Renewable Technologies
- ✓ Renewable Potential Assessment
- ✓ Renewables in Demand sectors
- ✓ Renewables in Power
- ✓ Summary

RE Model improvements

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RE Model improvements (actioned and under development)

- ✓ **Detailed RE templates for APERC data collection,**
- ✓ **APEC RE for Heating & Cooling applications assessment,**
- ✓ **RE tech-econ potential assessment by economy and by sector,**
- ✓ **RE model split into Buildings, Industry, Transport and Power,**
- ✓ **Extend the list of RE technologies in Power and Direct use,**
- ✓ **RE capacity stock dynamic modelling,**

Note: Splintegration = Split + Integration

RE Model improvements (under development and planned)

- ✓ **2 Degree Scenario (2DS) formulation,**
- ✓ **Transportation model is activity based and integrates biofuels,**
- ✓ **Develop capabilities for APEC electricity grid modelling to quantify the impacts of increasing RE penetration, incl. future economies' interconnections,**
- ✓ **Improved analysis of RE policies, incentives, FITs, RPSs, PPAs.**

Renewable Technologies

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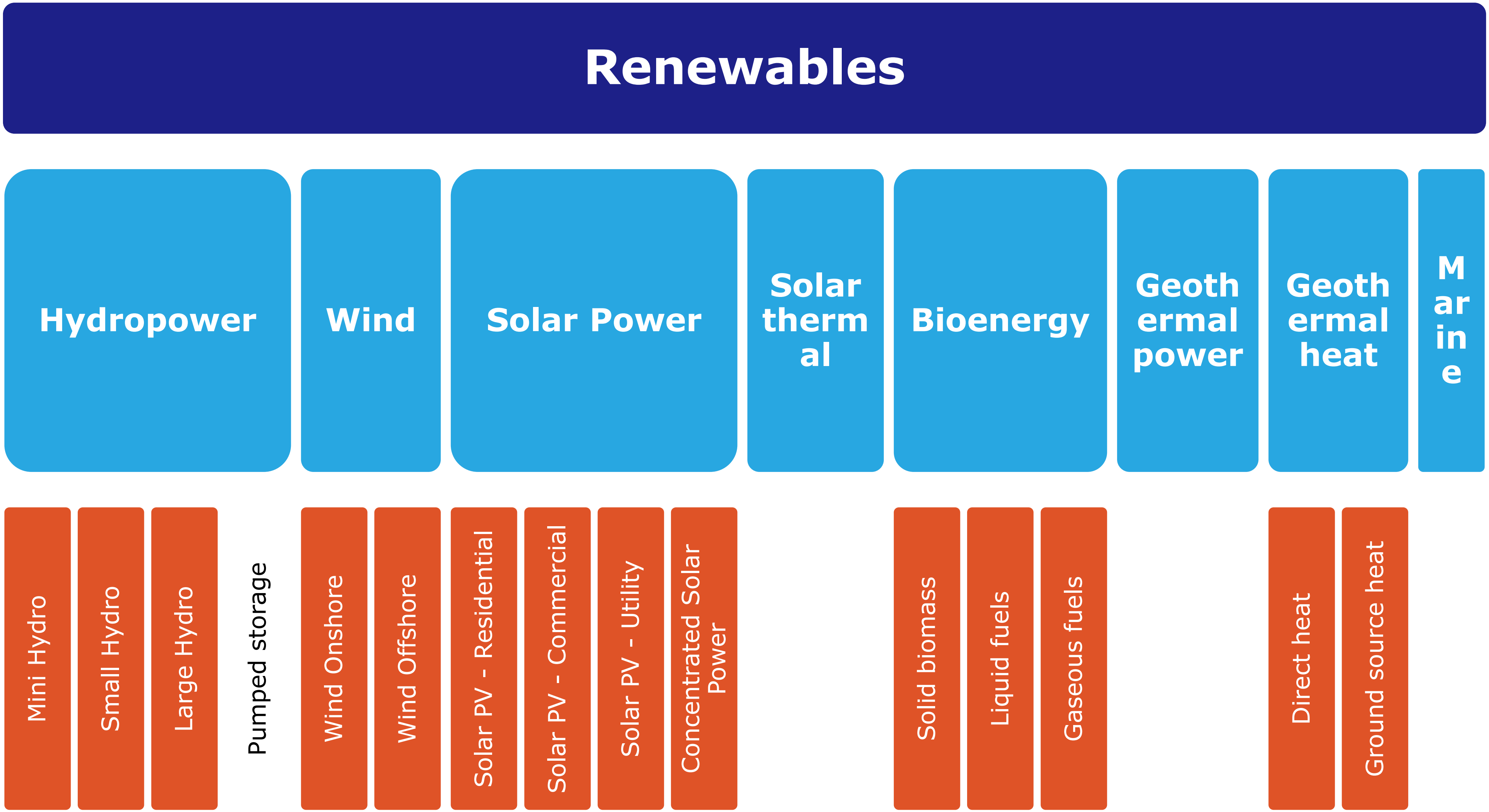
Renewable Energy technologies



Renewables potential assessment

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Solar rooftop PV and heat potential assessment

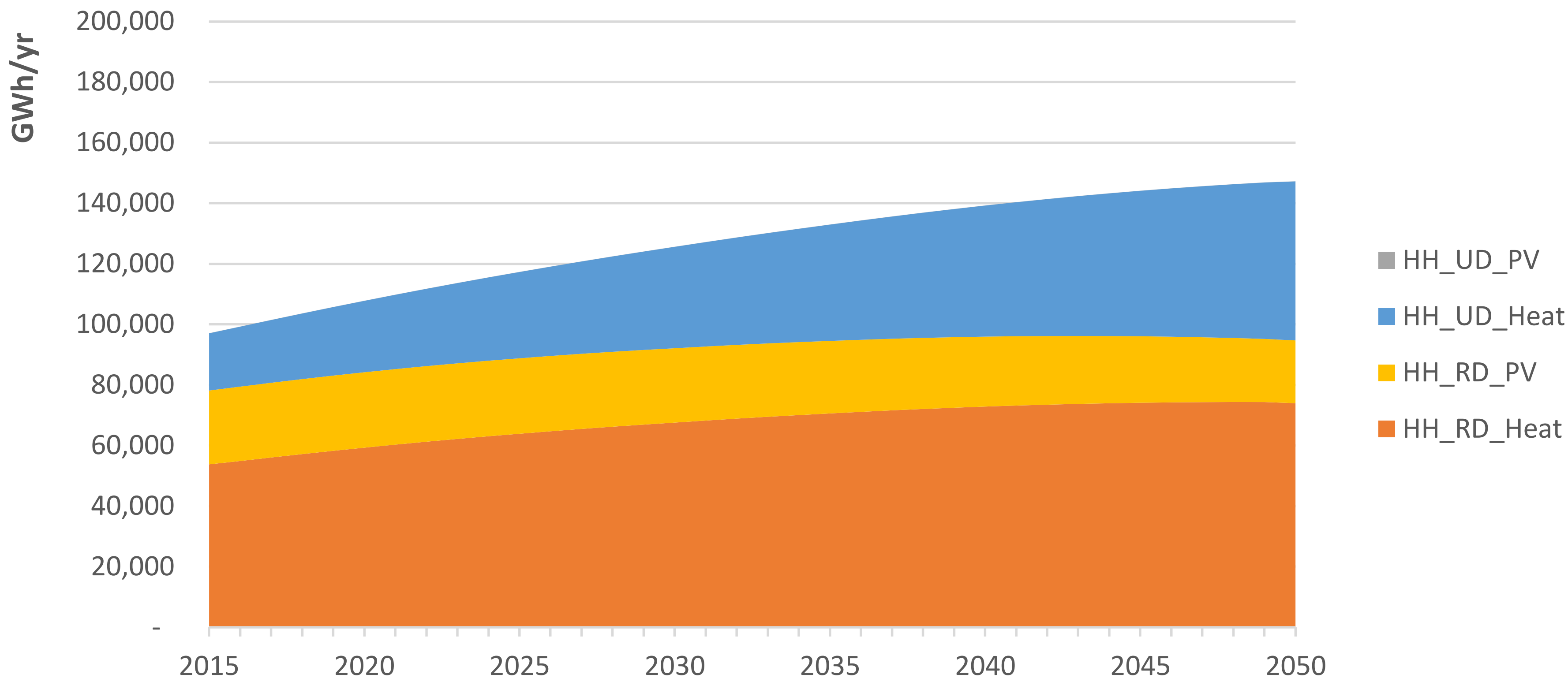
Estimates for Residential Rooftop solar PV and heat potential,

- ✓ An economy is split in urban and rural (urbanisation rate),
- ✓ Per capita floor size for urban and rural to calculate floor areas,
- ✓ Building footprints based on average floor count,
- ✓ Assume 1:1 ratio for footprint and roof area,
- ✓ Assume 10-25% of roof area is suitable for installations,
- ✓ Account for efficiency change from 2015 to 2050,
- ✓ Use average or regional insolation data,
- ✓ For max solar heat case:
  - ✓ Assume 3m2 solar water heater collector size, however requires 8m2 of roof,
  - ✓ Remaining area is covered with Solar PV with 80-90% density factor.

Note:

A trial calculation for Residential sector in Viet Nam:

- ✓ All urban areas roofs are covered by Solar Water Heaters (SWH),
- ✓ In rural areas Solar PV is 20-35%, gradually declines



Note:

Industrial solar rooftop PV and heat potential assessment

Estimates for Industrial Rooftop solar PV and heat potential,

- ✓ Industry is split into sub-sectors, as per UN ISIC,
- ✓ Individual plants with known production are assessed in sub-sectors,
  - ✓ Assessment includes Value Added/Physical Output and Buildings footprint,
- ✓ Assume 10-30% of roof area is suitable for installations,
- ✓ Calculate the Value Added/Physical Output per 1m2 of roof by sector,
- ✓ Account for efficiency change from 2015 to 2050,
- ✓ Use average or regional insolation data,
- ✓ For max solar heat case:
  - ✓ Assume solar heating installations with 80% density,
  - ✓ Assume Solar PV installation with 80-90% density.

Note:

Biomass Supply Potential

For 7th Outlook, estimates for biomass supply potential will be included covering agricultural and forestry residues and animal wastes. Initial estimates for municipal solid waste might also be considered.

- Used the FAO database for agriculture production, area harvested, livestock and forestry production

Source: Pinterest

Estimating biomass potential from agricultural residues

Projection for the total harvested area until 2050
Total Harvested Area = f (GDP, POP, Capital Stock)

↓

Assume the productivity using its historical trend
(logarithmic trend)

↓

Production by crops = Harvested area * Productivity

↓

Agriculture Residual = Production * Emission Rate (Waste)

↓

Residual Available = Agriculture Residual * Available Rate

Source: https://greenheatug.wordpress.com/page/2/

Source: biomassmagazine

Estimating biomass potential from forestry residues

Projection for forest area = f(POP, Capital Stock)

Industrial wood = f(forest area, GDP Industry)
Wood fuel = f(forest area, industrial wood)
Wood chips = f(forest area, industrial wood)

Forest Residual = Wood Production * Emission Rate (Waste)

Residual Available = Production Residual * Available Rate

Source: woodpelltesolutions.co.uk

Source: energybook.info

Estimating biomass potential from animal waste

Projection for Livestock Per Capita = f(historical trend logarithmic)

↓

Number of Livestock = livestock per capita * Population

↓

Animal Waste = Number of Livestock * Emission Rate (Waste)

↓

Animal Waste Available = Animal Waste * Available Rate

Source: woodpelltesolutions.co.uk

Source: energybook.info

Estimating biomass potential from municipal solid waste

Projection for municipal solid waste =
f(Waste per capita, POP, GDP per capita)

Available Municipal Waste = Volume of Municipal Waste * Recovery Rate

Note:

Higher recovery rate is assumed for developed economies with waste segregation policy/program.

In the case of Japan, the recovery rate is 50%.

Source: http://www.esru.strath.ac.uk/EandE/Web_sites/03-04/biomass/background%20info4.html

Source: care2.com

Renewables in Demand sectors

RE Heating & Cooling applicability assessment for APEC

The Applicability of Renewable Heating & Cooling in APEC

Demand sector	RE resource / Industry sub-sector	End-use / technology	Australia	Brunei	Canada	Chile	China	Hong Kong	Indonesia	Japan	Korea	Malaysia	Mexico	New Zealand	PNG	Peru	Philippines	Russia	Singapore	Chinese Taipei	Thailand	United States	Viet Nam
Residential	Solar thermal	Space heating	1	0	0	2	2	0	0	2	2	0	0	2	0	1	0	0	0	0	0	2	0
		Water heating	2	2	1	2	2	2	2	2	2	2	2	2	2	1	2	1	2	2	2	2	2
		Space cooling	2	2	0	0	1	2	1	1	0	1	1	0	1	0	1	0	1	1	1	1	1
	Biomass	Space heating	2	0	2	2	2	0	0	1	0	0	1	1	2	0	0	1	0	0	0	1	0
		Water heating	2	1	2	2	2	0	2	1	0	1	1	1	1	0	1	1	0	1	2	2	2
		Cooking	1	1	1	2	2	0	1	0	0	1	1	0	1	1	1	1	0	1	2	1	2
	Geothermal	Direct heat	1	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	1	0
		Heat pump	1	0	2	1	2	0	1	1	1	1	2	1	1	0	1	1	0	0	2	2	2
Services	Solar thermal	Space heating	1	0	0	2	2	0	0	2	1	0	1	2	0	0	0	0	0	0	0	2	0
		Water heating	2	2	1	2	2	2	2	2	0	2	2	2	2	1	2	1	2	2	2	2	2
		Space cooling	2	2	0	0	0	1	1	1	0	1	1	0	1	0	1	0	2	1	1	1	1
	Biomass	Space heating	2	0	2	2	2	0	0	1	0	0	0	1	0	0	1	1	0	0	2	1	2
		Water heating	2	1	2	2	2	1	2	1	0	1	1	1	2	0	2	1	1	1	2	2	2
	Geothermal	Direct heat	1	0	0	0	0	0	2	1	0	2	0	0	0	0	1	0	0	0	0	1	0
		Heat pump	1	0	2	1	2	0	1	1	0	1	2	1	1	1	1	1	0	0	2	2	2
Industry	Solar thermal	Low-temp heat	2	2	1	2	2	2	2	2	0	2	2	1	2	2	2	1	2	2	2	2	2
		Med-temp heat	2	2	0	2	1	2	2	1	0	2	1	0	2	1	2	0	1	1	1	1	1
		Hi-temp heat	2	1	0	2	1	1	1	0	0	1	0	0	1	1	1	0	0	1	1	1	0
	Biomass	Low-temp heat	2	1	2	2	2	0	2	1	0	2	1	1	2	2	2	1	0	0	2	1	2
		Med-temp heat	2	1	2	2	2	0	2	1	0	2	1	1	2	2	2	1	0	0	2	1	2
		Hi-temp heat	2	1	2	2	2	0	2	1	0	2	0	0	2	0	2	0	0	0	2	1	2
	Geothermal	Low-temp heat	1	0	1	0	1	0	1	2	0	1	1	1	1	0	1	0	0	0	1	2	1
		Med-temp heat	1	0	0	1	0	0	2	1	0	2	0	1	0	0	1	1	0	0	0	1	0

0 there is no technical potential

1 there is technical potential, but demand and policy support is weak

2 there is technical potential, and demand or policy support is strong

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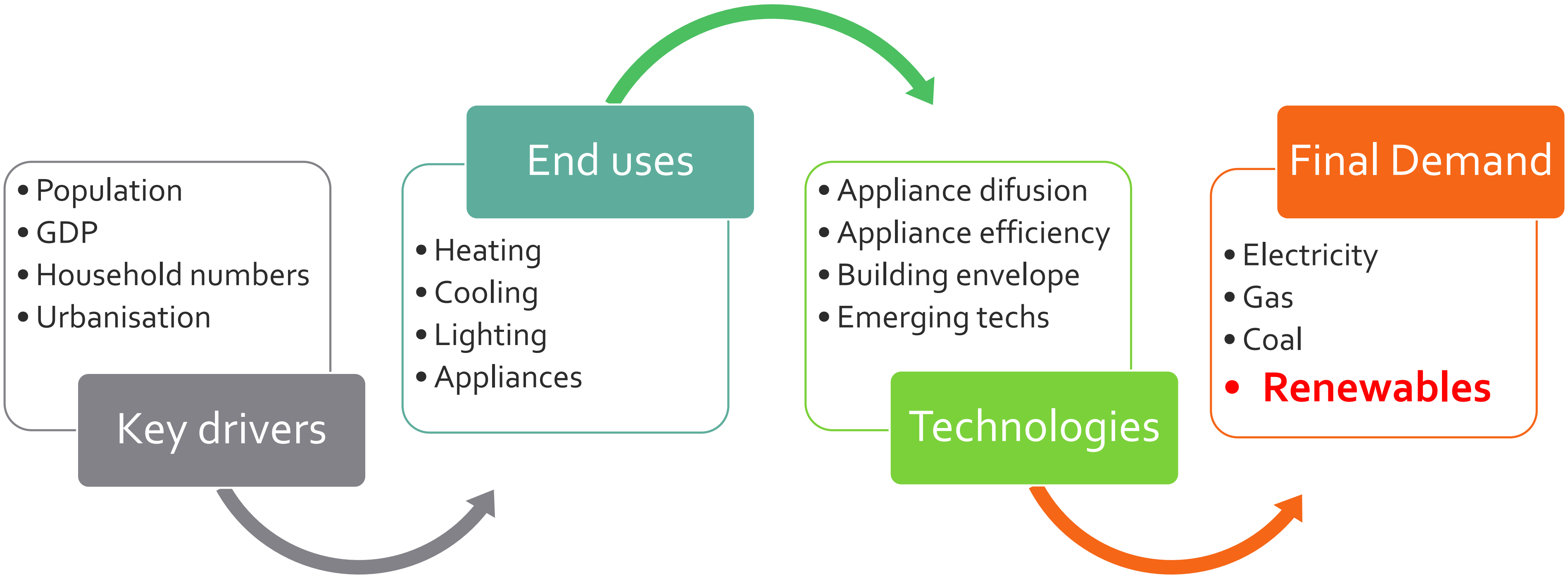
Renewables for Buildings (residential) (1)



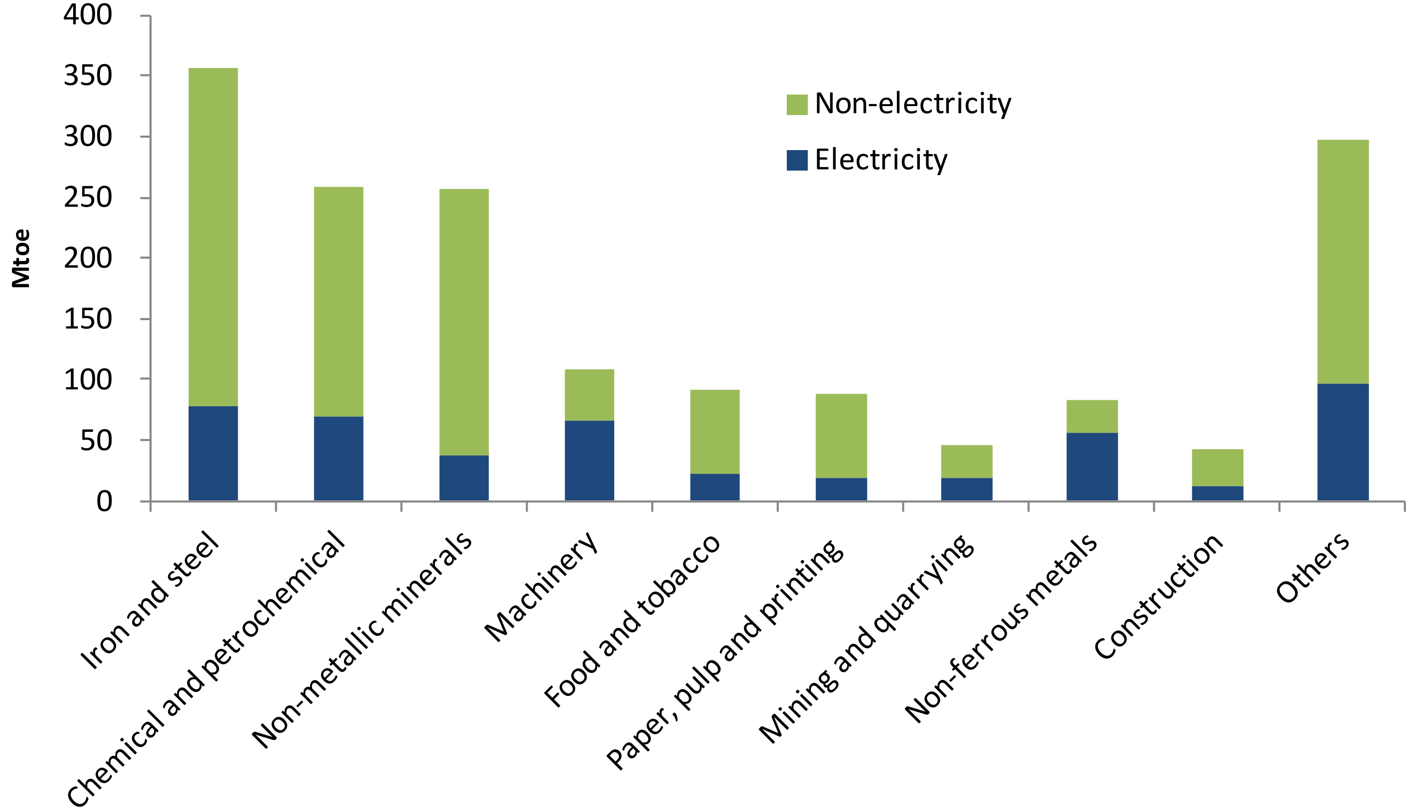
Technology/fuel mix in 2050?

- ✓ Consumer choice (logit) and stock dynamic modelling,
- ✓ Manual share assignment, based on literature review and expert opinions

Renewables for Industry: sub-sectoral analysis

Sub-sector	Temperature approach	Process approach
Chemical and petrochemical	• Using EU27 survey by IEA, • Low and mid temperature demand, • Applied to new installations	N/A
Non-metallic minerals	• Using EU27 survey by IEA, • Technically, RE could supply 100%,	• To be updated with detailed numbers on clinker production,
Machinery	• Using EU27 survey by IEA, • Low and mid temperature demand	N/A
Food and tobacco	• Using EU27 survey by IEA, • Low and mid temperature demand, • Geothermal heat pump for refrigeration (TBU)	N/A
Paper, pulp and printing	• Using EU27 survey by IEA, • Underestimates with increased efficiency / updated reporting,	• Using FAO production data, • Includes 9 processes in total
Others	• Using EU27 survey by IEA, • Low and mid temperature demand	N/A

Renewables for Industry: Japan's case



- A substantial part of energy demand is in the form of heat

Renewables for Power

Renewables for Power: Technology data

- ✓ **Increased number of technologies,**
- ✓ **Substantial data collection activity: IRENA, IEA, IEA PVPS, grid operators, economies, etc.**
- ✓ **Grid modelling capability development**

Renewables for Power: Assumptions

Renewables assumptions for **RESIDENTIAL** & **COMMERCIAL BUILDINGS** & **POWER** in **20_USA**		Indicator	Unit	2015	BAU 2020	BAU 2030	BAU 2040	BAU 2050	BAU 2015-2050,%	APEC Targets 2020	APEC Targets 2030	APEC Targets 2040	APEC Targets 2050	APEC Targets 2015-2050,%	Comments
POWER GENERATION															
Hydro	Large hydro	CAPEX	$/kW	2,411	2,411	2,411	2,411	2,411	0.0%	2,411	2,411	2,411	2,411	0.0%	Avg. size: 500MW
		OPEX	$/kW/yr.	24	24	24	24	24	0.0%	24	24	24	24	0.0%	
		Capacity factor	%	42.6%	42.7%	42.7%	42.8%	42.8%	na	42.7%	43.0%	43.2%	43.2%	na	
	Medium hydro	CAPEX	$/kW	3,020	3,020	3,020	3,020	3,020	0.0%	3,020	3,020	3,020	3,020	0.0%	
		OPEX	$/kW/yr.	44	44	44	44	44	0.0%	44	44	44	44	0.0%	
		Capacity factor	%	50.0%	50.0%	50.0%	50.0%	50.0%	n/a	50.0%	50.0%	50.0%	50.0%	n/a	
	Small hydro	CAPEX	$/kW	3,620	3,620	3,620	3,620	3,620	0.0%	3,620	3,620	3,620	3,620	0.0%	
		OPEX	$/kW/yr.	73	73	73	73	73	0.0%	73	73	73	73	0.0%	
		Capacity factor	%	88.0%	88.0%	88.0%	88.0%	88.0%	n/a	88.0%	88.0%	88.0%	88.0%	n/a	
Wind	Wind onshore	CAPEX	$/kW	1,644	1,630	1,600	1,560	1,530	-0.2%	1,600	1,500	1,410	1,330	-0.6%	Avg. size: 100MW
		OPEX	$/kW/yr.	46	46	46	46	46	0.0%	46	46	46	46	0.0%	
		Capacity factor	%	32.7%	33.2%	34.2%	35.0%	35.0%	n/a	34.0%	35.9%	37.5%	37.5%	n/a	
	Wind offshore	CAPEX	$/kW	6,331	6,170	5,870	5,590	5,310	-0.5%	6,080	5,610	5,180	4,780	-0.8%	Avg. size: 400MW
		OPEX	$/kW/yr.	76	76	76	76	76	0.0%	76	76	76	76	0.0%	
		Capacity factor	%	37.7%	38.2%	39.2%	40.0%	40.0%	n/a	39.4%	41.8%	44.0%	44.0%	n/a	
Solar	Solar PV: Residential	CAPEX	$/kW	3,690	3,460	3,030	2,660	2,330	-1.3%	3,400	2,900	2,470	2,100	-1.6%	Avg. size: up to 20kW
		OPEX	$/kW/yr.	32	32	32	32	32	0.0%	32	32	32	32	0.0%	
		Capacity factor	%	11.2%	11.4%	12.0%	12.5%	12.5%	n/a	11.8%	12.9%	14.0%	14.0%	n/a	
	Solar PV: Commercial	CAPEX	$/kW	3,090	2,890	2,540	2,230	1,950	-1.3%	2,850	2,430	2,060	1,760	-1.6%	Avg. size: up to 1MW
		OPEX	$/kW/yr.	27	27	27	27	27	0.0%	27	27	27	27	0.0%	
		Capacity factor	%	12.2%	12.4%	13.0%	13.5%	13.5%	n/a	12.8%	13.8%	14.8%	14.8%	n/a	
	Solar PV: Utility	CAPEX	$/kW	2,480	2,320	2,040	1,790	1,570	-1.3%	2,290	1,950	1,660	1,410	-1.6%	Avg. size: 150MW
		OPEX	$/kW/yr.	21	21	21	21	21	0.0%	21	21	21	21	0.0%	
		Capacity factor	%	13.2%	13.4%	14.0%	14.5%	14.5%	n/a	13.7%	14.6%	15.5%	15.5%	n/a	
	Concentrated Solar Power	CAPEX	$/kW	4,168	3,940	3,530	3,160	2,830	-1.1%	3,880	3,370	2,930	2,540	-1.4%	Avg. size: 100MW
		OPEX	$/kW/yr.	69	69	69	69	69	0.0%	69	69	69	69	0.0%	
		Capacity factor	%	28.2%	28.4%	29.0%	29.5%	29.5%	n/a	29.8%	32.2%	34.5%	34.5%	n/a	
Bioenergy	Solid biomass	CAPEX	$/kW	3,765	3,765	3,765	3,765	3,765	0.0%	3,710	3,600	3,490	3,390	-0.3%	Avg. size: 50MW
		OPEX	$/kW/yr.	141	141	141	141	141	0.0%	141	141	141	141	0.0%	
		Capacity factor	%	68.2%	68.2%	68.2%	68.2%	68.2%	n/a	68.2%	68.2%	68.2%	68.2%	n/a	
	Liquid biofuels	CAPEX	$/kW						-					-	
		OPEX	$/MWh						-					-	
		Capacity factor	%	14%	14%	14%	14%	14%	n/a	14%	14%	14%	14%	n/a	
	Biogas	CAPEX	$/kW	1,960	1,960	1,960	1,960	1,960	0.0%	1,930	1,860	1,800	1,740	-0.3%	
		OPEX	$/kW/yr.	111	111	111	111	111	0.0%	111	111	111	111	0.0%	
		Capacity factor	%	64.8%	64.8%	64.8%	64.8%	64.8%	n/a	64.8%	64.8%	64.8%	64.8%	n/a	
Geothermal		CAPEX	$/kW	2,687	2,687	2,687	2,687	2,687	0.0%	2,630	2,530	2,430	2,340	-0.4%	Avg. size: 50MW
		OPEX	$/kW/yr.	116	116	116	116	116	0.0%	116	116	116	116	0.0%	
		Capacity factor	%	60.4%	60.4%	60.4%	60.4%	60.4%	n/a	60.4%	60.4%	60.4%	60.4%	n/a	
Marine		CAPEX	$/kW						-					-	
		OPEX	$/MWh						-					-	
		Capacity factor	%						n/a					n/a	

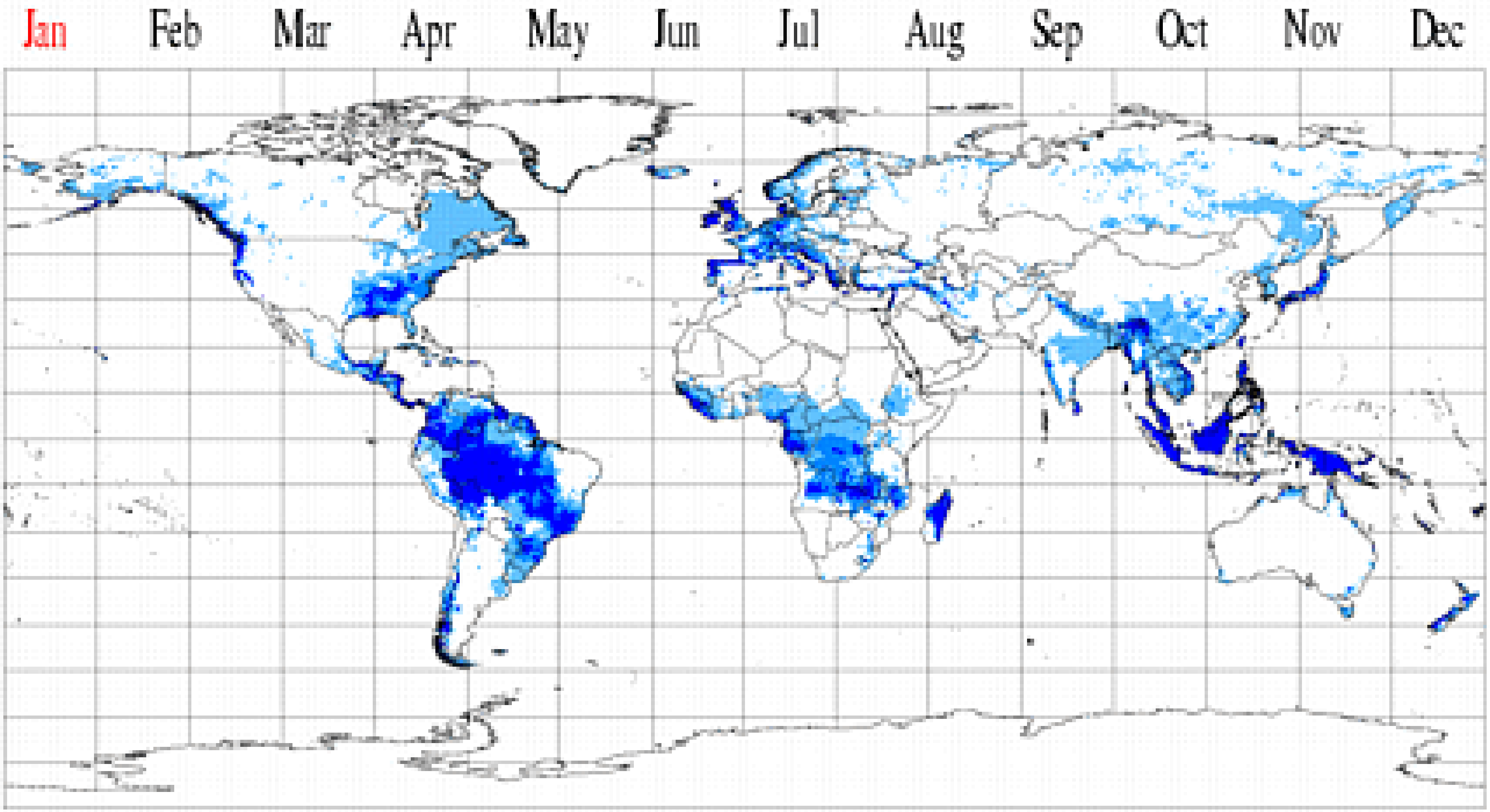
Discussion

Points for discussion

- ✓ **How to design scenarios to help inform the Roadmap and avoid overlapping?**
- ✓ **RE resource/technical/economical potential uncertainty,**
- ✓ **Technology/fuel shares/costs uncertainty,**
- ✓ **RE policy long-term analysis.**

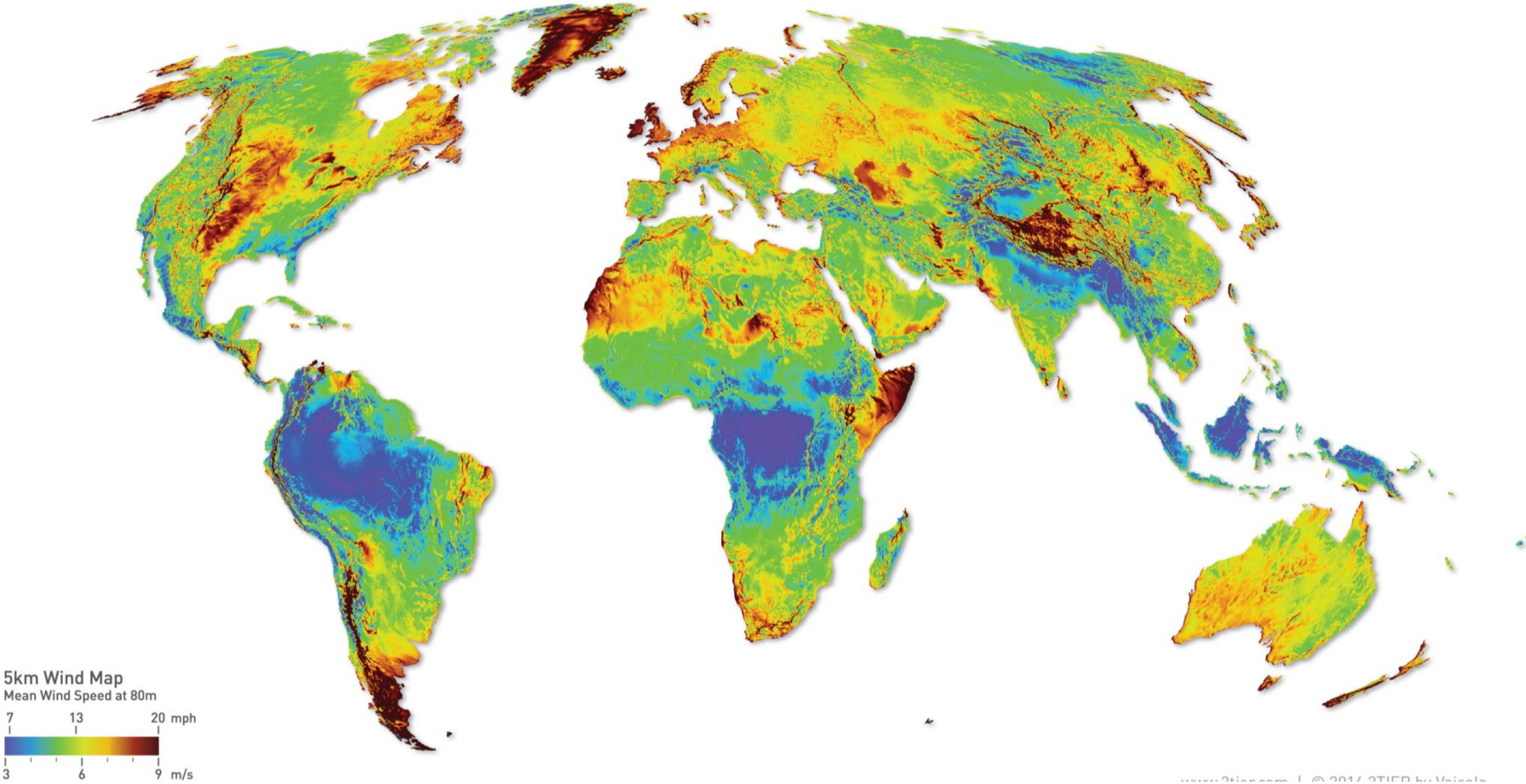
Hydro (resource availability)

Mean Monthly Runoff animation



Source: UNH/GRDC 2000.

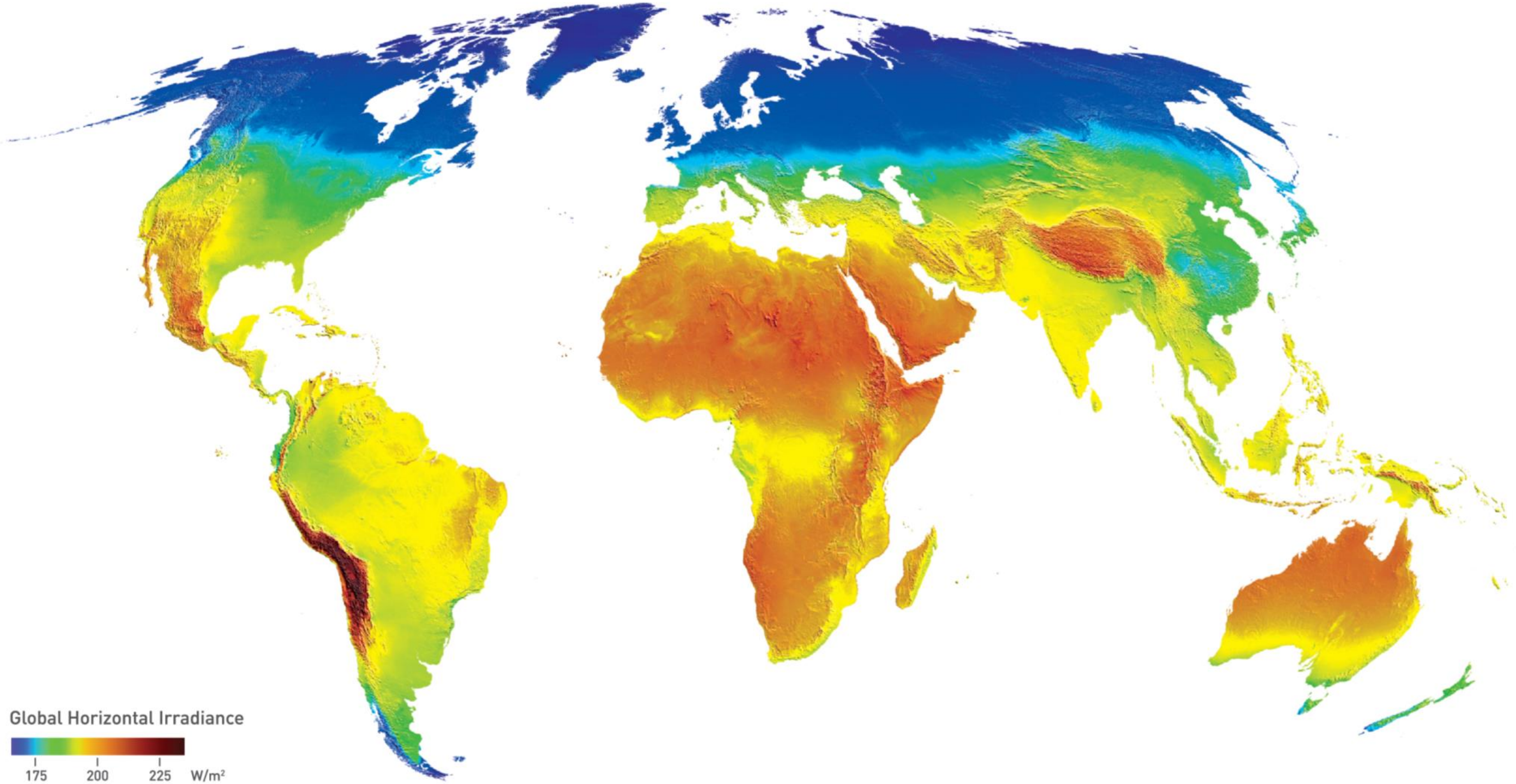
Global Mean Wind Speed at 80m



Source: Vaisala 2014.

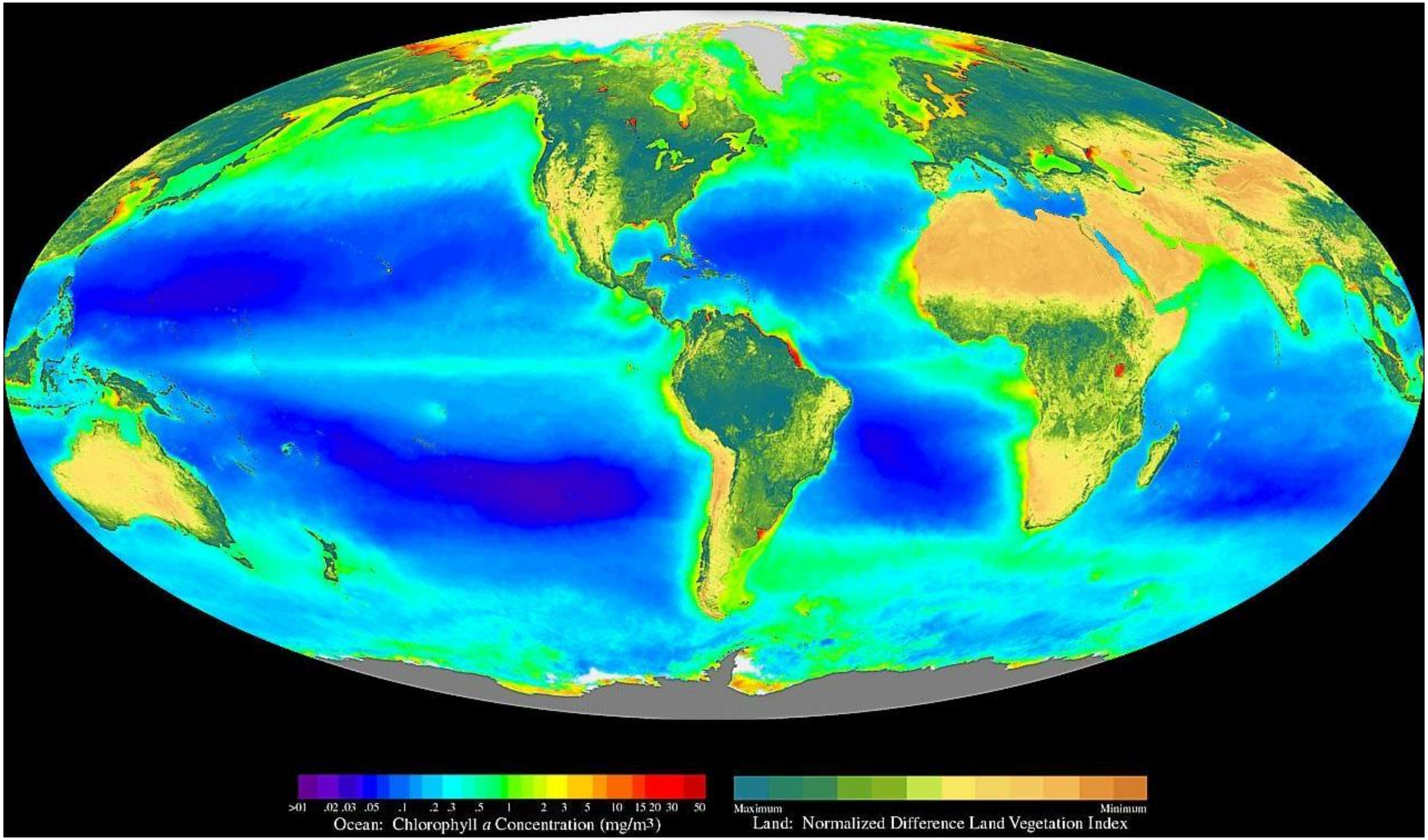
Solar PV (resource availability)

Global Mean Solar Irradiance



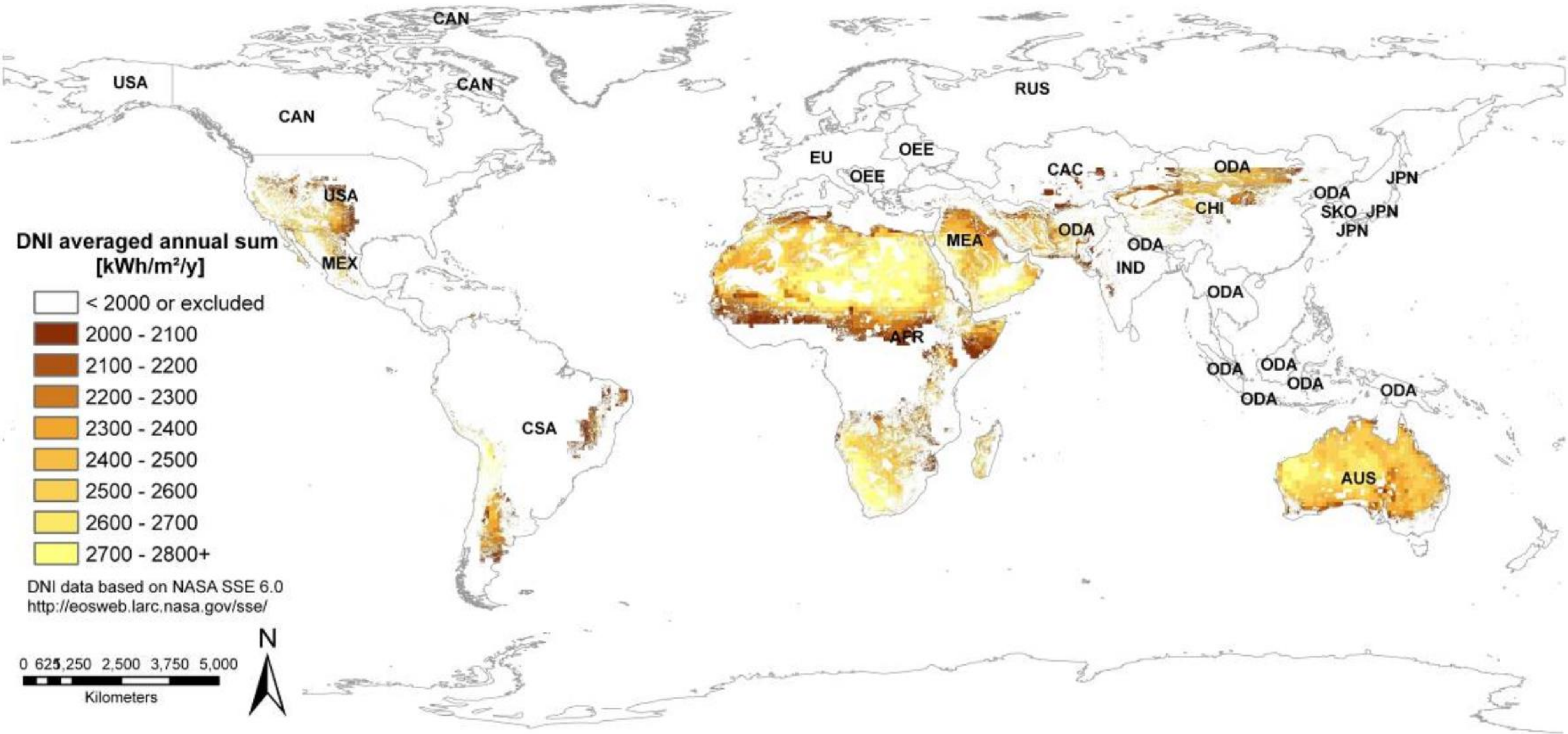
Source: Vaisala 2014.

Global terrestrial and oceanic biomass



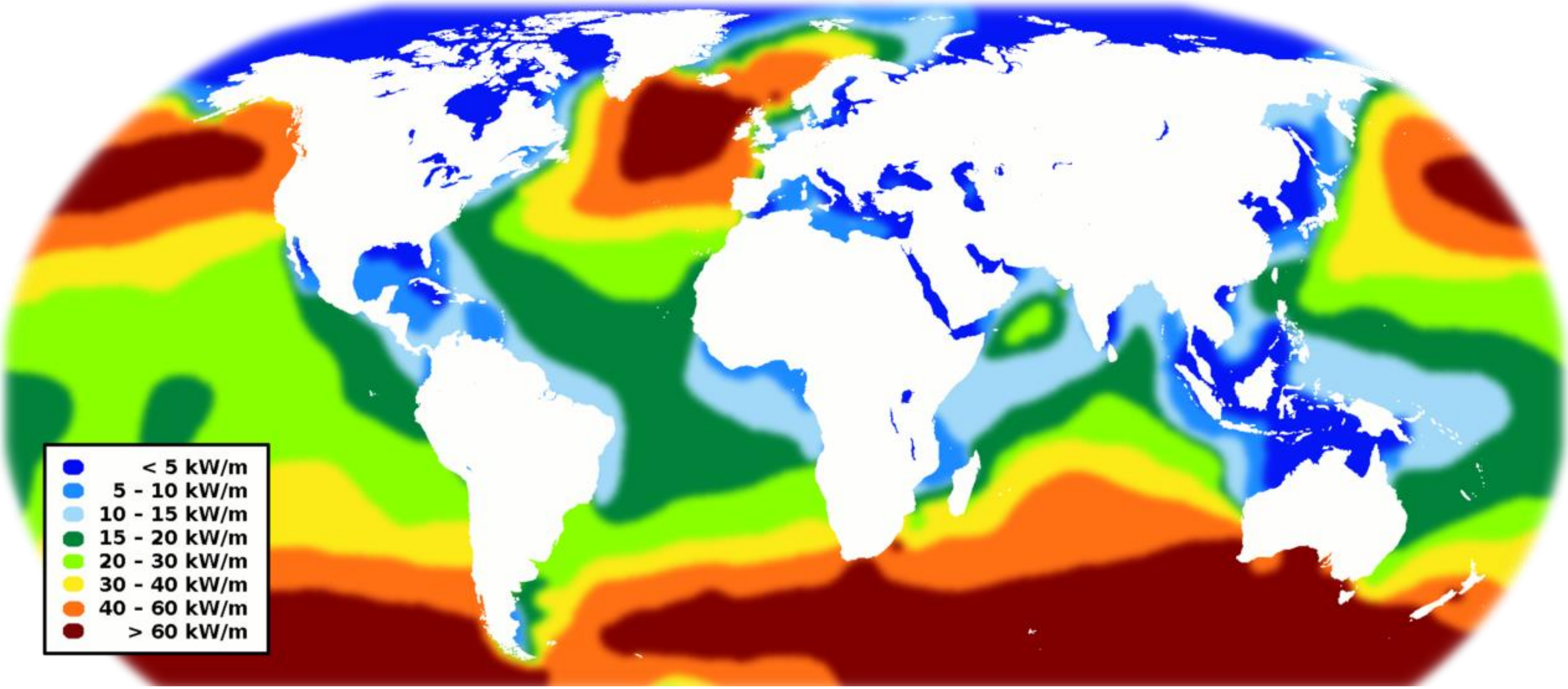
Source: NASA 2000.

Annual direct solar radiation for suitable sites



Source: Trieb et al. 2009.

Tidal and wave resource map



Source: NEU 2015.

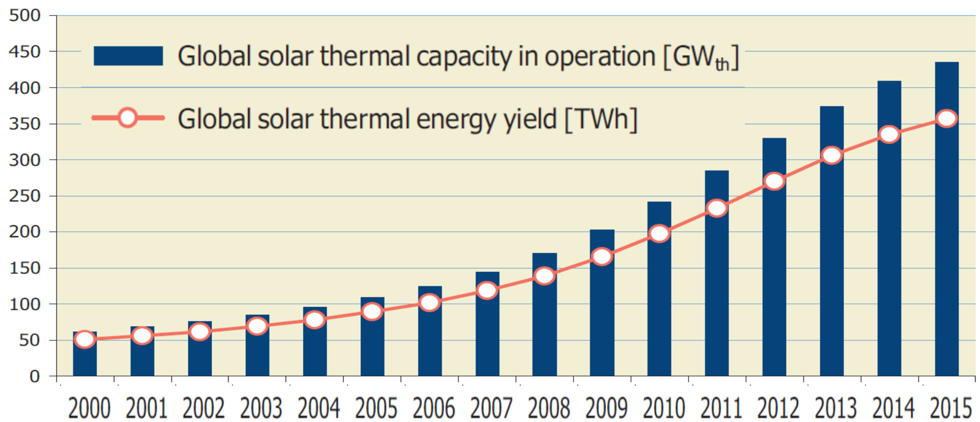
RE in BAU and High Renewables Scenarios in EDSO6

BAU	High Renewables
Current policies are maintained	Policies to support higher share of renewables are introduced
Energy demand follows historical trend	Energy demand is the same as BAU
Renewable capacity additions follow historical trend + current legislation	Renewable capacity additions include all announced targets + goals
Modest RE CAPEX reduction	Accelerated RE CAPEX reduction
Modest RE average capacity factor improvement	Accelerated RE average capacity factor improvement

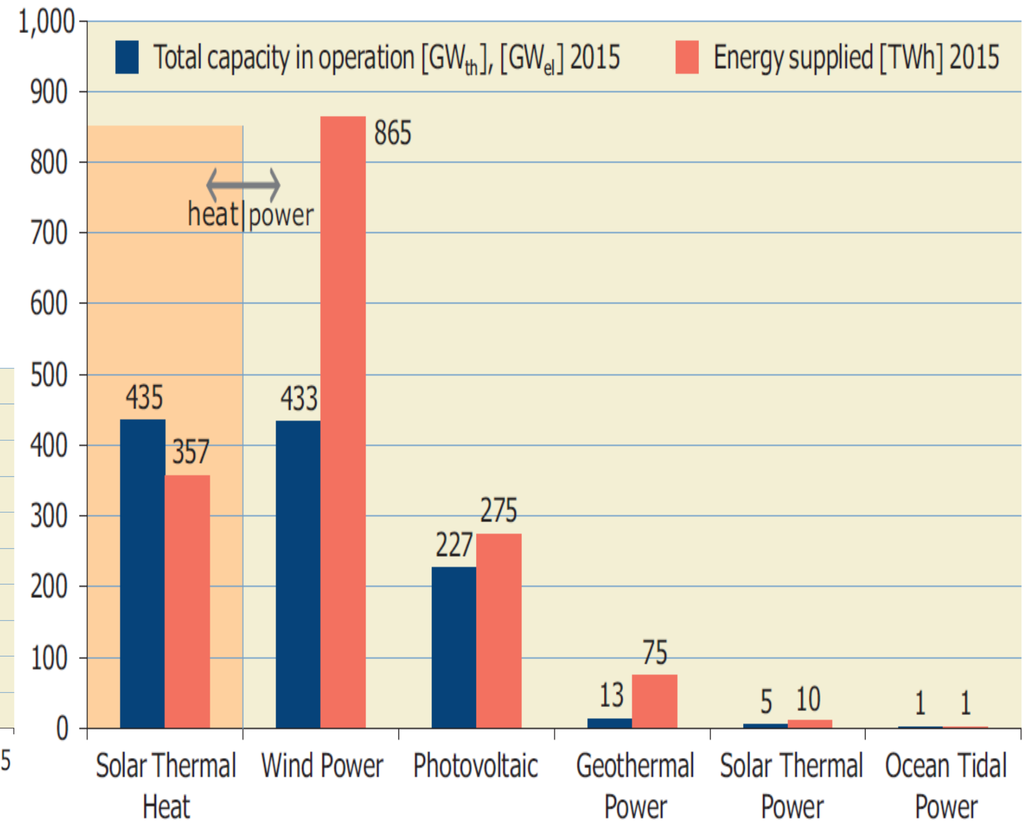
- ✓ Other demand sectors, i.e. Buildings, Industry left untouched,
- ✓ Heating & cooling component was excluded
- ✓ Biofuels are limited to 1st generation

Global Solar Thermal development

Global solar thermal capacity in operation and annual energy yields 2000–2015

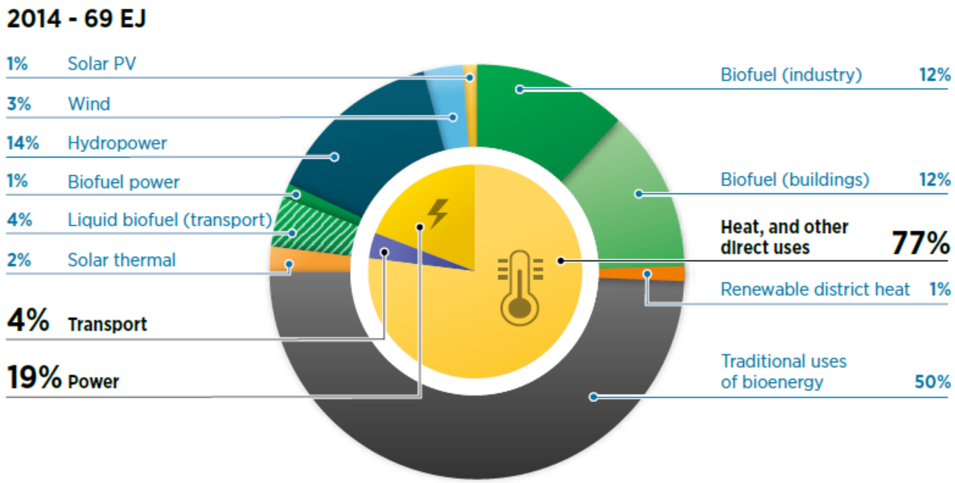


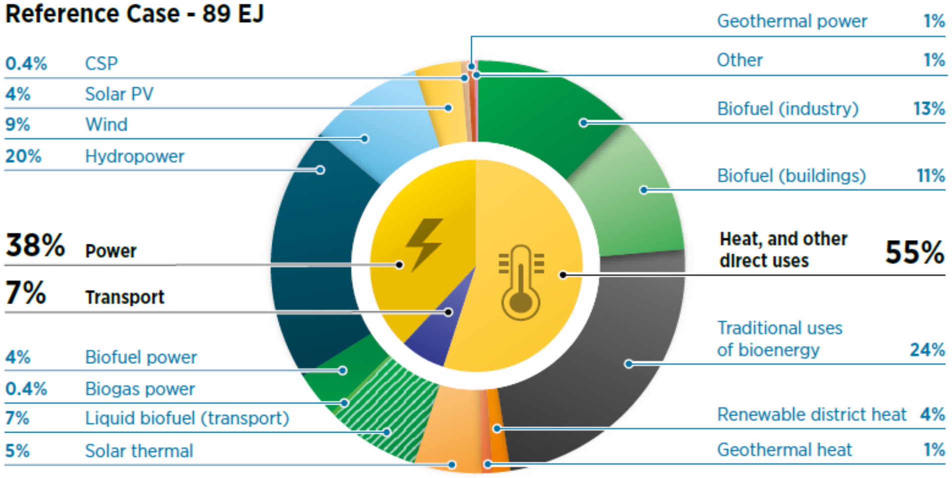
Global capacity in operation 2015 and annual energy yields



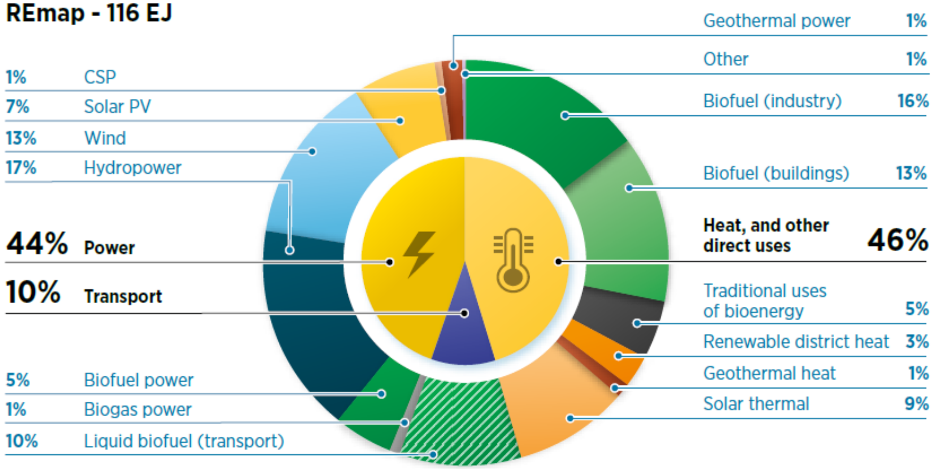
Global solar thermal capacity is nearing 450 GW$_{th}$,
Significant potential for future development

RE Heating & Cooling: IRENA's REmap 2030





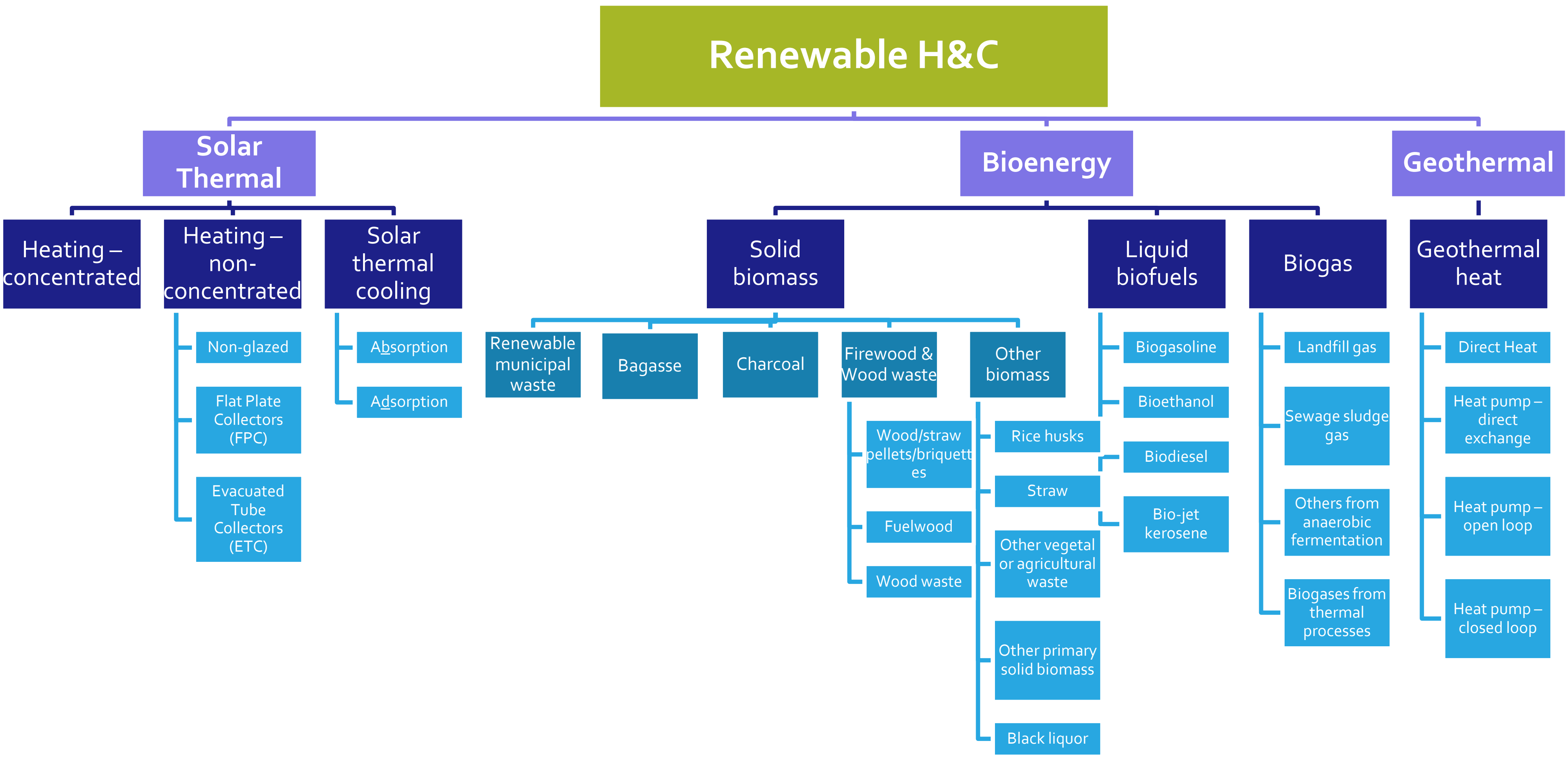
Mtoe	2014	Ref. 2030	REmap 2030
Heat and other direct uses	1,270	1,170	1,275
Solar thermal	33	106	249
Traditional biomass	824	510	139



Strong growth of Solar thermal, Geothermal and Modern biomass with decline in Traditional biomass

Source: IRENA (2016)

Renewable technologies for Heating & Cooling



Note: RE technology breakdown is partially based on the new data collection format proposed by ESTO/EGEDA.

REH&C project introduction

In APEC Energy Demand and Supply 6th Edition we said:

- *"Further modelling would be necessary to assess the renewable potential for heating and cooling applications in industry and buildings"*

Now 1-year-long joint APERC-IEEJ project is underway.

Objectives:

- assess data availability for REH&C: all 21 APEC economies,
- assess maximum supply potential of RE suitable for Heating & Cooling applications:
  - ✓ in China, Russia, the United States, Japan, Chile, New Zealand, Thailand and the Philippines,
  - ✓ For Solar thermal (rooftop / utility), Geothermal (direct / heat pumps), Biomass: gas/liquid/solid,
- assess maximum deployment potential of RE Heating & Cooling in:
  - ✓ Buildings: Residential and Commercial,
  - ✓ Industry: Chemical & Petrochemical, Non-metallic minerals, Machinery, Food & Tobacco, Paper, Pulp & Printing, Textile & Leather, Others (non-specified),
- develop the methodology to evaluate the economic viability of RE for heating and cooling in APEC,
- enhance the RE model to be used for the 7th Outlook (planned for 2019).

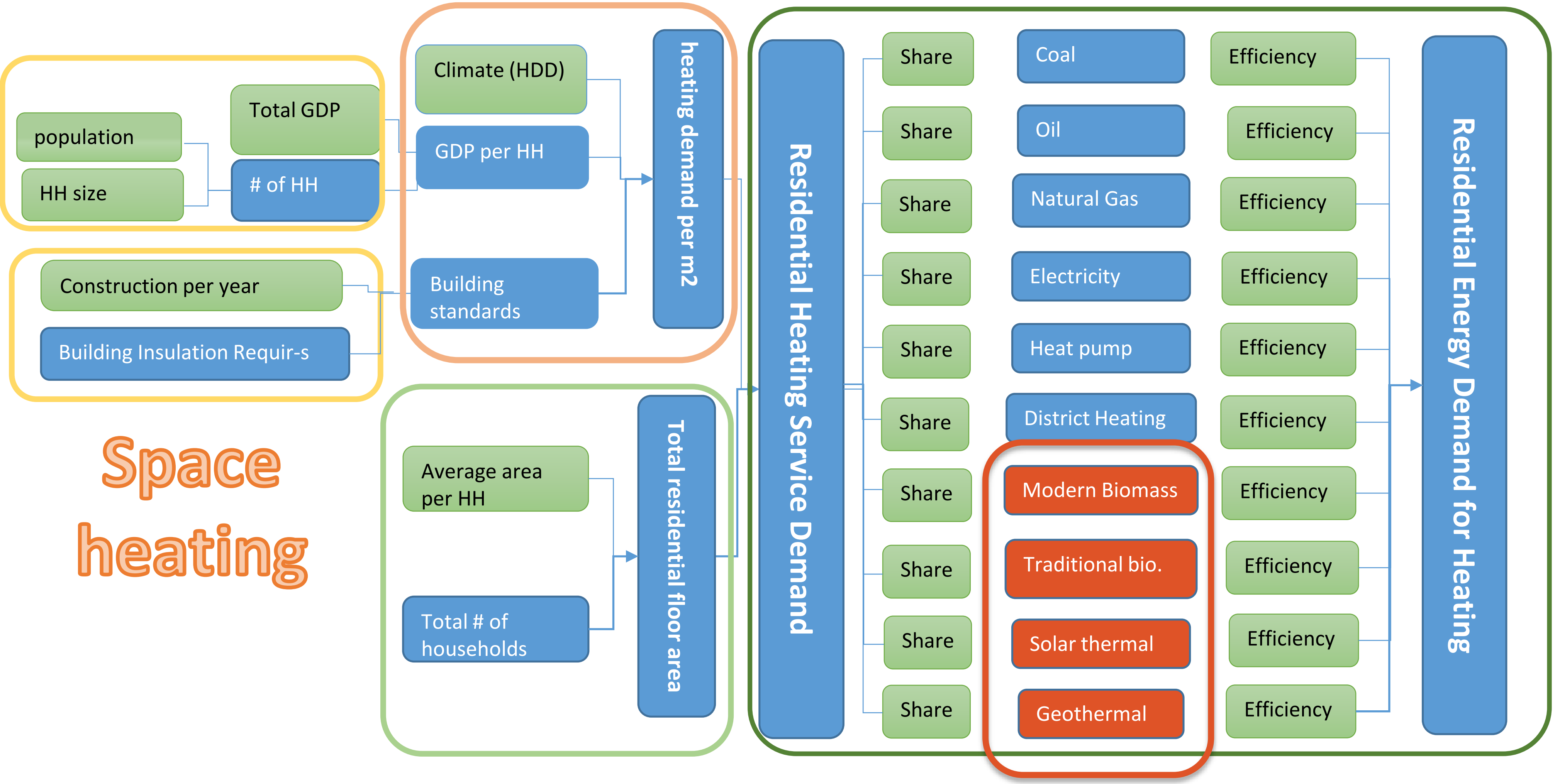
Note: APERC (2016).

RE Heating & Cooling technology vs end-use Matrix (draft)

The Technology vs End-Use Matrix for Renewable Heating & Cooling in APEC (draft)

RE resource	Application / resource type	Technology	Residential: Space heating	Residential: Water heating	Residential: Space cooling	Residential: Cooking	Services: Space heating	Services: Water heating	Services: Space cooling	District Heating & Cooling	Industry overall: low-temp heat	Industry overall: med-temp heat	Industry overall: hi-temp heat	Non-metallic minerals: low-temp heat	Non-metallic minerals: med-temp heat	Non-metallic minerals: hi-temp heat	Paper, pulp and printing: low-temp heat	Paper, pulp and printing: med-temp heat	Paper, pulp and printing: hi-temp heat	Chemical and petrochemi: low-temp heat	Chemical and petrochemi: med-temp heat	Chemical and petrochemi: hi-temp heat	Machinery: low-temp heat	Machinery: med-temp heat	Machinery: hi-temp heat	Food and tobacco: low-temp heat	Food and tobacco: med-temp heat	Food and tobacco: hi-temp heat	Others: low-temp heat	Others: med-temp heat	Others: hi-temp heat
Solar Thermal	Heating	Non-glazed	☆	★	☆	☆	½	★	☆	☆	½	☆	☆	½	☆	☆	½	☆	☆	½	☆	☆	½	☆	☆	½	☆	☆	½	☆	☆
		Flat Plate Collectors (FPC)	★	★	☆	☆	★	★	☆	☆	½	☆	☆	½	☆	☆	½	☆	☆	½	☆	☆	½	☆	☆	½	☆	☆	½	☆	☆
		Evacuated Tube Collectors (ETC)	★	★	☆	☆	★	★	☆	☆	½	½	☆	½	½	☆	½	½	☆	½	½	☆	½	½	☆	½	½	☆	½	½	☆
		Concentrated	½	½	☆	☆	½	½	☆	½	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Cooling	Open-loop	☆	☆	½	☆	☆	☆	½	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆
		Closed-loop	☆	☆	½	☆	☆	☆	½	½	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆
Biomass	Solid biomass	Biomass boiler	☆	★	☆	☆	★	★	☆	½	½	½	☆	½	½	☆	½	½	☆	½	½	☆	½	½	☆	½	½	☆	½	½	☆
		Combined Heat & Power (CHP)	½	½	☆	☆	★	★	☆	★	½	½	☆	½	½	☆	½	½	☆	½	½	☆	½	½	☆	½	½	☆	½	½	☆
		Cement kiln	▨	▨	▨	▨	▨	▨	▨	▨	☆	☆	½	☆	☆	½	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆	☆
		Cook stoves	☆	☆	☆	★	☆	☆	☆	☆	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
		Open fire	★	☆	☆	☆	☆	☆	☆	☆	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
		Closed fire	★	½	☆	☆	☆	☆	☆	☆	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
	Biogas	Combined Heat & Power (CHP)	½	½	☆	☆	½	½	☆	★	½	½	☆	½	½	☆	½	½	☆	½	½	☆	½	½	☆	½	½	☆	½	½	☆
Geothermal	Direct heat	Direct heat exchange	½	½	☆	☆	½	½	☆	½	☆	☆	▨	☆	☆	▨	☆	☆	▨	☆	☆	▨	☆	☆	▨	☆	☆	▨	☆	☆	▨
	Heat pump	Open loop	★	★	½	☆	★	★	½	½	☆	☆	▨	☆	☆	▨	☆	☆	▨	☆	☆	▨	☆	☆	▨	☆	☆	▨	☆	☆	▨
		Closed loop	★	★	½	☆	★	★	½	★	½	☆	▨	½	☆	▨	½	☆	▨	½	☆	▨	½	☆	▨	½	☆	▨	½	☆	▨

Renewables for Buildings (residential) (2)



RE in Demand sectors: Assumptions

✓ Engaging the economy experts to review and comment our modelling assumptions

Renewables assumptions for **RESIDENTIAL** & **COMMERCIAL BUILDINGS** & **POWER** in **20_USA**		Indicator	Unit	2015	BAU					Comments
					2020	2030	2040	2050	2015-2050,%	
RESIDENTIAL BUILDINGS										
Solar Thermal	Water heating	CAPEX	$	3,300	3,000	2,600	2,600	2,600	-0.7%	Avg. size: 2m^2, 200L
		Solar factor	SF	2.5	3.0	3.5	3.5	3.5	n/a	
Bioenergy	2015 Tech-Econ. potential and future market uptake		TWh, %						n/a	
	Solid biomass boiler: Space & Water heating	CAPEX	$	4,700	4,900	5,100	5,300	5,500	0.5%	Avg. size: 36kBTU/h = 10.5kW
		Fuel cost	$/t	245	250	260	270	280	0.4%	
		Efficiency	%	78%	80%	81%	83%	84%	n/a	
	Biogas boiler: Space & Water heating	CAPEX	$	4,050	5,900	5,900	5,900	5,900	1.1%	Avg. size: 36kBTU/h = 10.5kW
		Fuel cost	$/1,000m^3	150	160	170	180	190	0.7%	
		Efficiency	%	82%	90%	90%	90%	90%	n/a	
Geothermal	Ground source heat pump: Space heating & cooling & Water heating	CAPEX	$	12,500	17,500	17,500	17,500	17,500	1.0%	Avg. size: 36kBTU/h = 10.5kW, EER is [kBTU/h / kWh]
		Efficiency heating	COP	3.2	3.6	3.8	4.0	4.2	n/a	
		Efficiency cooling	EER	14.2	17.1	21.0	24.0	26.0	n/a	