Wind power energy from AIM point of view

Shinichiro Fujimori
D. H. Silva, H. Dai, T. Masui
National Institute for Environmental Studies (NIES)
CCI/IA workshop, @Snowmass Colorado
Jul. 22th, 2013

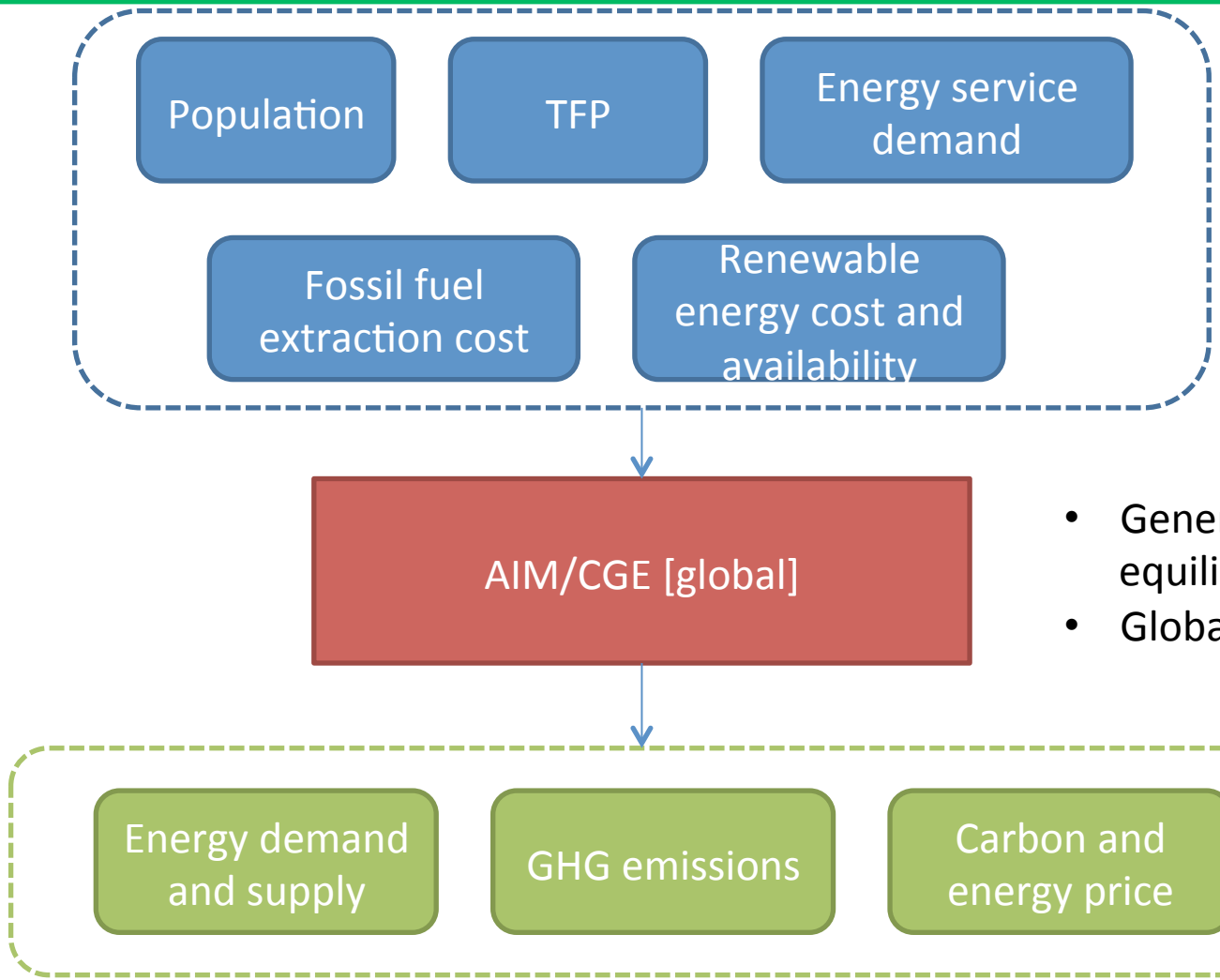
Outline

- AIM scenario exercise results
  - AIM modeling approach
  - Scenario results of the wind power
- Resource assessment
  - Why do we have different resource amount?
  - Suggestions for the next steps

1st topic

- AIM scenario exercise results

AIM modeling framework



- General equilibrium model
- Global 17 regions

How to model the power system

- Logit function is used to determine power supply share by energy sources
  - Integration cost is included in the wind and PV generation cost
- Similar to GCAM or previous SGM approach

$$Share\ of\ EnergySource_i = \frac{\beta_i \left(Producer\ \ price_i \right)^{\rho_i}}{\sum_{ii \in I} \beta_{ii} \left(Producer\ \ price_{ii} \right)^{\rho_{ii}}}$$

The crucial assumption

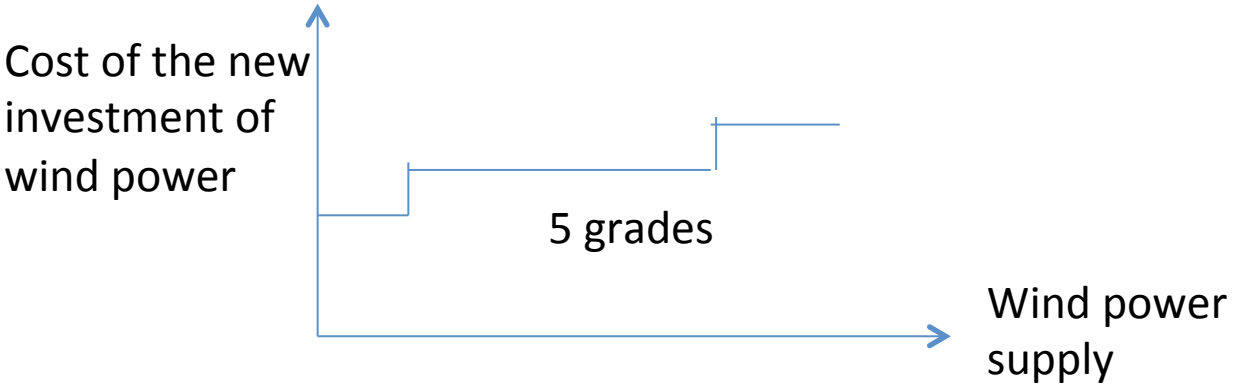
- The scale parameter is equalized in 2050 among renewable energy with current fossil fired power
  - If the price of each power is equal → the share would be same in 2050
  - Nuclear and Hydro are exception

$$Share\ of\ EnergySource_i = \frac{\beta_i \left(Producer\ \ price_i \right)^{\rho_i}}{\sum_{ii \in I} \beta_{ii} \left(Producer\ \ price_{ii} \right)^{\rho_{ii}}}$$

How we treat the wind power data

- NREL provides 30 classifications
  - 10 Capacity Factor * 3 distances

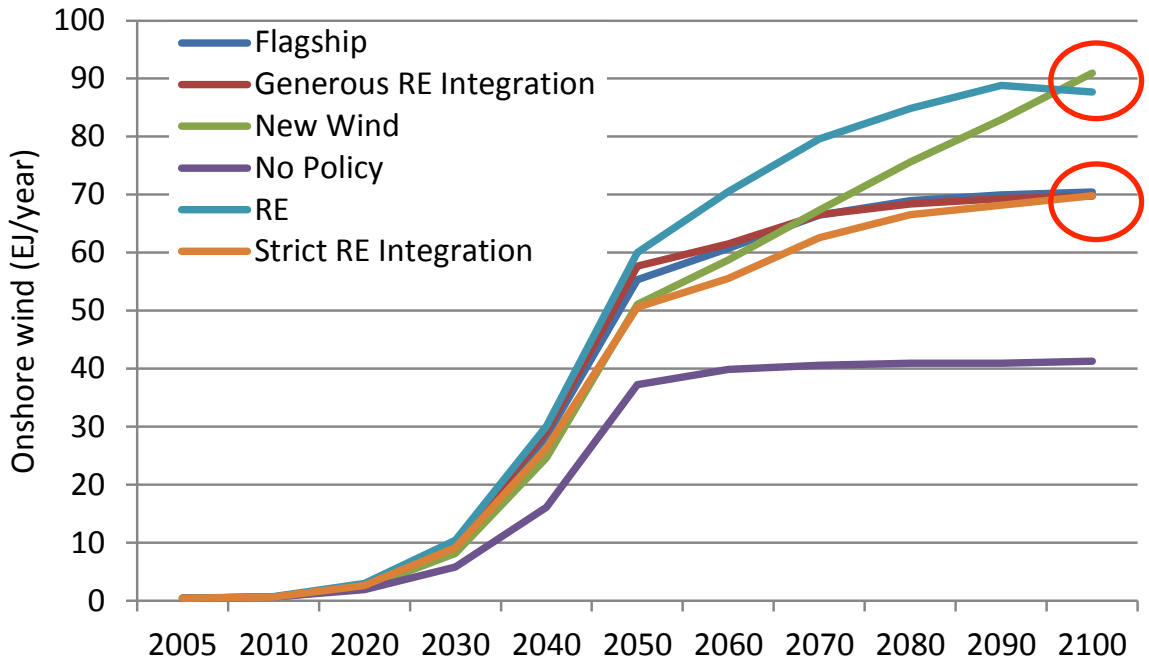
- We reclassified and simplified into 5 grades for the model implementation.
  - According to the cost order.
  - The new investment cost is corresponding to that curve



Scenario setting

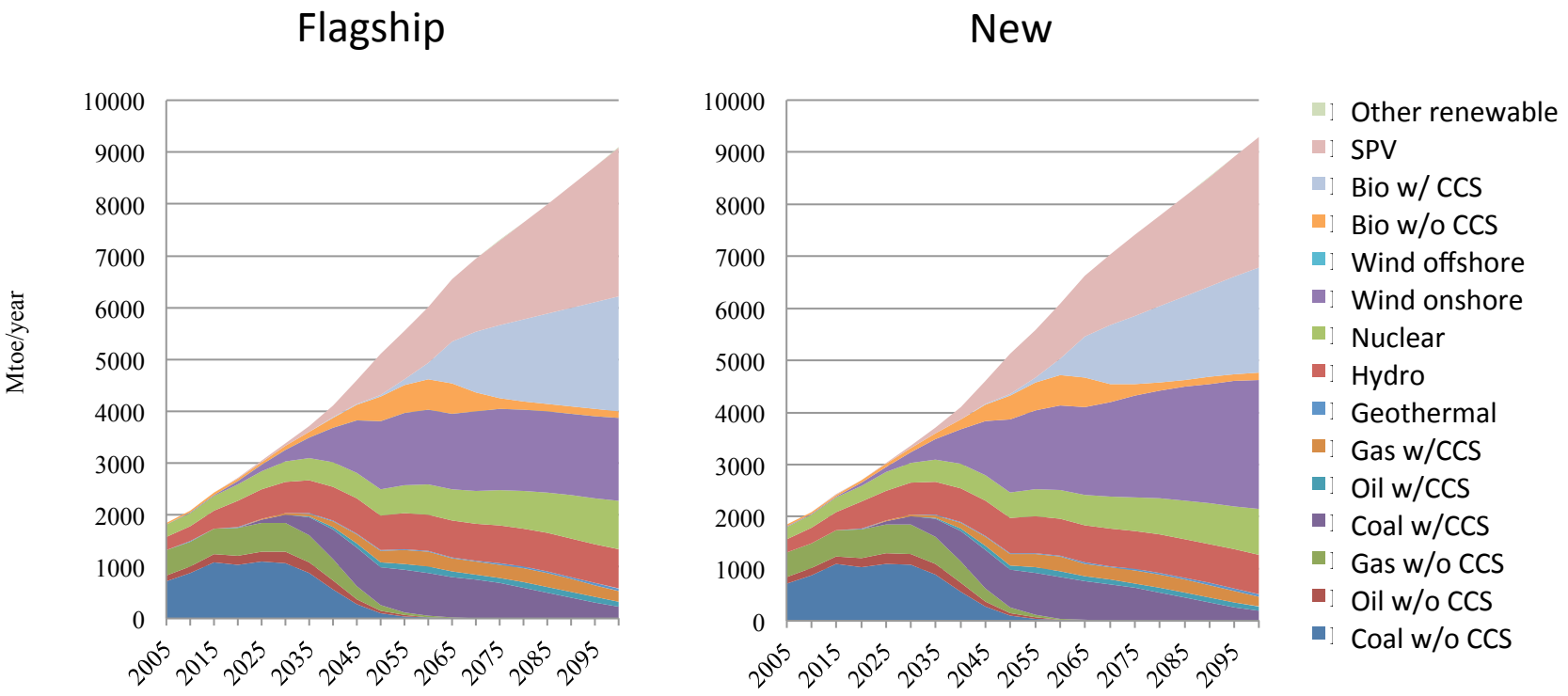
	Wind Resource	Wind Cost	Carbon Policy	Integration Cost/ Limit	Nuke/CCS Availability
1. Flagship	Model's existing supply curve	Standard	Tax	Standard	All tech
2. New Wind	NREL supply curve, new	Standard	Tax	Standard	All tech
3. No Policy	Model's existing supply curve	Standard	None	Standard	All tech
4. RE	Model's existing supply curve	Standard	Tax	Standard	Nuke phase-out, no CCS
5. Generous RE Integration	Model's existing supply curve	Standard	Tax	Relaxed	All tech

Scenario results



- "New wind" is larger than "Flagship".
- "RE" is also larger than "Flagship". It is due to the CCS and nuclear constraints.
- The comparison of "Flagship" and "New wind" provides the difference of individual modeling team's resource data and NREL new data.

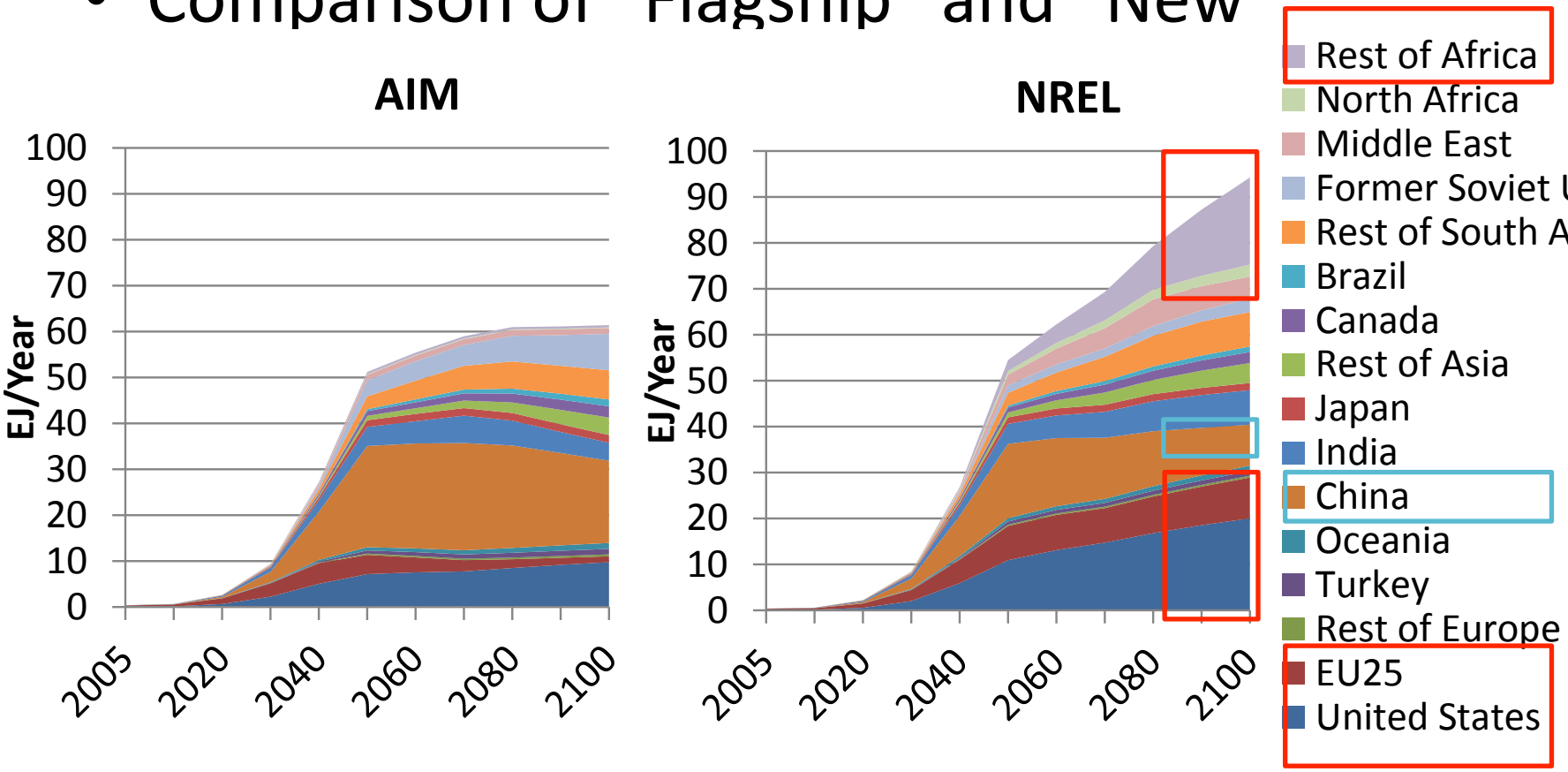
Global power generation breakdown by energy sources



- CCS installation, renewable energy increase in both scenarios
- Wind is one of the dominant factors

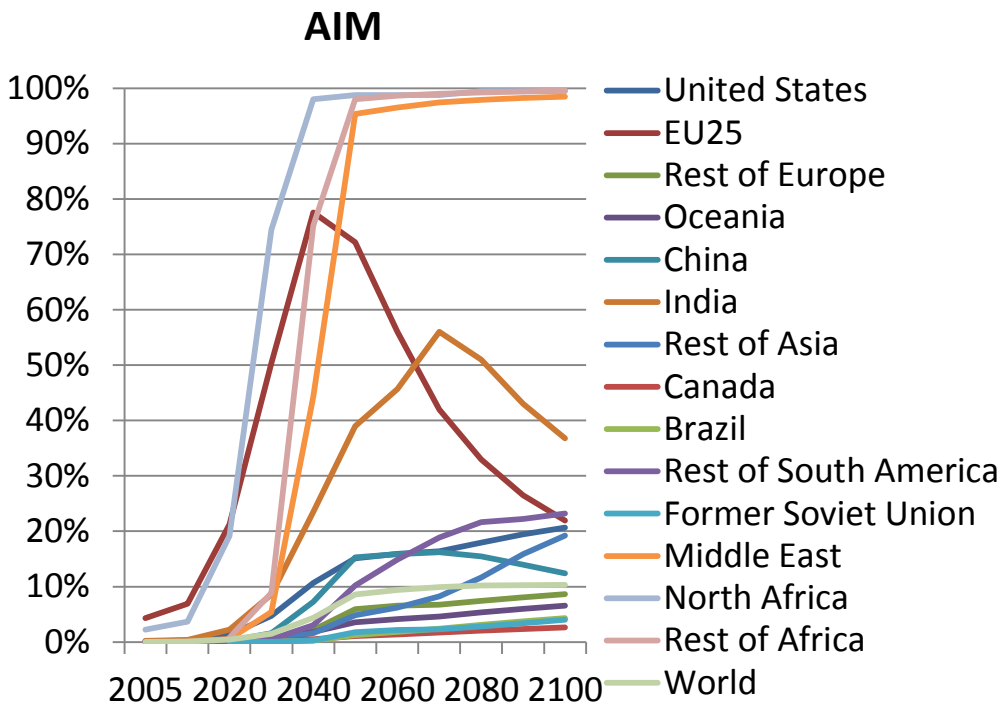
Scenario results
wind power regional breakdown

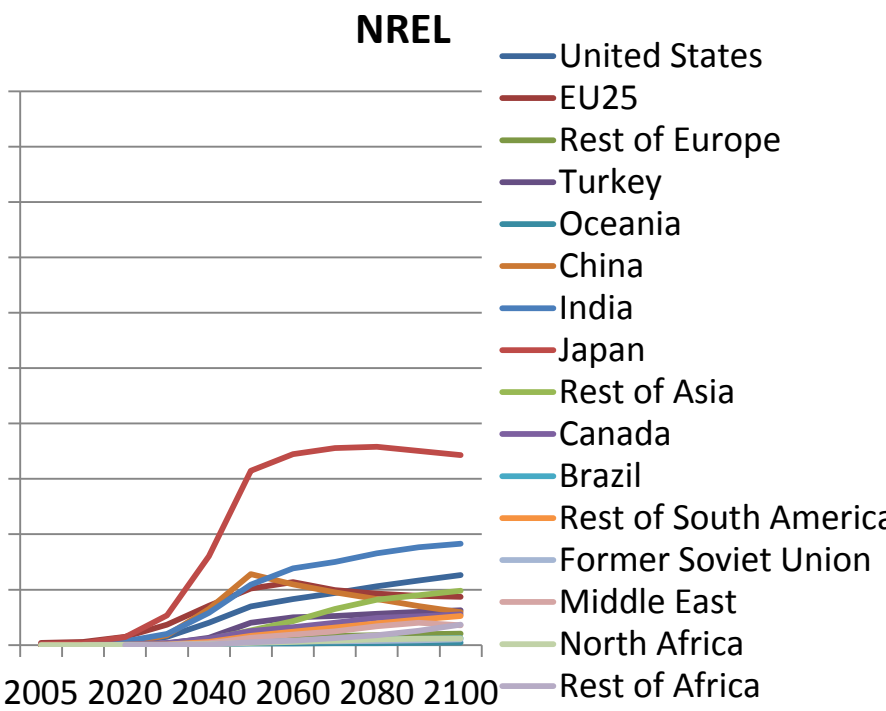
- Comparison of “Flagship” and “New”



- Africa and USA are larger in NREL
- China is small in NREL

Percentage of potential usage by regions in “Flagship” and “New”





- Potential usage is higher in AIM resource potential
- NREL is low → Potential is not fully used.

Preliminary implications

- We, original AIM resource potential assessment, could underestimate the wind power potential in some countries.
  - data checking is needed.
  - Very old wind speed data are used now, (Published in 2000 capturing 1983- 1993's situation by NASA)
    - Therefore it would be better to be revised.
- We simplified the cost curve but it should be much more detailed in the next analysis.
- To compare with NREL data, we start from looking at wind data and many assumptions behind the resource assessment.

2nd topic

Resource assessment

Earlier studies

1. Zhou, Y., Luckow, P., Smith, S.J., Clarke, L. (2012) Evaluation of global onshore wind energy potential and generation costs. Environ Sci Technol, 46, 7857-7864.
2. Hoogwijk, M., de Vries, B., Turkenburg, W. (2004) Assessment of the global and regional geographical, technical and economic potential of onshore wind energy. Energy Economics, 26, 889-919.
3. Lu, X., McElroy, M.B., Kiviluoma, J. (2009) Global potential for wind-generated electricity. Proc Natl Acad Sci U S A, 106, 10933-10938.

- Wind speed data were different among those studies.
  - Discussed in Zhou et al.(2012)
- Parameter sensitivity analysis was made.

Resource assessment

- If we compare the resource potential or cost curves, the assumptions behind the assessment is crucial
  - Wind speed data?
  - Technological, geographical or any other factors?
  - Should be opened and discussed that point
- We compare AIM team approach and earlier studies trials

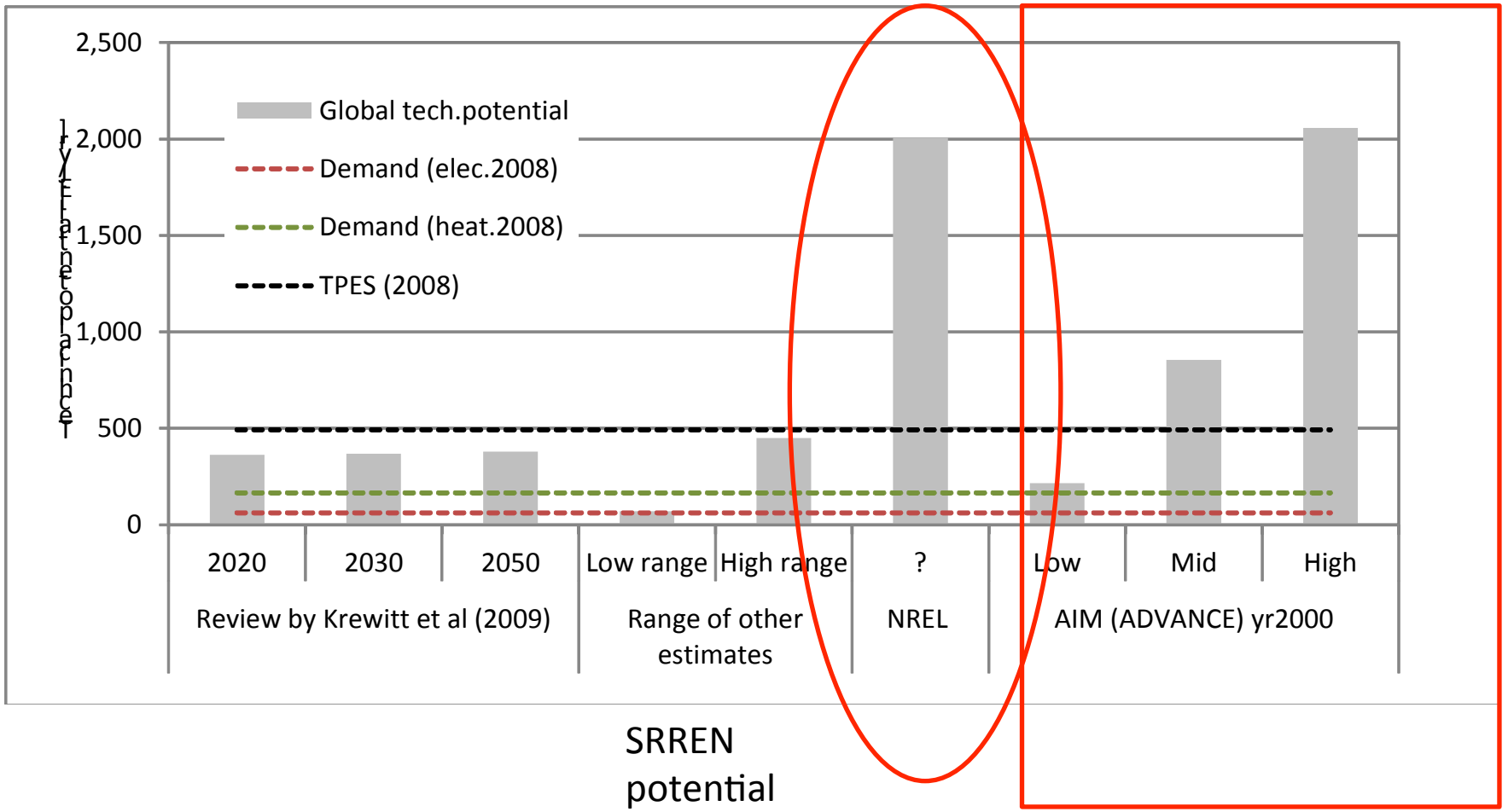
Three types of assumptions

- High, medium and low

Parameter	Units	Low	Mid	High
Rated capacity of technology	MW	2	2	2
Hub (turbine) height	m	80	90	100
Turbine density	MW/km2	2	5	9
Power correction factor	%	80	90-95	100
Availability factor	%	80	90	97
Other losses	%	30	20	10
Elevation (maximum suitable)	m.a.s.l.	2000	2000	2000
Slope (maximum suitable)	%	40	60	80

$$Q_{Wind\_onshore} = A_G \cdot r_{LC} \cdot (P_{Turbine} / A_{Turbine}) \cdot \text{FullLoadH} * f_{AV} * \eta_{Eff} * C_{correct}$$

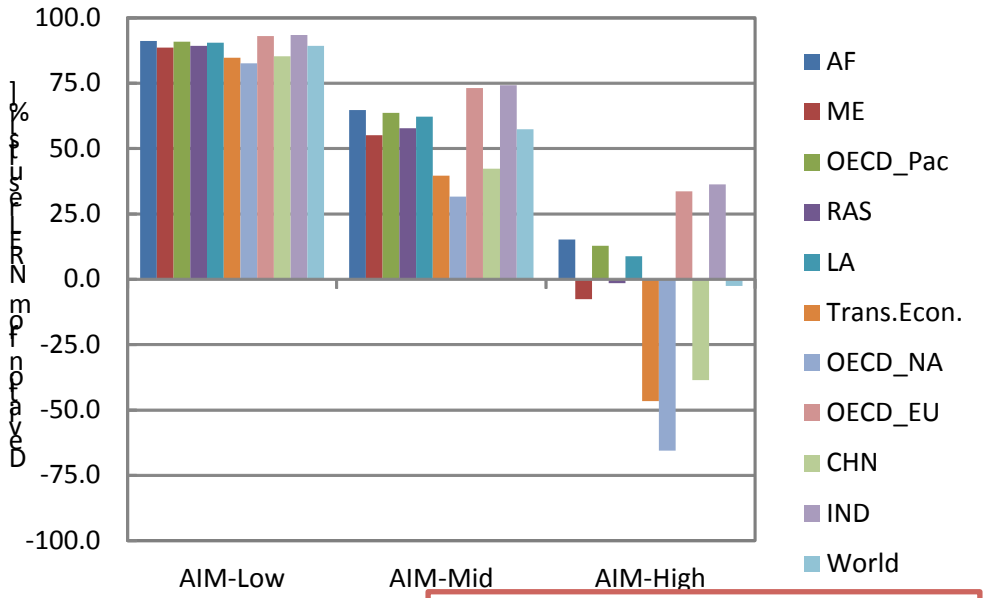
NREL and AIM's assessment



NREL and AIM's assessment

Region	Technical potential [TWh/yr]			
	NREL	AIM-Low	AIM-Mid	AIM-High
Africa	179,985	16,027	63,627	152,656
Middle East	39,377	4,466	17,692	42,365
OECD Pacific	67,061	6,167	24,391	58,501
Rest of Asia	56,866	6,079	23,981	57,680
Latin America	61,158	5,859	23,171	55,812
Transition Economies	43,951	6,731	26,552	64,440
OECD North America	46,680	8,108	31,951	77,303
OECD Europe	17,495	1,230	4,694	11,625
China	32,503	4,780	18,777	45,044
India	9,587	633	2,471	6,108
World	**557,494**	**60,106**	**237,405**	**571,767**

NREL estimates are very higher



Almost same in globally but regionally different

- AIM's high case is approximately corresponding to NREL.
- But regional differences have varieties

Comparing parameters with other studies

Parameter/dataset		AIM	NREL	Range
Wind speed data resolution	arc-degree	1.0 arc-degree	40km	1 – 0.25
Rated capacity of technology	MW	2	2	1 - 5 MW
Hub (turbine) height	m	80	90	60 – 100
Turbine density	MW/km2	2.4	5	2 – 8
Land use restrictions		Urban, elevation >5km, forests, wetland, water, snow	Protected, urban, high elevation	
Land suitability	[%]	30 (cropland)-50 (other)	?	
Distance		Under progress	Potential categorized by distance to large load center or power plant	

Comparison based on information provided on NREL results spreadsheet (values of other parameters used in NREL estimation are not reported).

Comparing parameters with other studies

- Check agreement on range of assumptions (i.e. parameter's values)
  - It would be helpful to give us comments about the assumptions.
- Maybe consider discussion on suitability of assessment approach/methodology for future meetings [?]