

Wind Resource Assessment

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28 February, 2014

Anil Agarwal Dialogue
Energy Access and Renewable Energy

Why do RE Resource Assessments?

Planning activities:

- Macro – e.g. energy security, trade deficits, etc.
- Power sector – e.g. generation mix, transmission planning
- System operation – e.g. balancing, markets, etc.

These are routinely done for – Coal/Natural Gas/etc.

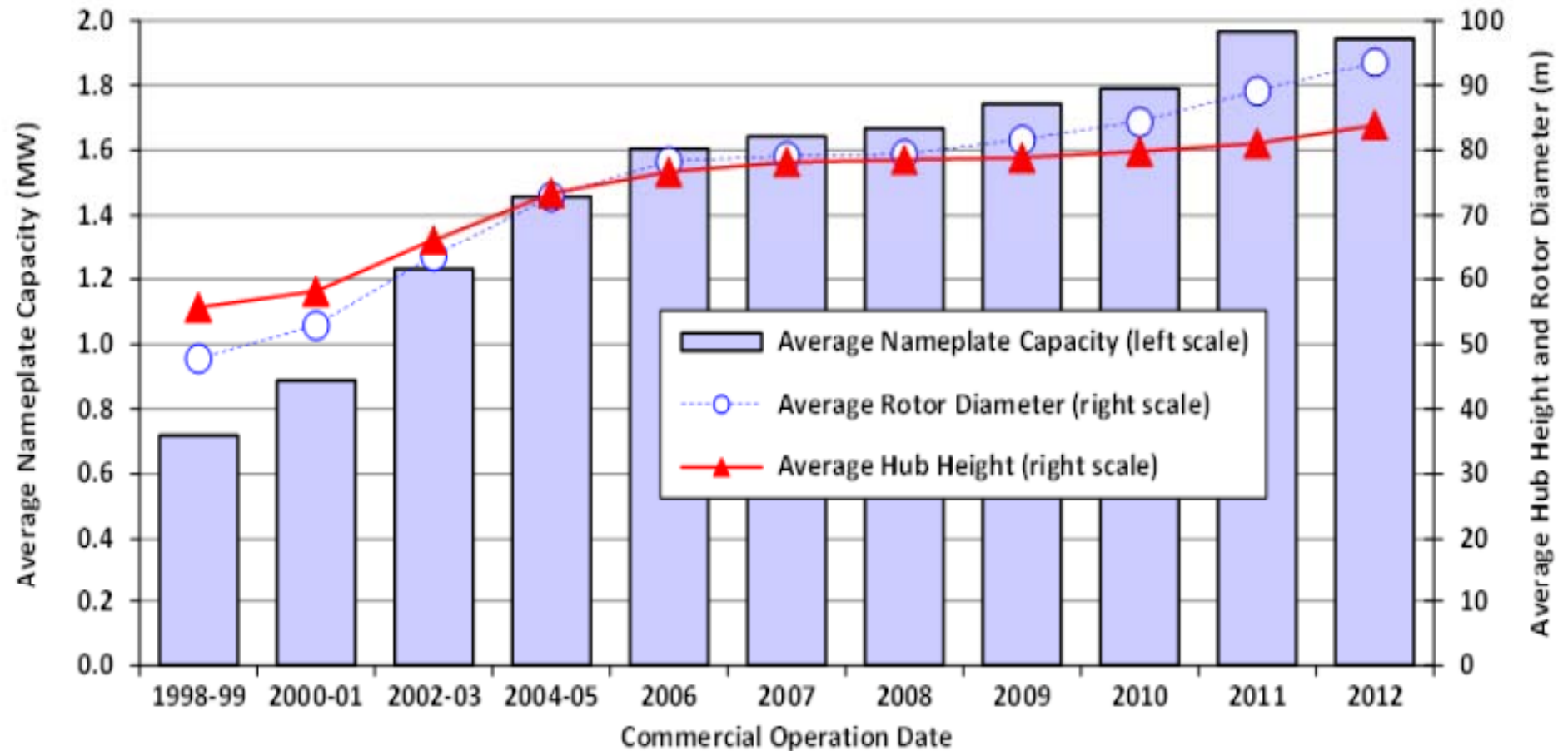
Assessments depend on...

- Technology – hub-height, rotor diameter, control systems, etc.
- Economics – relative to other sources of power
- Other – environmental, social, cultural, etc.
- Data – wind speed and power density, land use and cover, etc.
- Analysis tools and capability – GIS, algorithms, computing power, etc.

Key Caveats

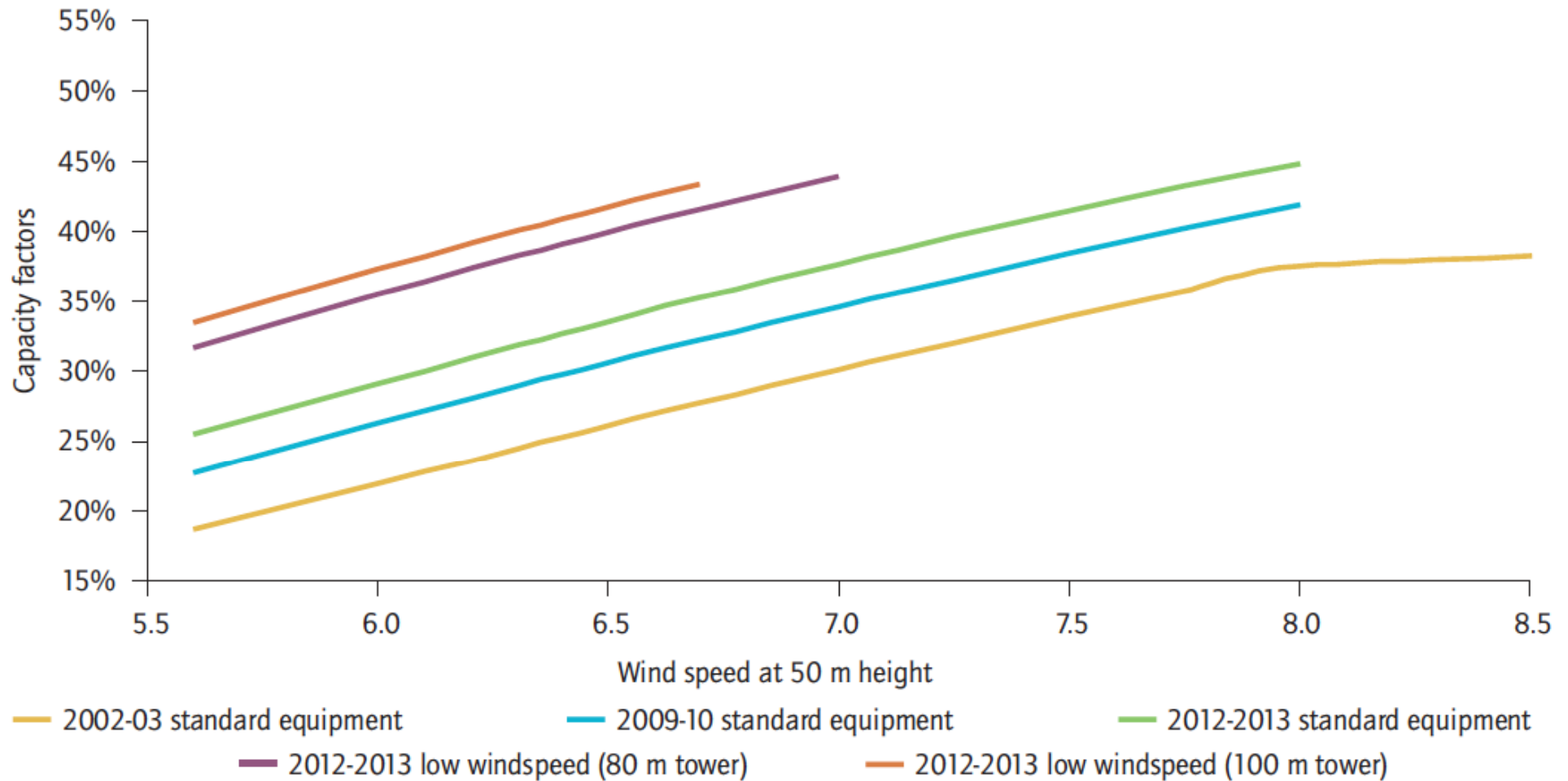
- As the factors evolve, the assessments will also change and hence, need to be undertaken **REGULARLY**
- These are high-level assessments and are meant to assist with energy planning exercises – **NOT** meant for integrated electricity planning or project development purposes
- Ground-truthing is **NECESSARY**

Capacity, Hub-Height, Rotor Diameter



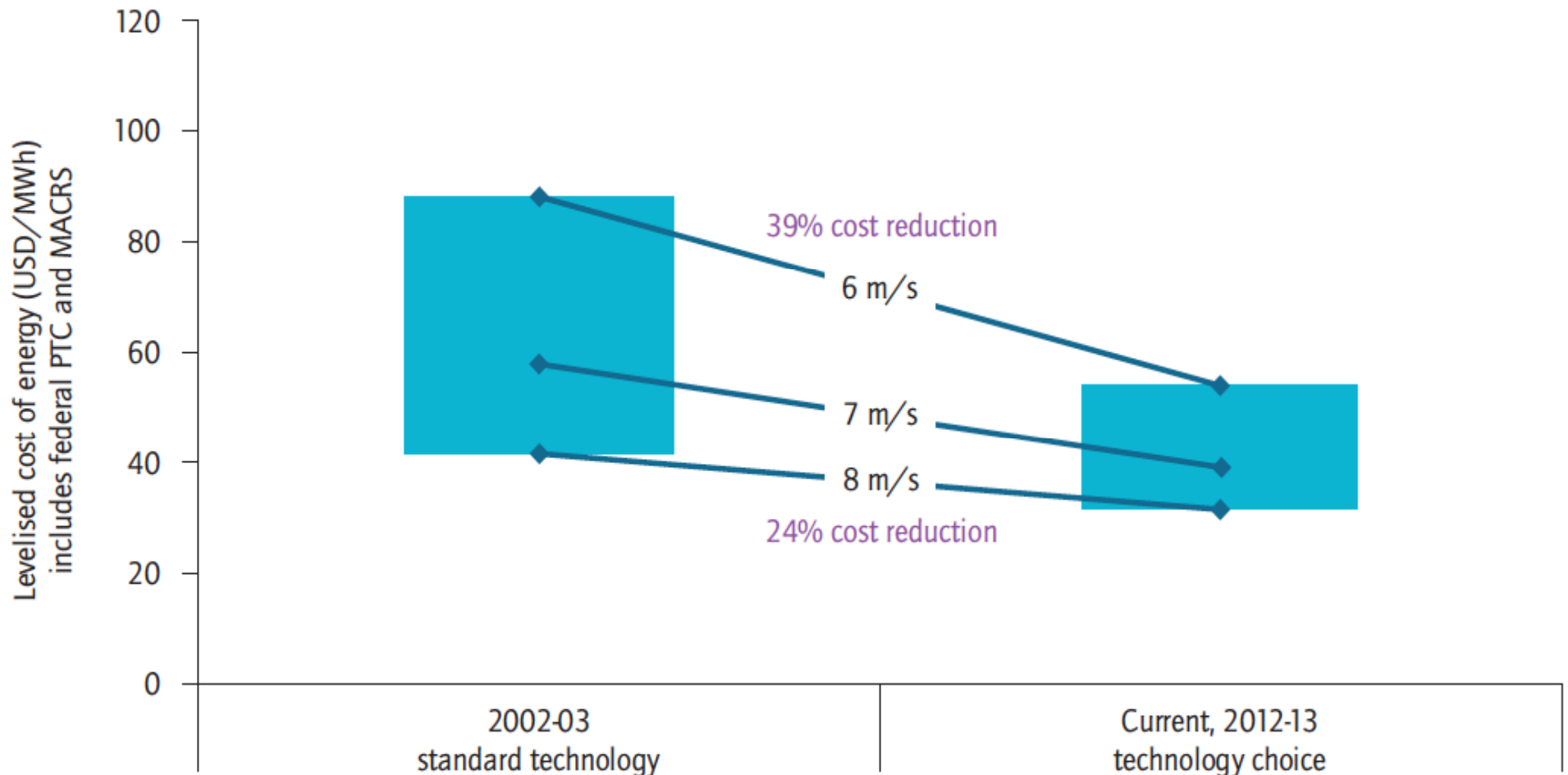
Source: AWEA project database

Capacity Factors



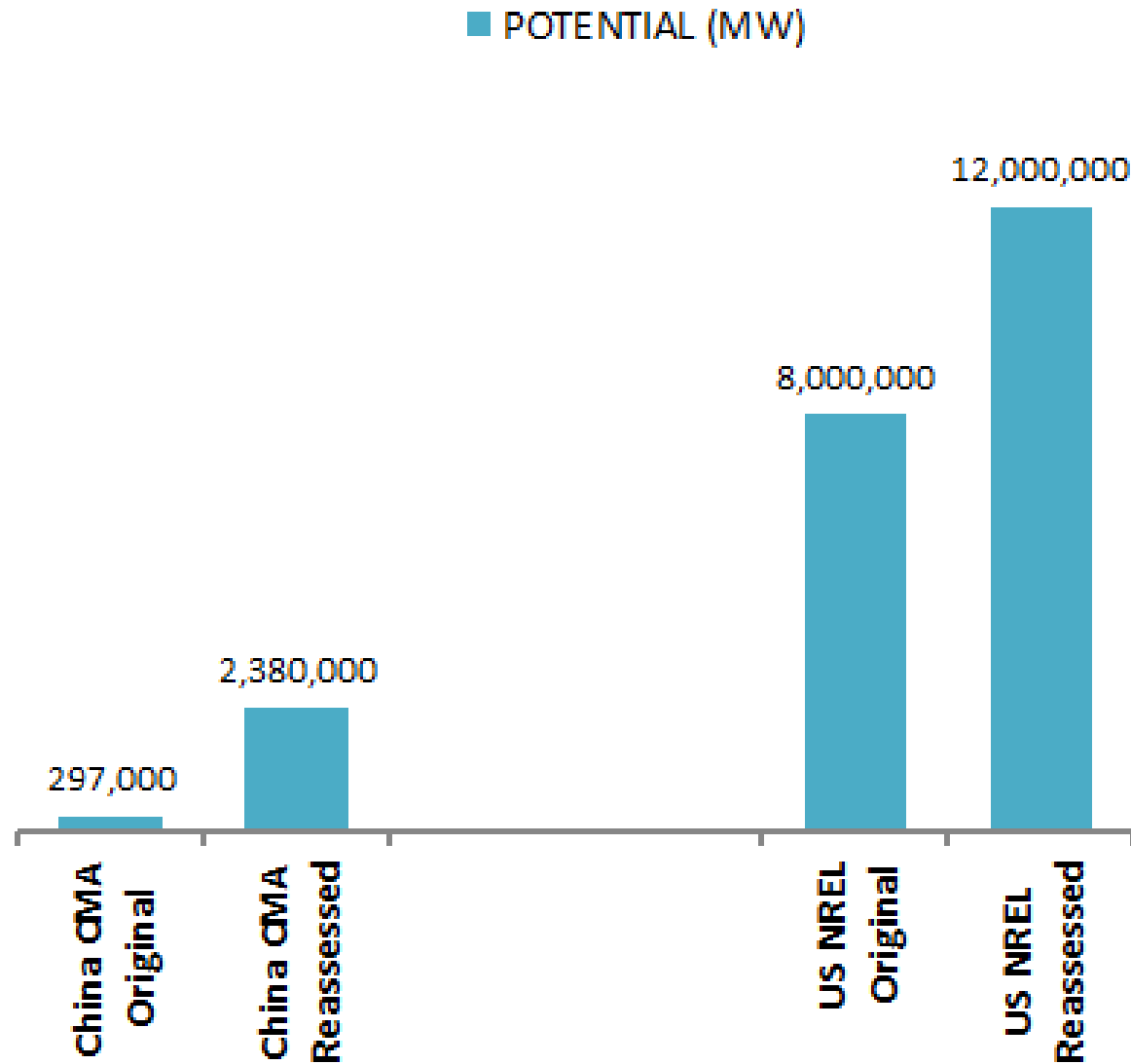
Source: Wiser *et al.*, 2012.

Levelized Cost of Energy Trends for Low- and High-wind-speed Sites

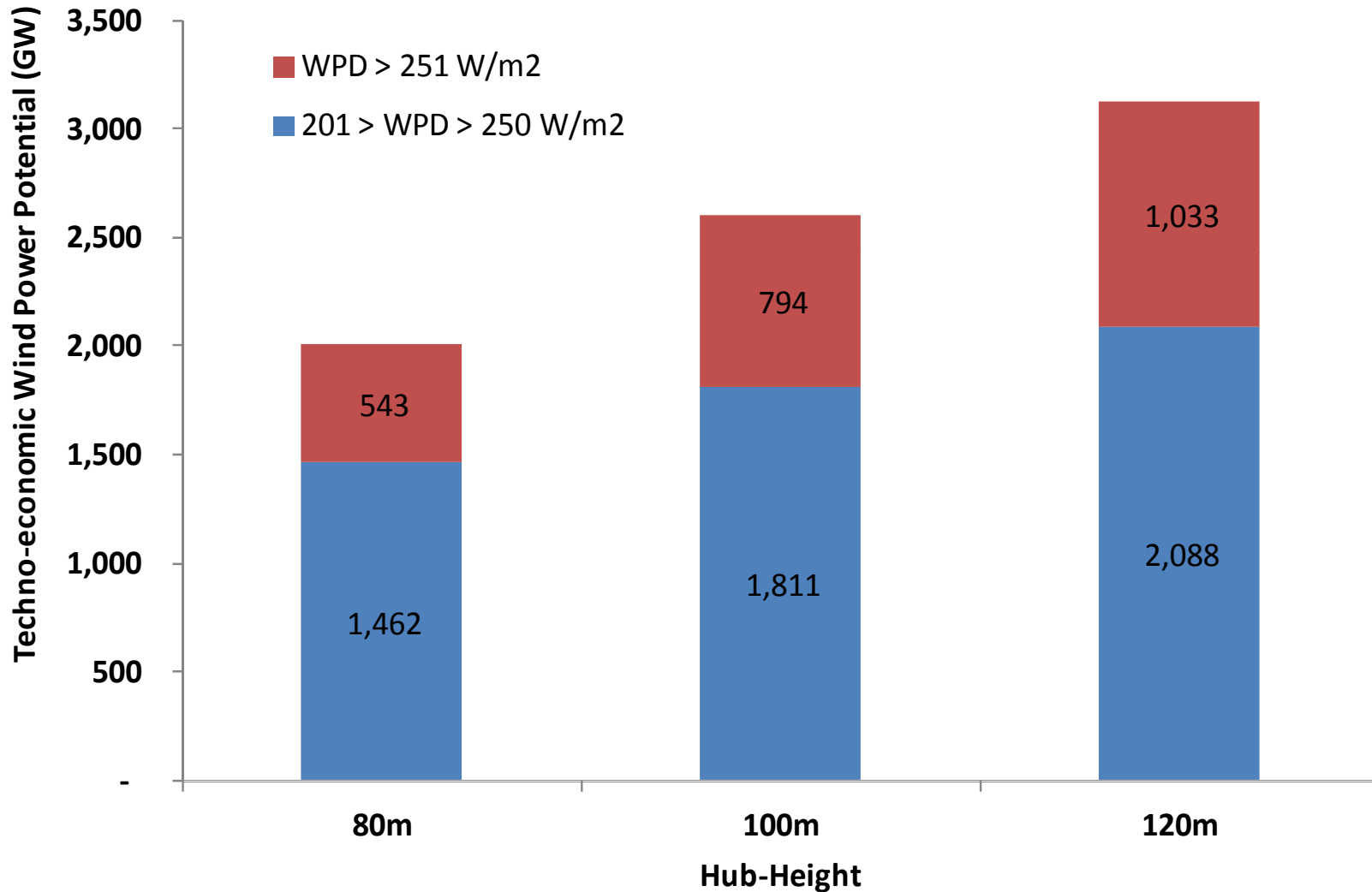


Source: Wiser *et al.*, 2012.

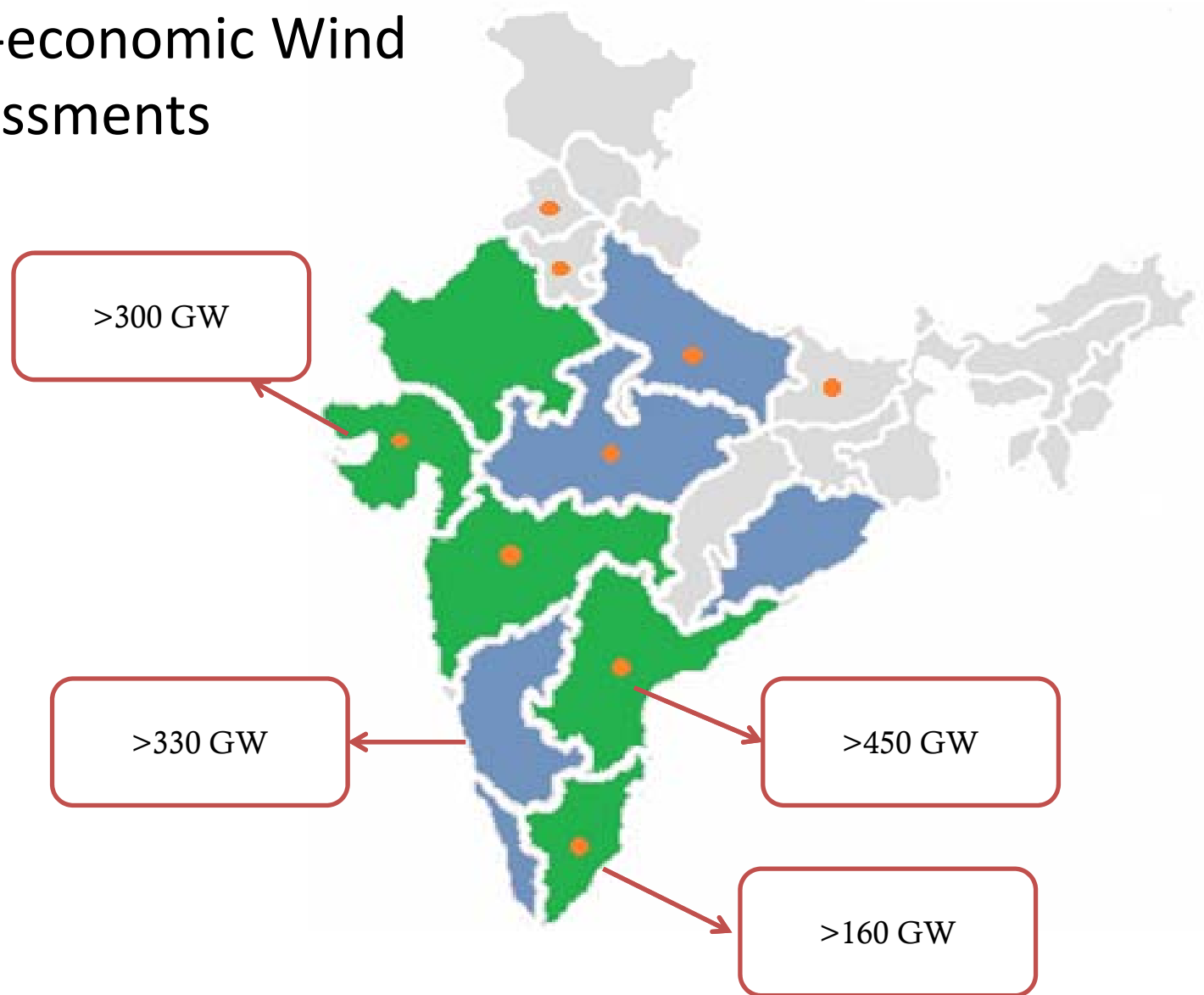
Several countries have recently made significant upward revisions to wind potential estimates



Techno-economic wind potential



Other Techno-economic Wind Potential Assessments



Source:

Gujarat http://www.shaktifoundation.in/cms/uploadedImages/final%20report_irerag_v1.pdf

Karnataka, AP: <http://www.shaktifoundation.in/cms/UploadedImages/wind%20report%20-%20final%20-%202020%20jan.pdf>

Tamil Nadu: http://www.shaktifoundation.in/cms/uploadedImages/tamil%20nadu_re%20action%20plan_jan%202013.pdf

Methodology

Meso-scale Modeling

- Climate simulation

Down-scaling to Micro-level

- Wind speed and wind power density modeling

Application of Land Availability Constraints

- Accomodate factors that would limit development of wind farms

Estimation of wind energy potential

- Assumes wind turbine technology and wind farm configuration

Data Sources

Data-set	Attribute	Remarks
3Tier	Wind speed and Wind power density	Resolution: 3.6 km by 3.6 km Root data/model: Meso-scale model called <i>Weather Research and Forecasting</i> Date: 2010
GlobCover	Land Cover (including water, urban areas)	Resolution: 0.3 km by 0.3 km Root data: ENVISAT MERIS Satellite Date: 2004-06
GTopo30	Slope and Altitude	Resolution: 30 arc-seconds (~1 km by 1 km) Root data: Eight sources including National Imagery and Mapping Agency, Digital Chart of the World and International Map of the World
World Database of Protected Areas		Date: 2010 Created by: the UNEP, World Conservation Monitoring Centre, and the IUCN's World Commission of Protected Areas

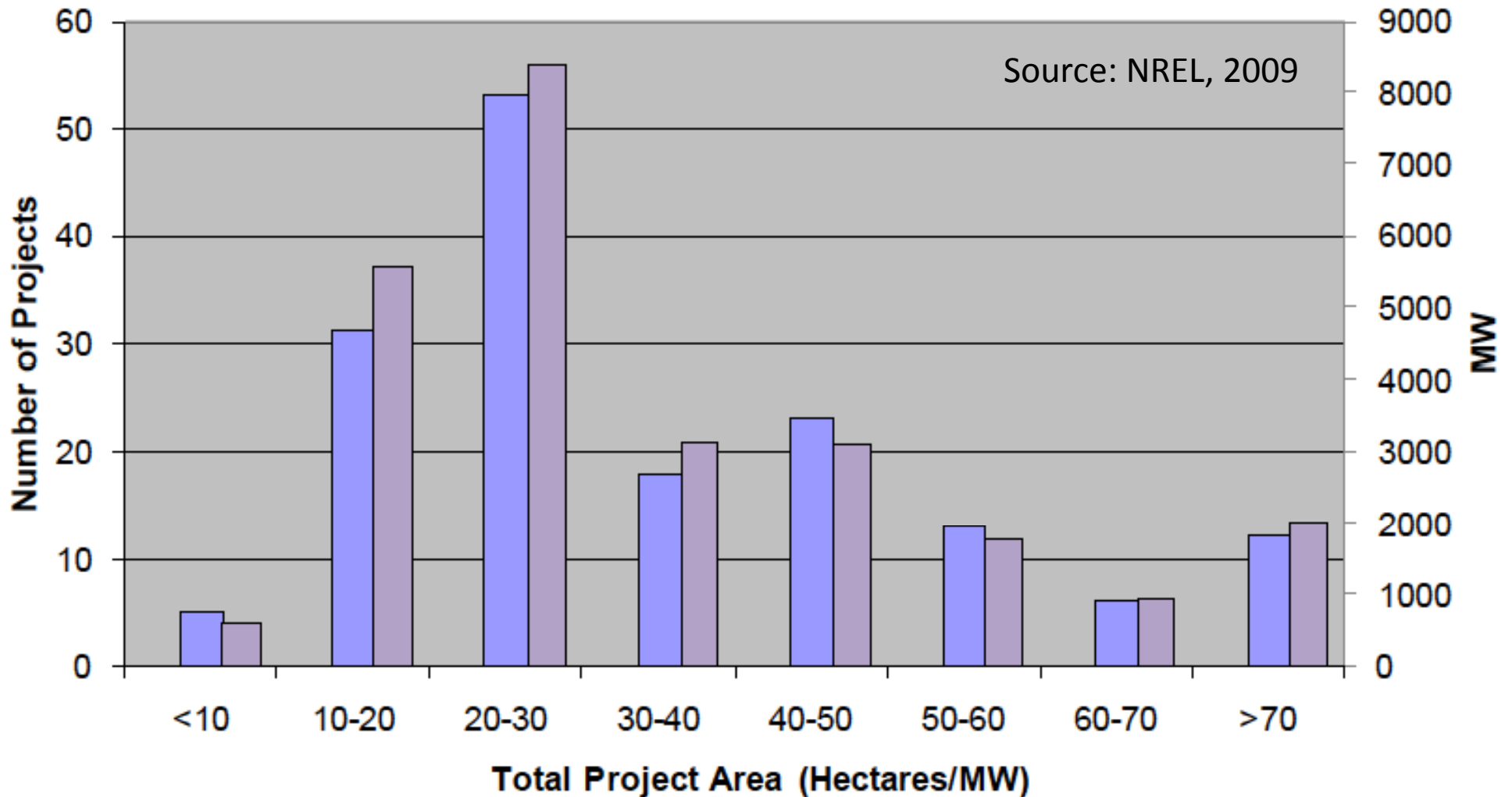
Land Availability Constraints Assumed

- **Excludes** land having:
 - Low quality wind area ($WPD < 200 \text{ W/m}^2$)
 - Slope above 20%
 - Elevation above 1500 m
 - **Forests, protected areas, water bodies**
 - Urban and rural developed areas
- **Includes** land having:
 - Rain-fed cropland, irrigated/flooded cropland etc.
 - bare land
 - grassland/cultivated land

Category	Land Use/Cover Classification Provided by GlobCover	Land (km ²)	Techno-Economic Wind Potential (GW)
Water Bodies	Water bodies	0	0
	Closed (>40%) broadleaved forest or shrub-land permanently flooded - Saline or brackish water	105	1
	Closed to open (>15%) broadleaved forest regularly flooded (semi-permanently or temporarily) - Fresh or brackish water	1	0
	Closed to open (>15%) grassland or woody vegetation on regularly flooded or waterlogged soil - Fresh, brackish or saline water	62	1
Snow/Ice	Permanent snow and ice	51	0
Rural/Urban	Artificial surfaces and associated areas (Urban areas >50%)	1,698	15
Forests	Closed (>40%) broadleaved deciduous forest (>5m)	12,806	115
	Closed (>40%) needle-leaved evergreen forest (>5m)	391	4
	Closed to open (>15%) broadleaved evergreen or semi-deciduous forest (>5m)	17,678	159
	Closed to open (>15%) mixed broadleaved and needle-leaved forest (>5m)	0	0
	Mosaic forest or shrub-land (50-70%) / grassland (20-50%)	16	0
	Mosaic grassland (50-70%) / forest or shrub-land (20-50%)	21	0
	Mosaic vegetation (grassland/shrub-land/forest) (50-70%) / cropland (20-50%)	22,625	204
	Open (15-40%) broadleaved deciduous forest/woodland (>5m)	2	0
Miscellaneous	Bare areas	1,073	10
	Closed to open (>15%) (broadleaved or needle-leaved, evergreen or deciduous) shrub-land (<5m)	5,159	46
	Closed to open (>15%) herbaceous vegetation (grassland, savannas or lichens/mosses)	8,280	75
	Mosaic cropland (50-70%) / vegetation (grassland/shrub-land/forest) (20-50%)	47,326	426
	Post-flooding or irrigated croplands (or aquatic)	48,551	437
	Rain-fed croplands	112,436	1,012
	Sparse (<15%) vegetation	18	0
TOTAL		278,301	2,505

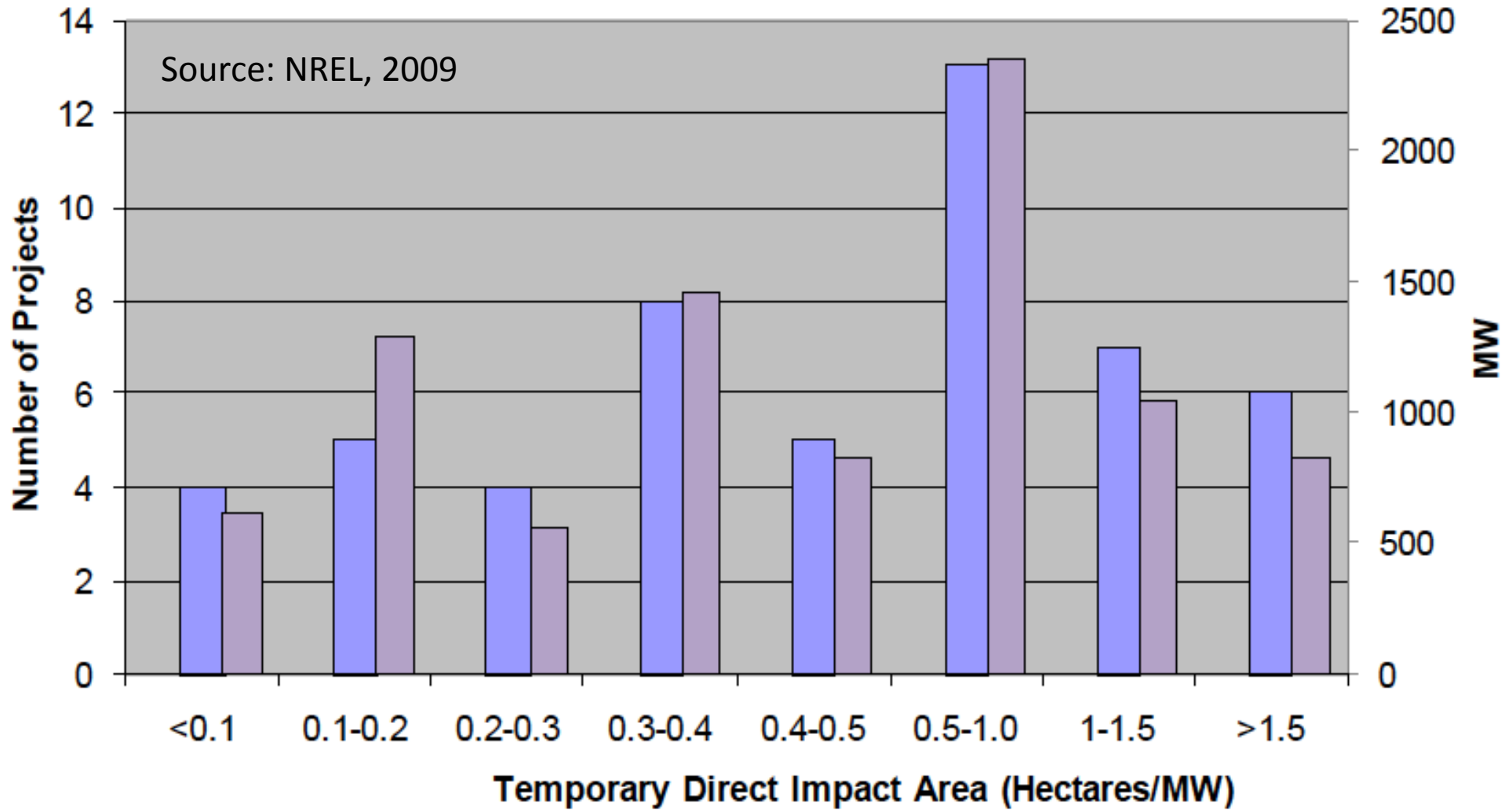
Wind Project Total Area Requirements

Number of Projects MW

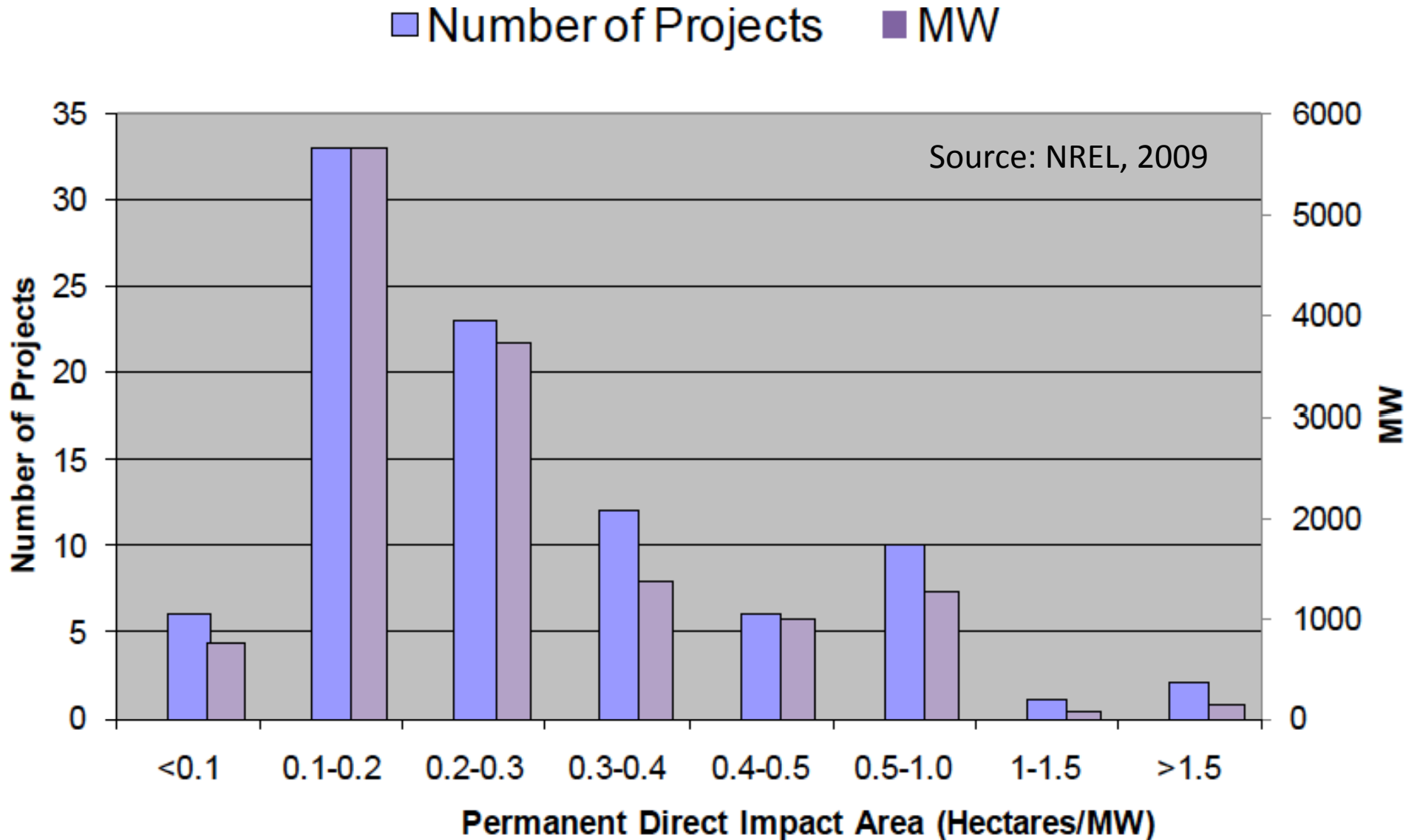


How much area is disturbed temporarily?

■ Number of Projects ■ MW



How much area is disturbed permanently?



Distribution of Direct Impact Area

Permanent Impact Category	% of Area	Temporary Impact Category	% of Area
Turbine Area	10%	Staging Area	30%
Roads	79%	Temp Roads	62%
Substation	6%	Sub/Trans construction	6%
Transmission	2%	Other	3%
Other	2%		

Source: NREL, 2009

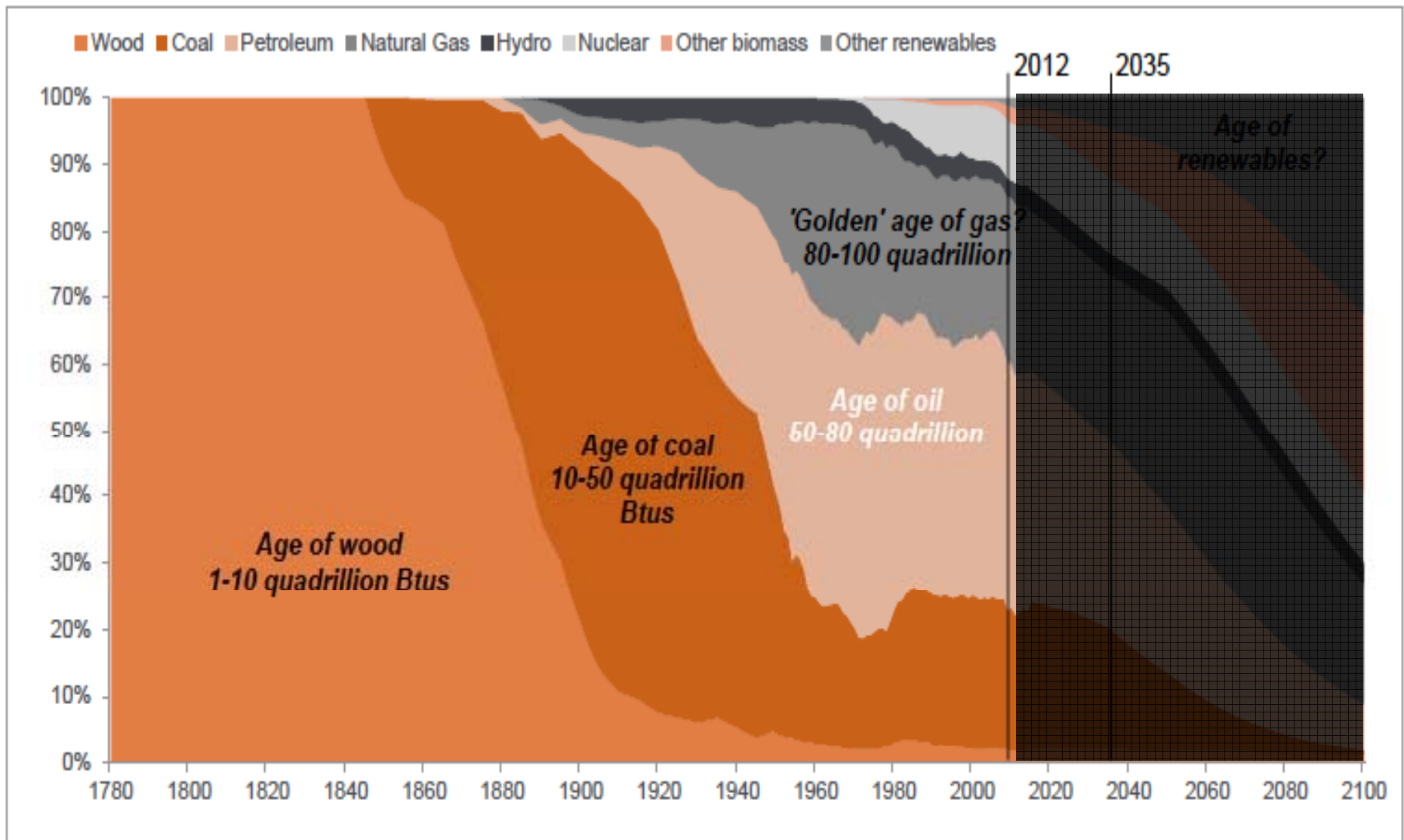
Wind Development in Forests

- Can be done and is being considered – but experts suggest “Avoid it if you can!”
 - Hub-heights need to be significantly higher and the rotor-lengths may have to be shorter – i.e. higher levelized costs
 - Turbulence can be significantly higher leading to lower capacity factors – i.e. higher levelized costs
 - Spacing between turbines has to be larger – i.e. more roads – higher costs
 - Wind measurement and monitoring more important – i.e. higher costs

Wind Energy Impacts

Key question is – **Compared to what?**

- Coal mining
- Coal transport
- Coal generation
- Impact of pollution through different pathways
 - Ash-ponds, air/water, etc.
- Dam back-waters



Source: IEA, EIA, Citi Research

**“The Stone Age did not end for lack of stone,
and the Oil Age will end long before the world runs out of oil.”**