WIND PROJECT OPTIMIZATION

COLLOQUE AQPER 2017

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February 16, 2017

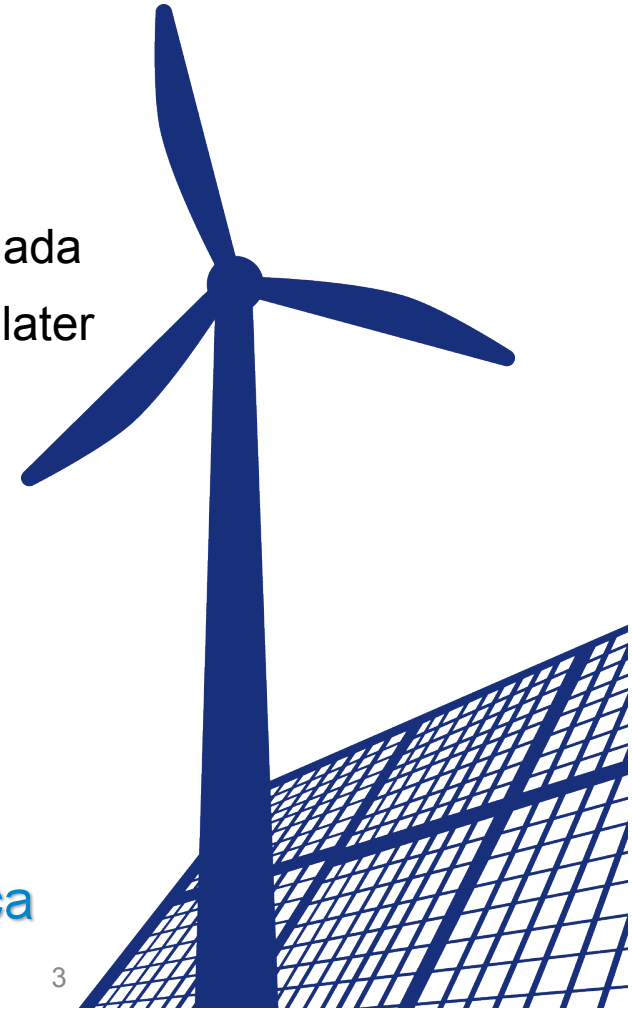
Agenda

- Reality of wind projects
  - Historical LCOE evolution
  - LCOE Forecasts
- Wind competitiveness & optimization
  - Maturity of Wind Industry
  - Technology Road Map
  - Other potential optimization avenues
- Solar competitiveness
  - Recent trends
  - LCOE Forecasts
- Conclusion

Me

- Started my career in wind, 12 yrs ago… as a met mast!
- Hydromega ➔ Saint-Laurent Énergies ➔ EDF EN Canada
- Heavily involved in the QC RFPs from 2005 going fwd; later in BlackSpring Ridge, Ontario RFPs, NIC project, etc.
- At the moment, different roles:
  - ENG Canada
  - Procurement Canada
  - Technical Coordination & Optimization Team - NA

→ Technical Director - North America

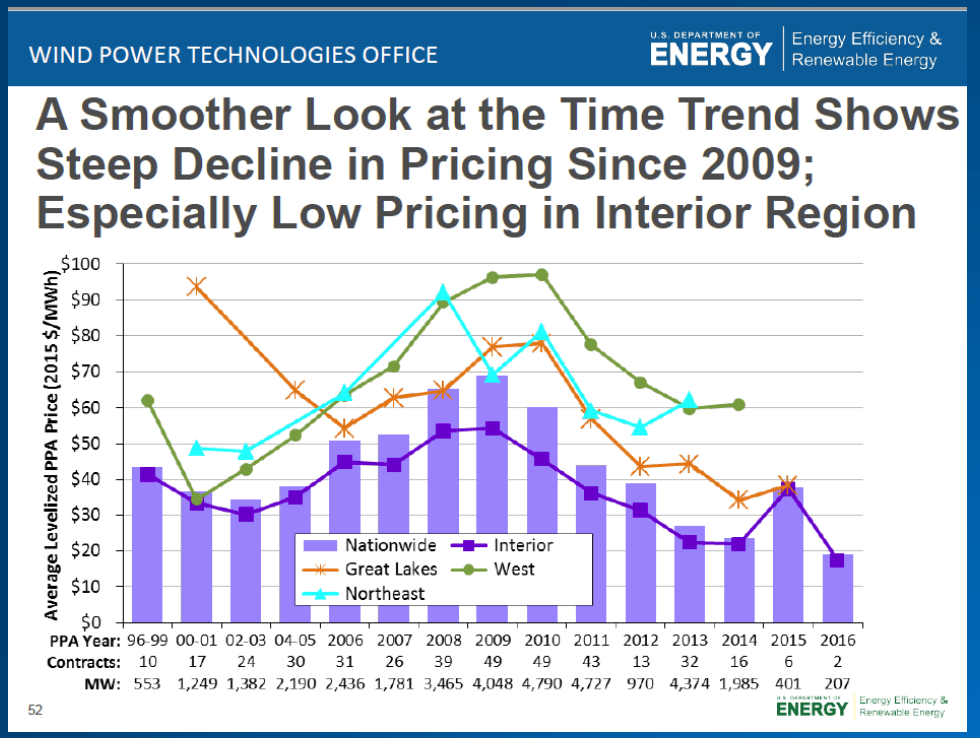


Reality of wind projects in recent years

- Optimal sites have been taken (wind resource, grid connection, etc.)
- Significant increase in environmental requirements
- Significant increase in Interconnection costs and congestion risks
- Size of RFPs reduced, lowering the potential volume effect

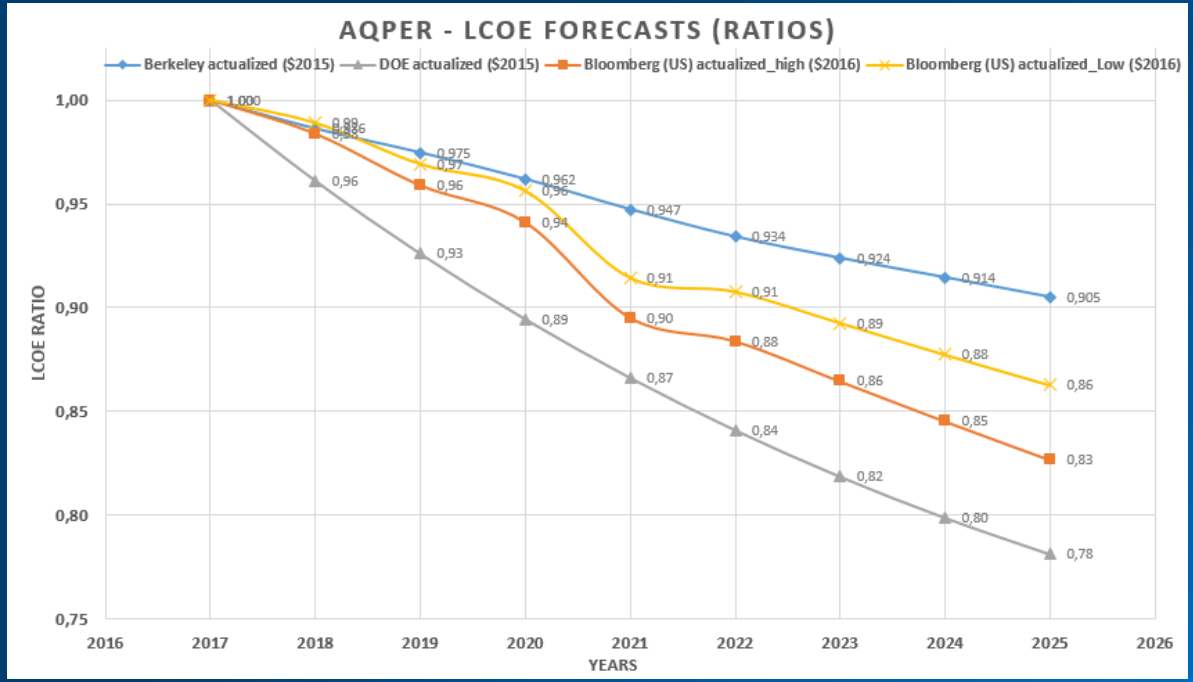
Wind LCOE in recent years

- Even with the « wind reality » described previously, the LCOE trend is still downward;
- We'll discuss further about some of the reasons explaining this trend



Wind LCOE forecasts

- Forecasts keep consistent trends;
- How to get there?
  - ➔ OPTIMIZATION
- We'll investigate:
  - Key variables
  - Maturity of Wind Industry
  - Technology Road Map
  - Other potential optimization avenues



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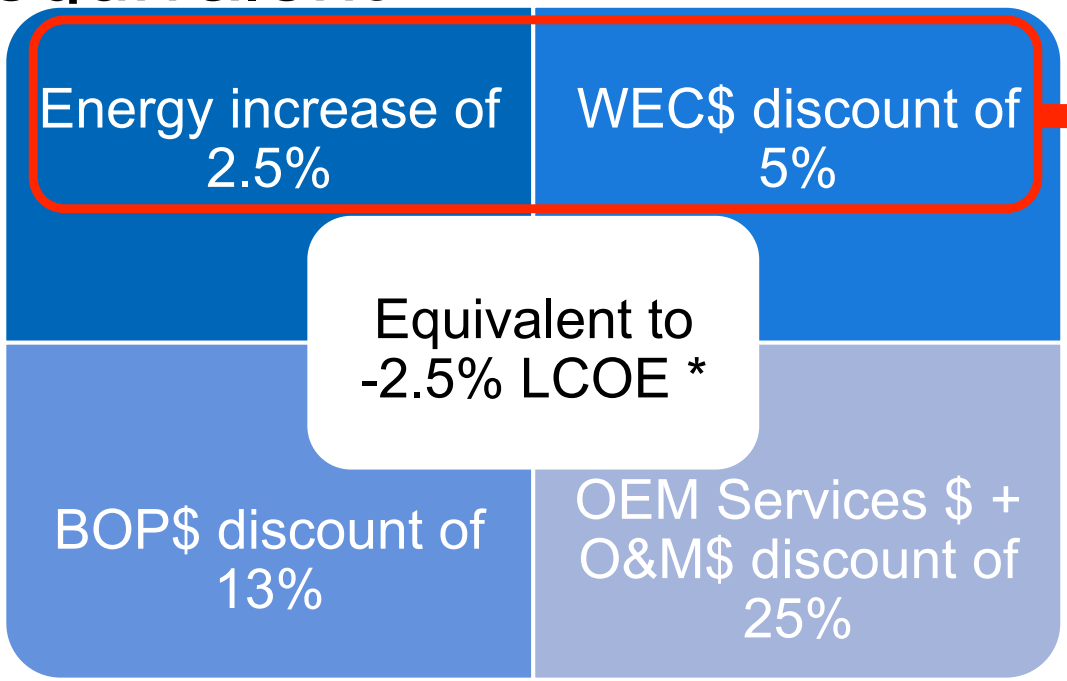
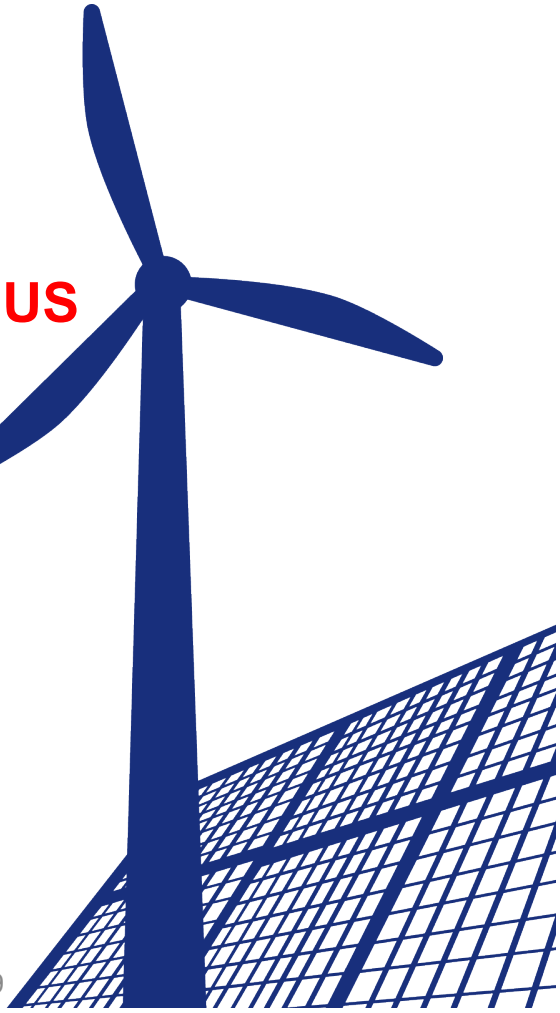
Consolidation of OEM market

- Sign of Maturity in the industry;
  - Multiple Energies Suppliers
- Improved "bankability" of some of the new entities;
  - RECENT ACQUISITIONS & MERGERS BETWEEN MAJOR OEMs
- Great diversity of product;
- Far from the time where we had « one WEC model fits-all »;
  - WIND BUSINESS ONLY
- Now technology competitive on all types of wind regime and site conditions.
  - INDEPENDENT OEMs

Key variables – LCOE equivalent



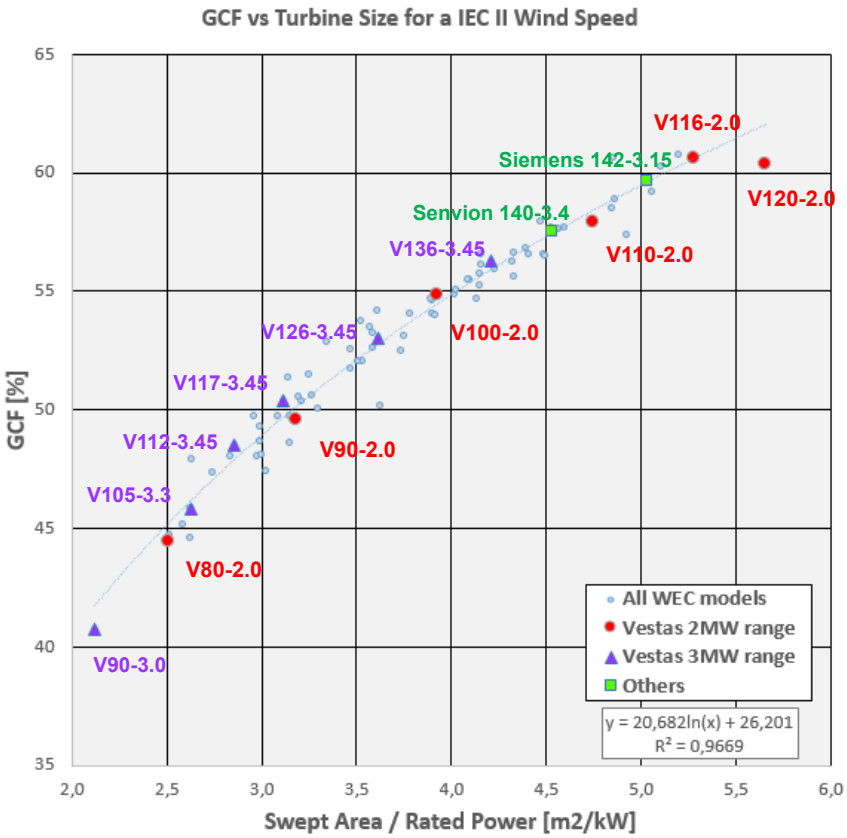
FOCUS



* Analysis based on US project located in central corridor

Energy trends - swept area to nameplate ratio

- Very useful ratio:
  - Estimate the efficiency of a WEC model
  - Evaluate trends of the market
  - Evaluate forecasts
- 2MW ➔ Clear trends
- 3.X MW ➔
  - Clear trends
  - Still not as efficient as 2MW
  - But for how long…

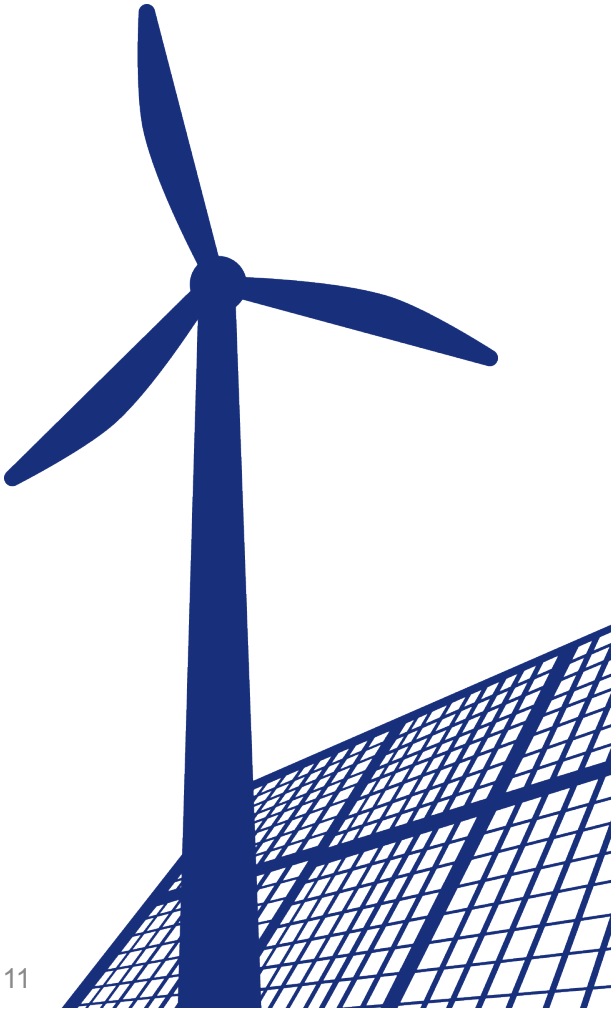


Energy trends – PC efficiencies

- For a given WEC model, energy increases over time due to:
  - Power Curve improvements
  - Uprate
  - Extended cut-out

OEM	WEC model	Evolution 1 *	Evolution 2 *
Vestas	V100*	Mk7H to Mk10A +40 bps on NCF	… to Mk10B +90 bps on NCF
	V110*	Mk10A to Mk10B +60 bps on NCF	… to Mk10D +40 bps on NCF
Siemens	2.3-108*	Power Boost + 1.2% in P50	Uprate in Name Plate +0.6% P50
Senvion	MM82*	2009 PC evolution + 0.2% in P50	
	MM92*	2008 PC evolution + 3.0% in P50	2009 PC evolution + 0.5% in P50
…		Many other examples	

*** Energy gains based on a US project located in central corridor**



Energy trends – Suitability

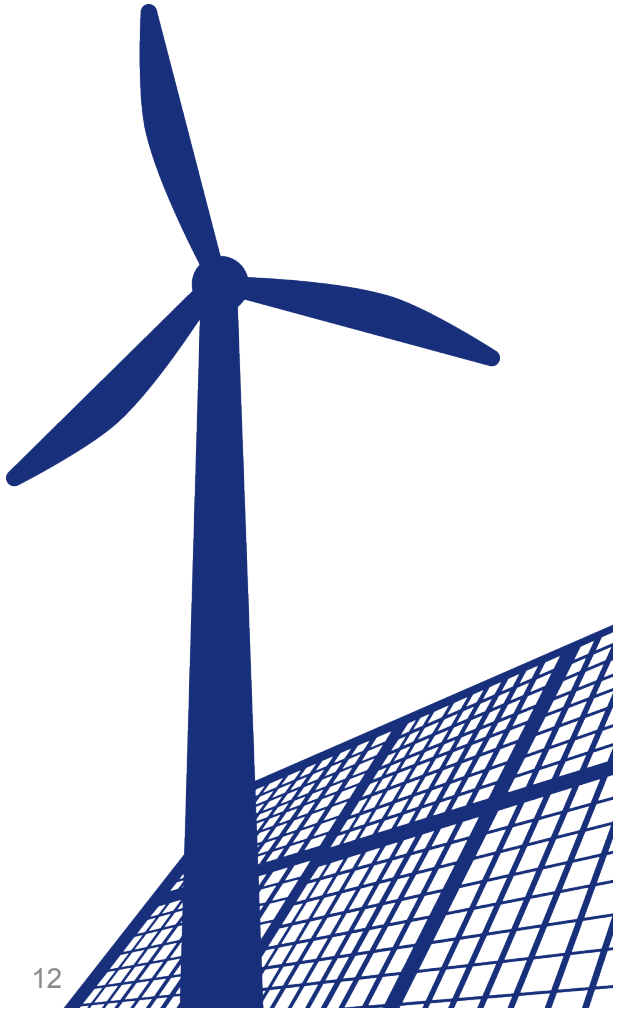
- A given model is often “upclassed” in terms of IEC or sited more aggressively with time

Time

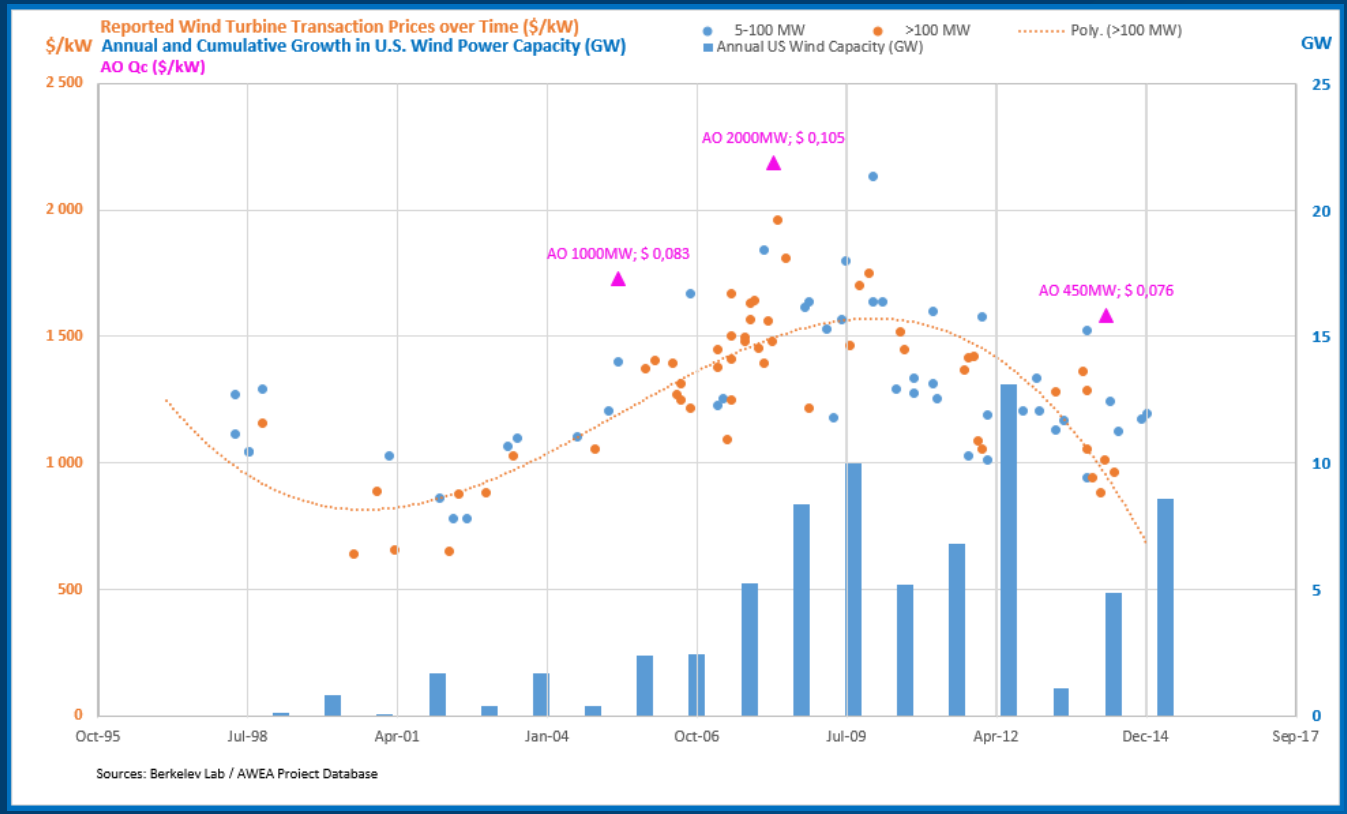
Wind

Trend

		2011	2012	2013	2014	2015	2016	2017
IEC I	a							
	b				G97 (s)	G114 (s)		V117
IEC II	a		G97			G114 V117		V126
	b							V136
IEC III	a	G97		G114		V126		
	b						V136	

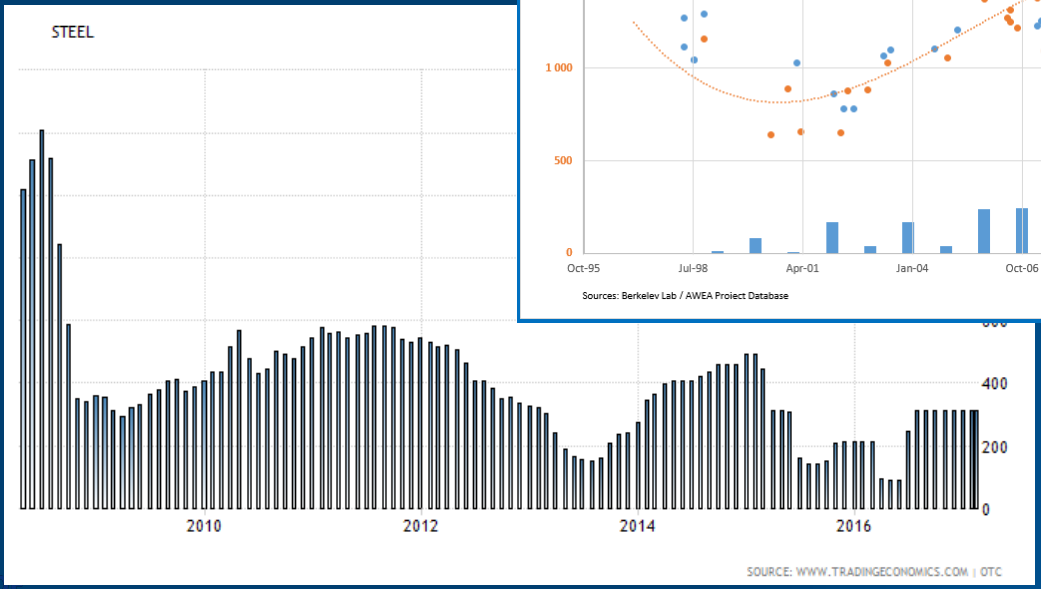


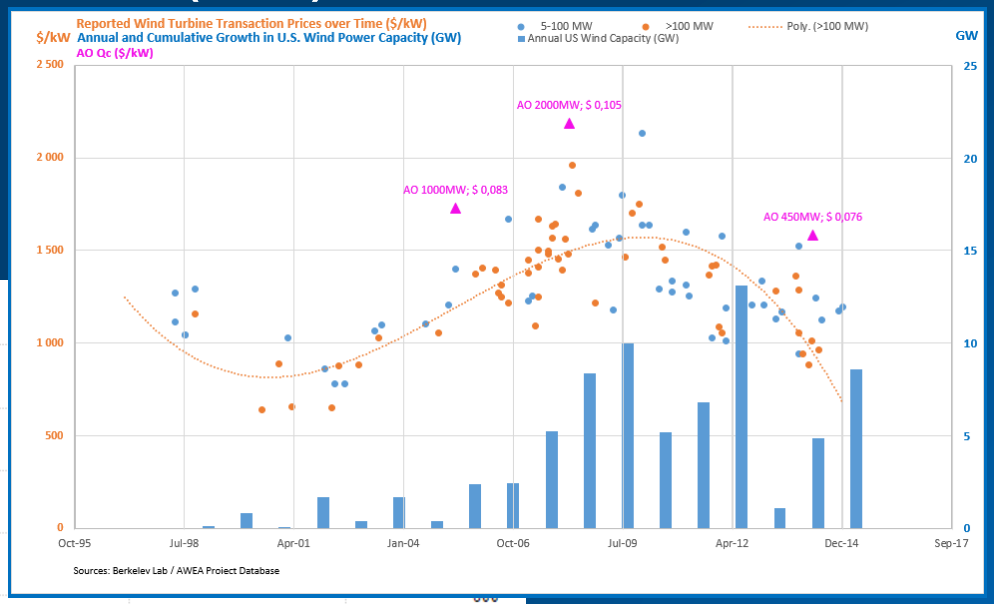
Cost trends – WEC



Cost trends – WEC (ctd)

http://www.tradingeconomics.com/commodity/steel





Optimization - WEC model selection (ctd)

- Site-specific wind regime
  - Suitability?
  - Suitable doesn't mean optimal…
- What is limiting the project size; land or transmission line?
- Type of terrain; Flat or complex?
- Sources of revenues; PPA$ expected
- Specific site constraints: noise, tip height, minimal land footprint, etc.

➔ **Very complex equation to solve**

Optimization - WEC model selection (ctd)

Who is the Buyer for the deal

+

Apply the "Dogs and Master look alike" theory

=

Optimal WEC model for the deal

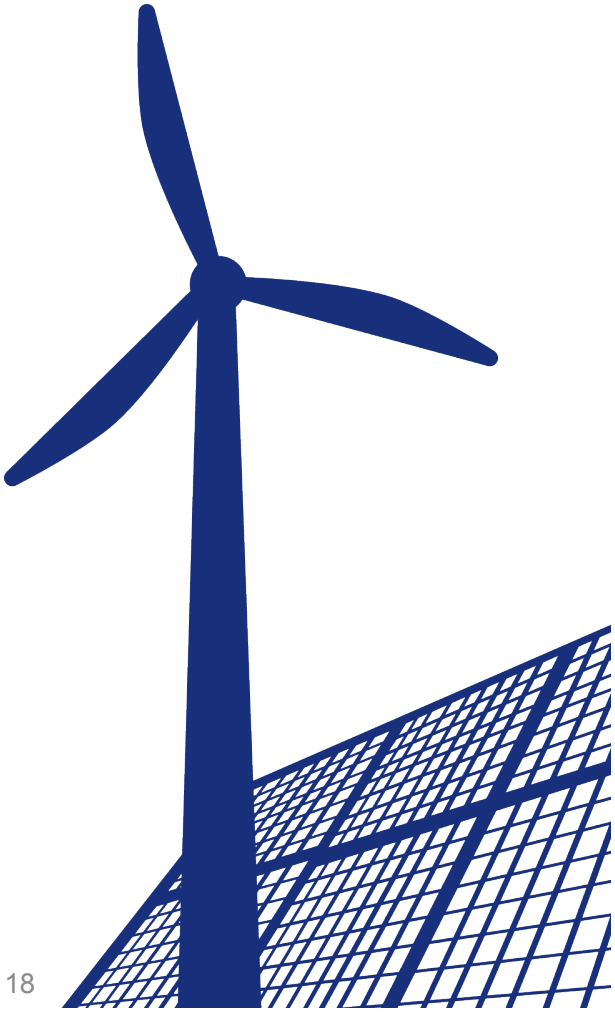
Optimization - WEC model selection (ctd)

- Using latest EDF EN Canada recent success as test case:
  - Vestas 3.45MW platform, HH 116 - 132m
  - Tall Hub Heights, very large rotor, sp

http://www.viralnova.com/dog-owners/

Optimization – Others…

- Project location;
  - Wind resource quality
  - Accessibility (BOP $, transport $, qualified labour, etc)
  - Acceptability
- Project size;
  - Bigger doesn't necessarly mean more competitive
- Interconnection strategy;
  - Becoming more and more important
  - Congestion risks
- Bidding strategy
  - Each bid is different…



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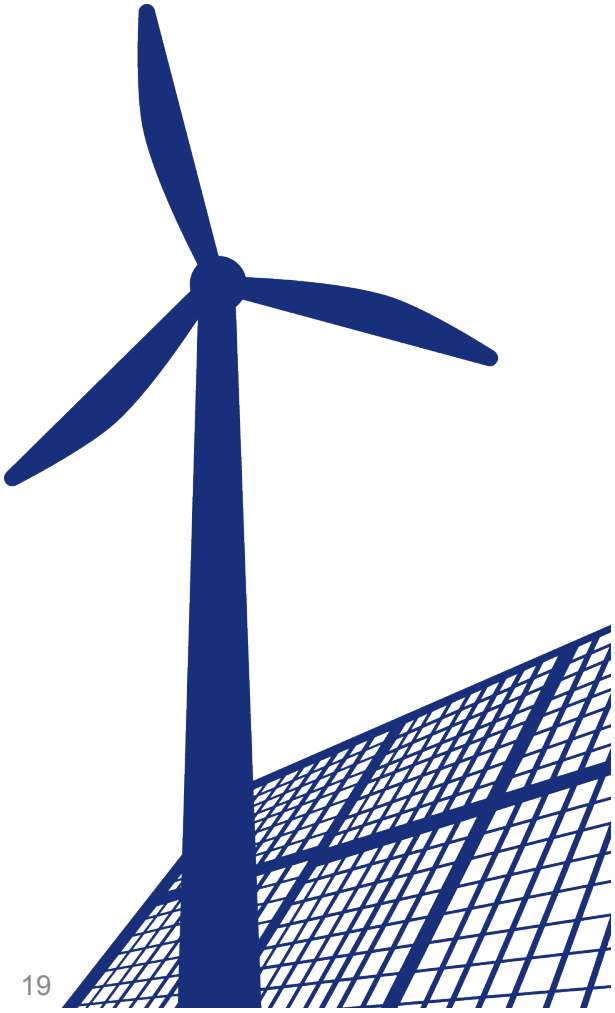
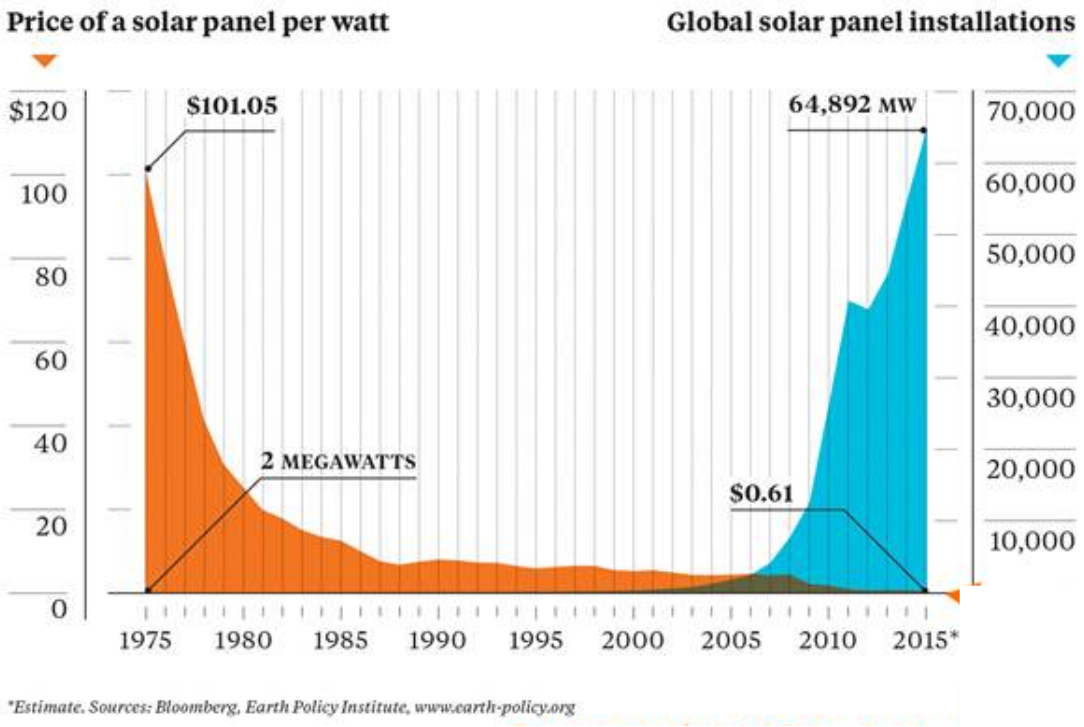
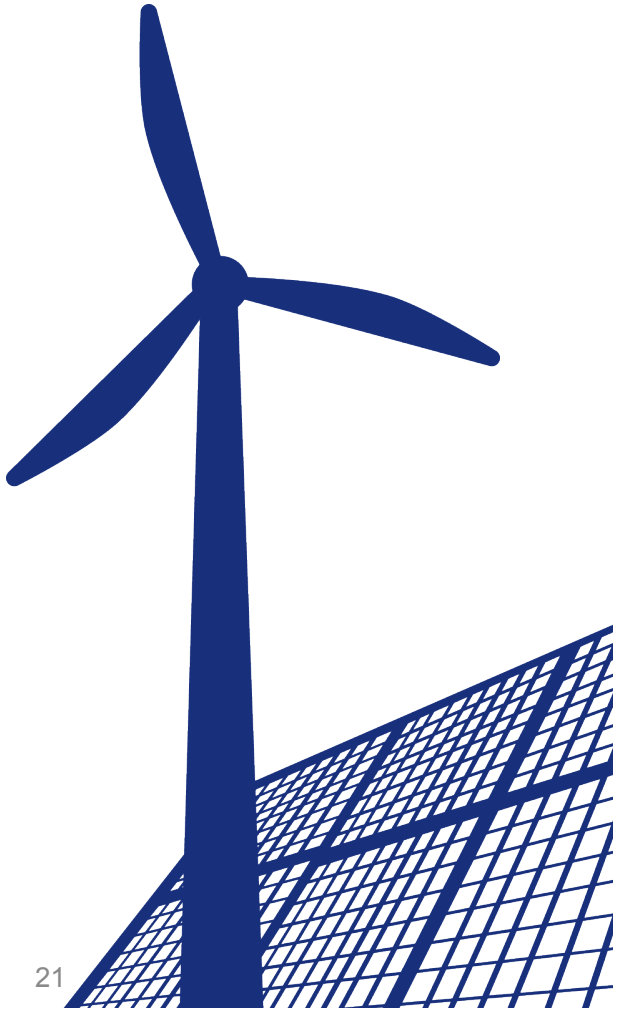


SOLAR

- Why talk about solar in Far North?!?
- Drastic reduction of LCOE costs year after year
- Different solar opportunities in Canada

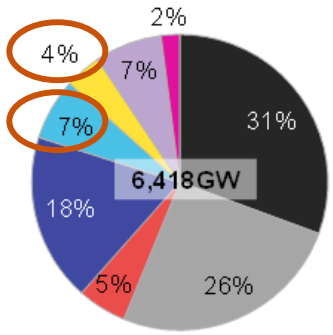
Solar - Historical trends



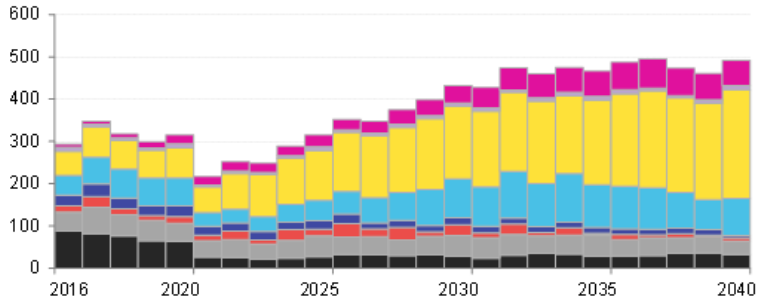


Energy - Forecasts

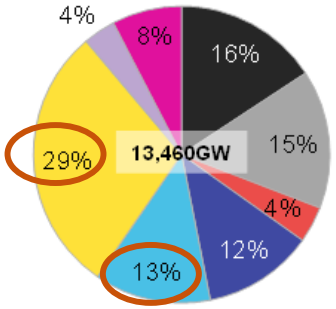
Power mix, 2015 (GW)



Gross annual capacity additions, 2016-40



Power mix, 2040 (GW)

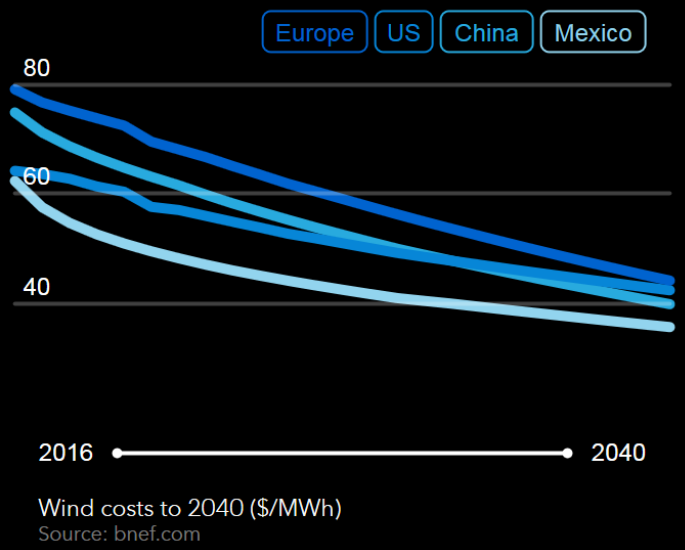


Coal Gas Nuclear Hydro Wind Solar Other Flexible Capacity

Source: Bloomberg New Energy Finance

Wind - Forecasts

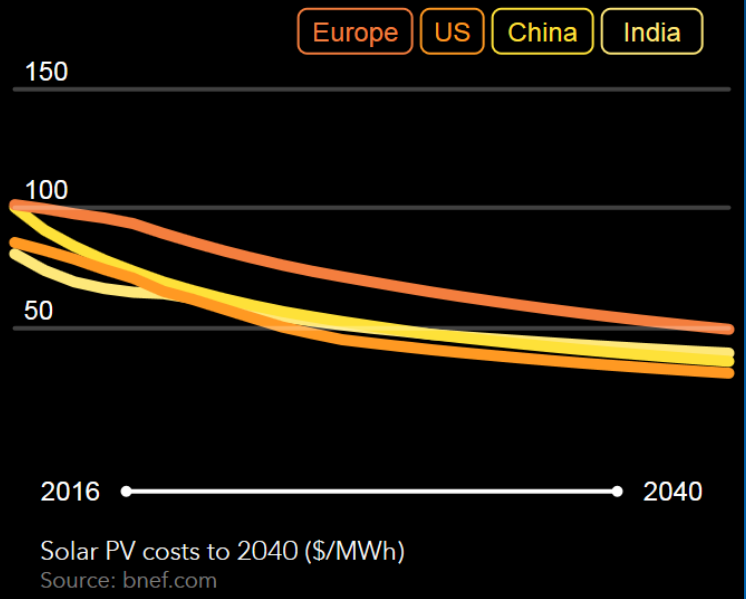
On the other, wind and solar keep getting cheaper. Onshore wind will fall 41% by 2040....



Wind costs to 2040 ($/MWh)
Source: bnef.com

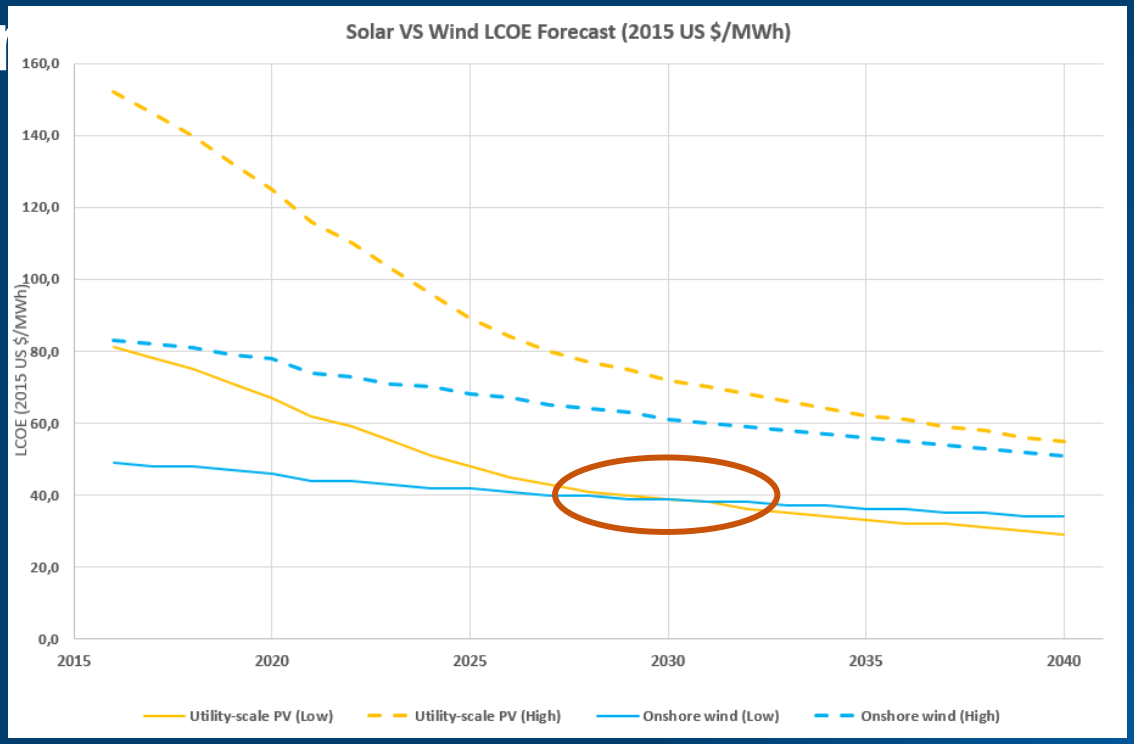
Solar - Forecasts

... and solar by 60%. This means these two technologies will be the cheapest ways of producing electricity in many countries during the 2020s and in most of the world in the 2030s.



Solar PV costs to 2040 ($/MWh)
Source: bnef.com

LCOE – Solar & Wind for



Source: Bloomberg New Energy Finance

CONCLUSION

- Wind & Solar LCOE forecasts have a downward trend;
- Historically, the Wind LCOE has been driven by different factors, including the “supply & demand” factor and commodities;
- Going forward, the pressure on Wind will most likely be driven by Solar;
- Project optimization will be key to the success of the wind industry.

QUESTIONS ?
COMMENTS?
RUDE REMARKS?