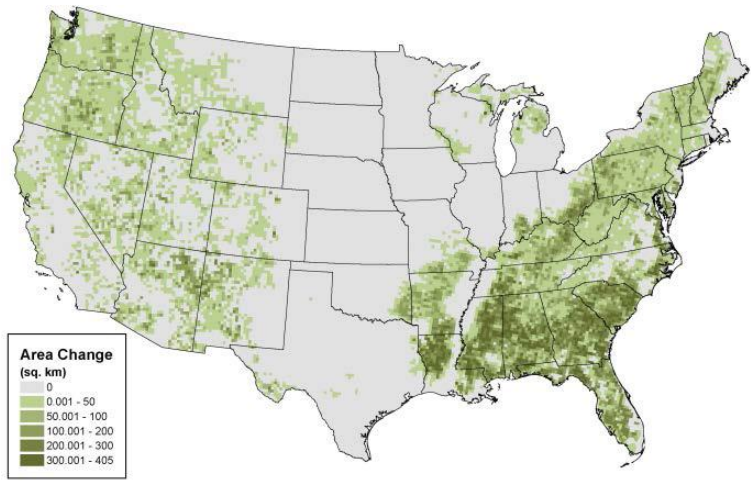


Wind Turbine Towers for Greater Hub Heights

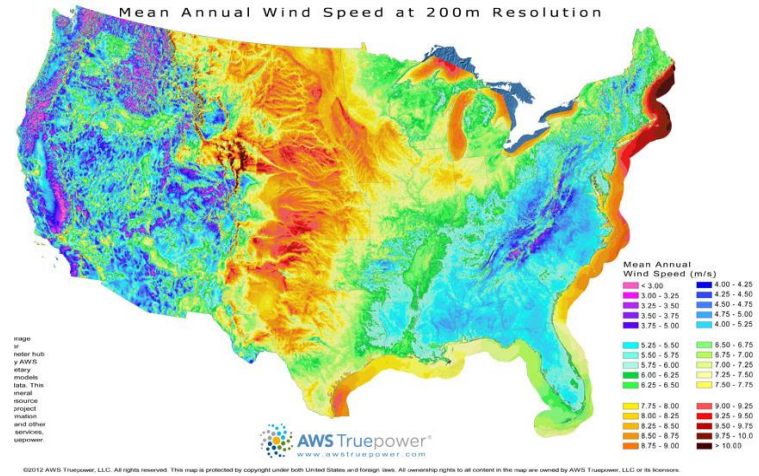
Why higher wind turbine tower can contribute to increase energy output?

- Energy output is proportional to the cube of wind velocity, 100m towers (versus 80m) would produce about 12% more power per installed turbine (NREL)



Source: NREL Report No. TP-5000-61063.

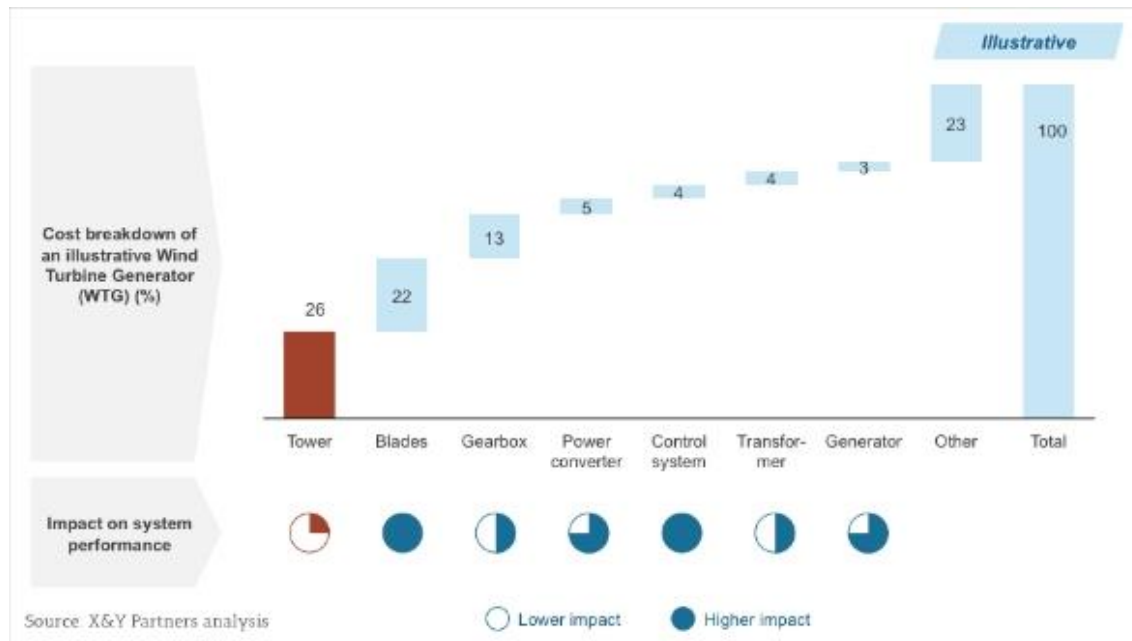
Expanded Area of Potential Wind Energy Deployment Resulting from Increasing Hub Height from 96m to 140m



Source: NREL and AWS Truepower

Land-based Annual Average Wind Speed at 200m Resolution

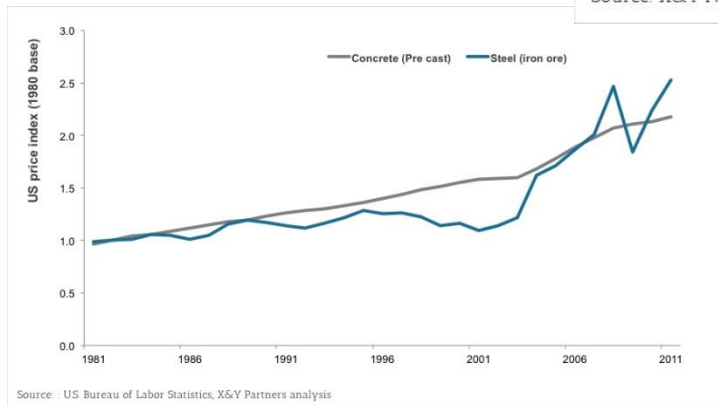
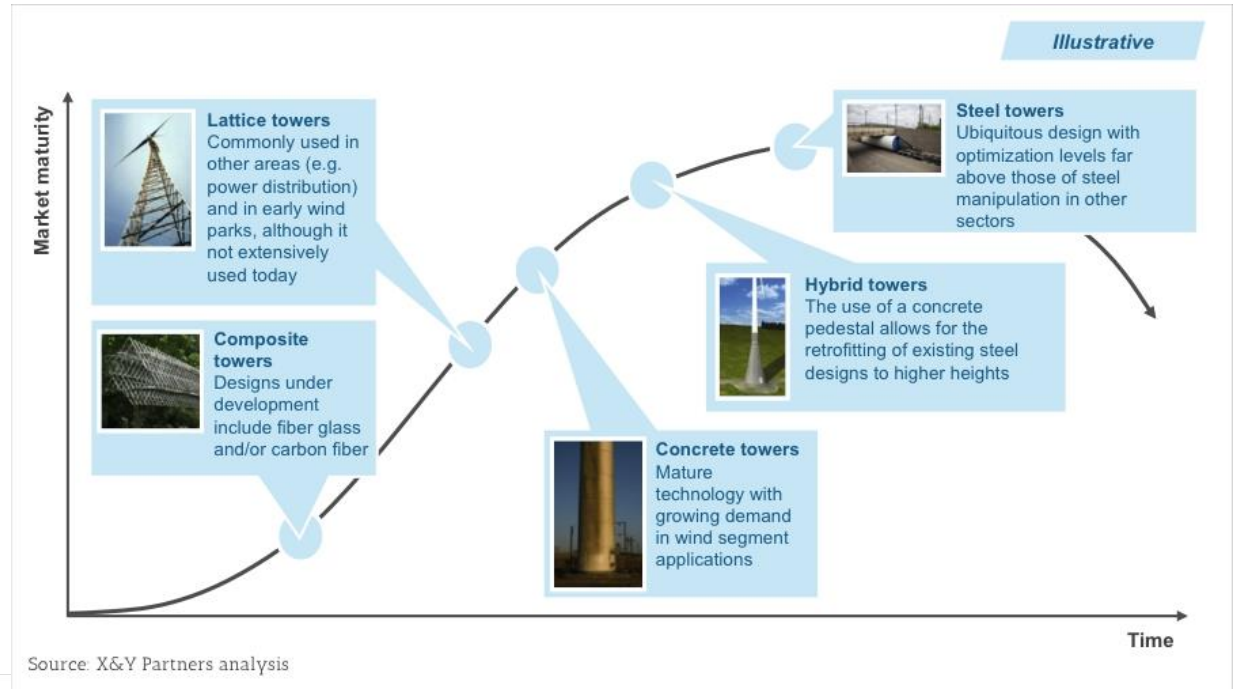
- wind towers represent 26% of the total WTG (Wind Turbine Generator) cost



Why concrete tower is an alternative for higher wind turbine tower?

Steel towers:

- Limited environmental impact
- Transport as complete tubes
- Speedy construction



- Limitation in tower base diameter;
- Deeper foundation;
- More volatility in price than concrete

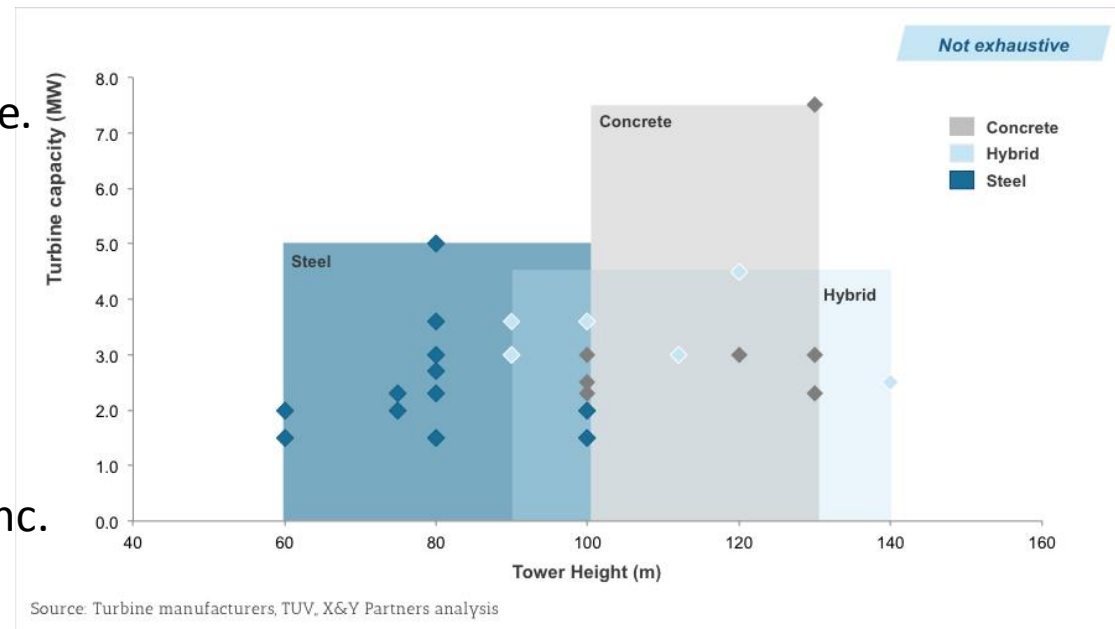


Concrete towers:

- Easy transportation with small modules;
- Allow for mobile factories;
- Deflection (3''-3'/300ft tower);
- Increase steel's 20 year tower life.

Two designs:

- Full concrete designs
 - Enercon;
 - Acciona;
 - Inneo Terro;
 - Precast Concrete Tower Inc.
- Hybrid system
 - Advanced Tower System;
 - Tindall



Sample of current offering of turbine-tower combinations





Acciona Windpower Concrete Tower



- Prestressed concrete shells (precasted in the mobile factory and transported to site)—20m



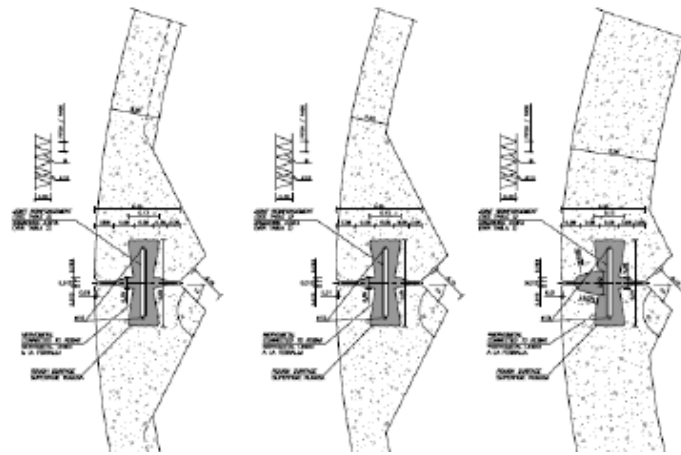
Source: Acciona Windpower





Acciona Windpower Concrete Tower

- Joined through vertical patented joins on site configuring 20 meters tower sections



Source: Acciona Windpower





Inneo Torres

- Great interior space at the base of the tower thanks to its larger diameter, which promotes the assembly of equipment within the tower on one level without space constraints.
- Very easy to anchor on the walls of the tower interior elements and equipment needed.
- Not conditioned by transport limitations and therefore provides freedom in the choice of the geometry of the tower



Source: Peña Blanca Wind Farm, featuring a tower of 100 m



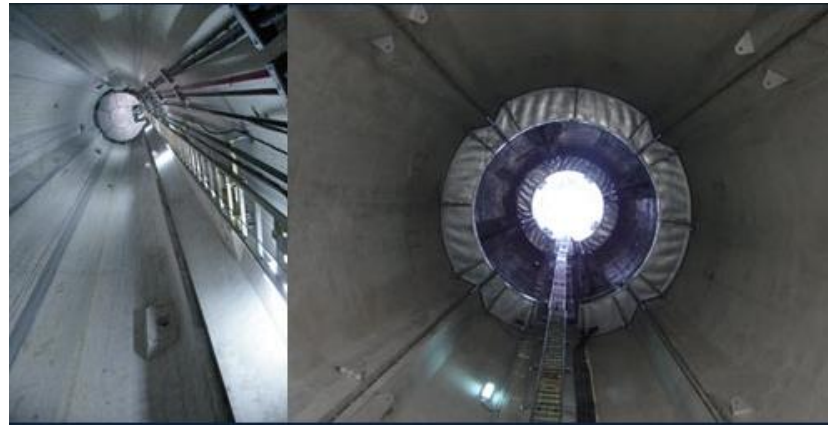


Inneo Torres



Source: Peña blanca Wind Farm, featuring a tower of 100 m

- **Functionality**
Larger door that allows the passage of the complete equipment, which greatly facilitates installation or repair possible and, in some cases, avoids the need for additional booths for processing equipment.

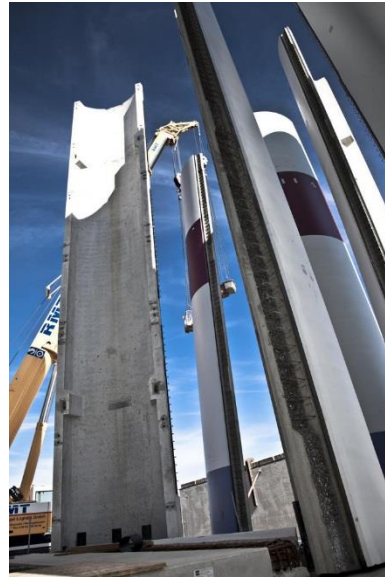


ATS Advanced Tower System (ATS hybrid tower)



Advanced Tower Systems BV

- combines a pre-cast concrete segmented tower with tubular steel sections on top.
- consists of three or more 15 meters long, slender segments and corner elements



ATS Advanced Tower System (ATS hybrid tower)

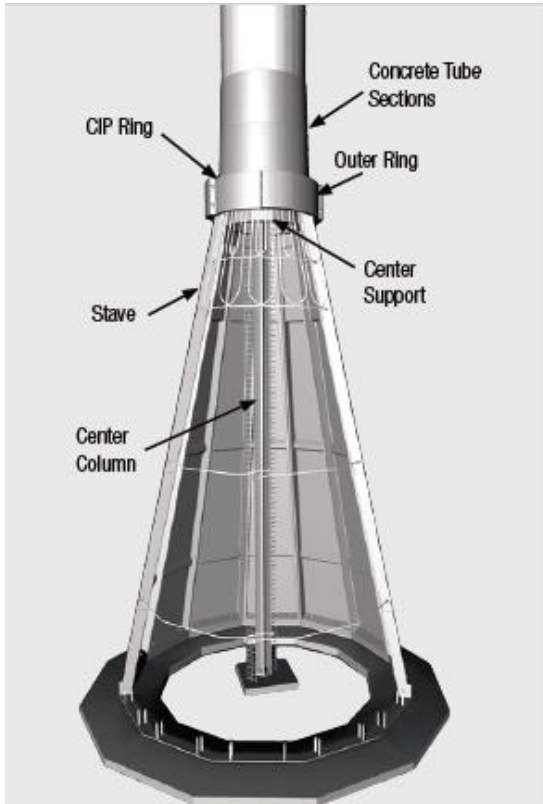


Advanced Tower Systems BV

- The lower tower sections, which require a diameter bigger than the 4.3m transport limit, are vertically divided into three or more slender segments made of high-quality pre-cast concrete. The segments can be easily transported via ordinary trucks.
- The installation of the entire tower takes less than a week and can be done under most weather conditions.



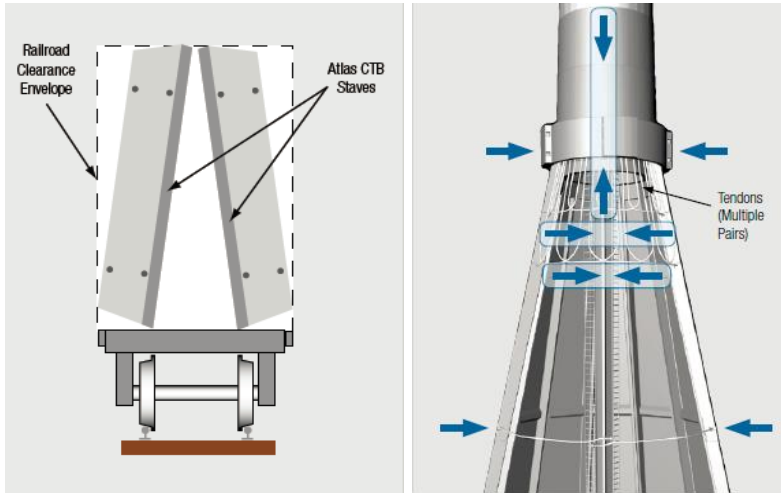
Tindall - Atlas Concrete Tower Base



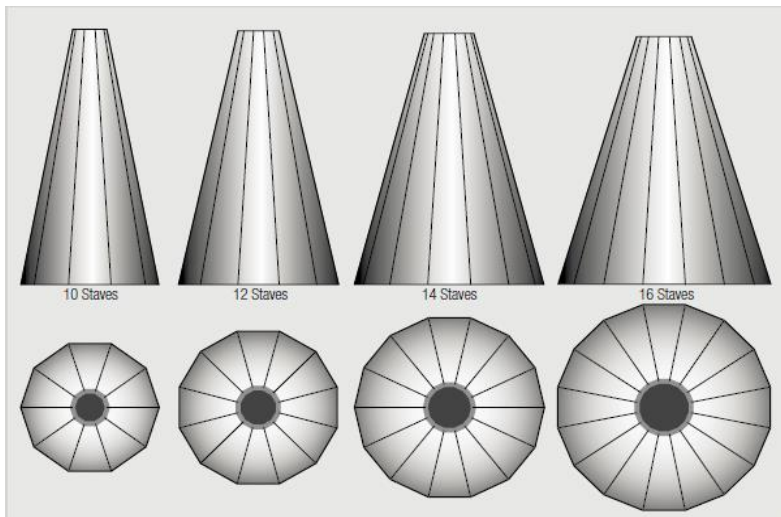
- Accommodates 100 -140 meter class hub heights
- No bolts – post-tensioned tendons only
- Components can be factory manufactured or site cast
- Employ prefabricated concrete rings bolted together on-site and post-tensioned using external tendons.



Tindall-Atlas CTB



- A pair of Atlas CTB staves are easily transportable by rail within a 3-m Width x 4.5-m Height conventional rail transportation footprint.



- One size stave with multiple base diameters makes easily transportable in pairs by rail;
- As the number of staves increases, so does the base diameter, making this design concept able to accommodate the loads presented by higher towers and larger output turbines



Technique challenges in tower design

Short-term loads:

- **Seismic/earthquake loads:** Tower may not be capable of resisting the local seismic demands.
- **E-stop:** The short/hard stop creates a shock load spectrum on the structure and results in a drastic dynamic impulse load to the system, resulting in large lateral deflections.

Long-term sustained loads:

- The most unique aspect of wind tower structural design is the dynamic characteristics and fatigue-related issues. Long-term loads are the normal operational wind loads that include dead, live, static wind pressure and standard operational overturning moments, shears and axial loads. The frequency of these long-term sustained loads may reach over 20,000,000 cycles in 20 years. Therefore, every aspect of the tower-foundation design must consider these provisions.



Questions

Thank you !