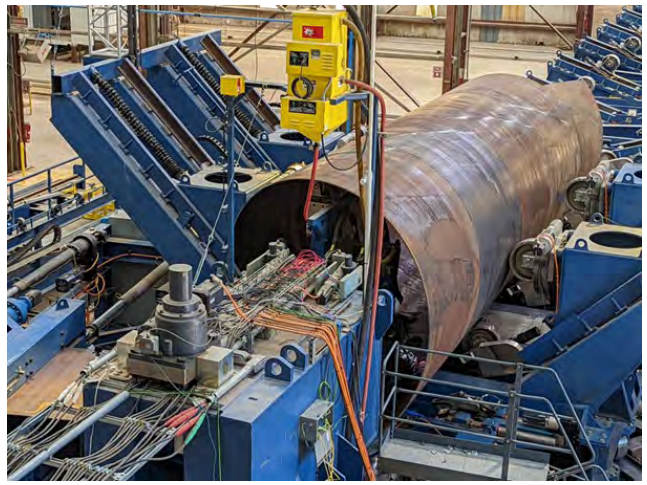
Keystone
Tower Systems

# Next Generation Towers For The Next Generation Of Wind Power

## WESE Workshop, August 31st, 2022

**Eric Smith, CEO Keystone Tower Systems**

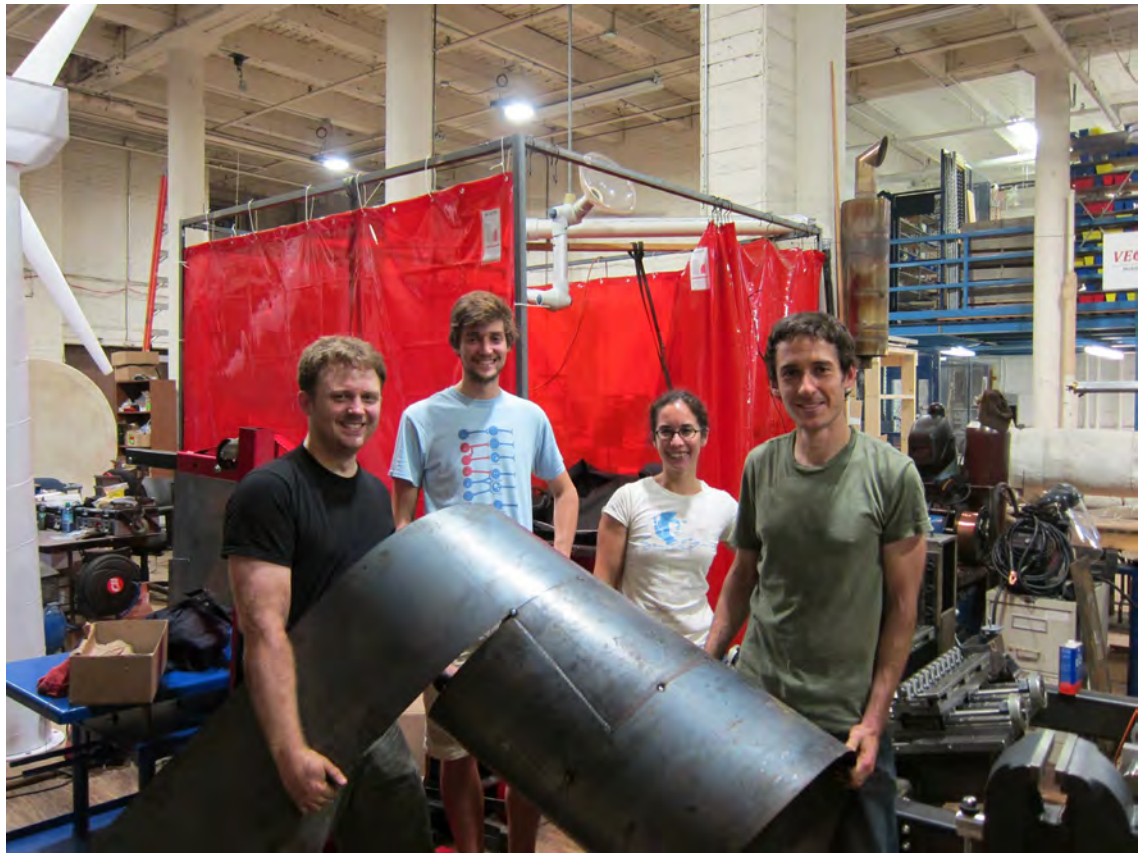
Keystone Tower Systems

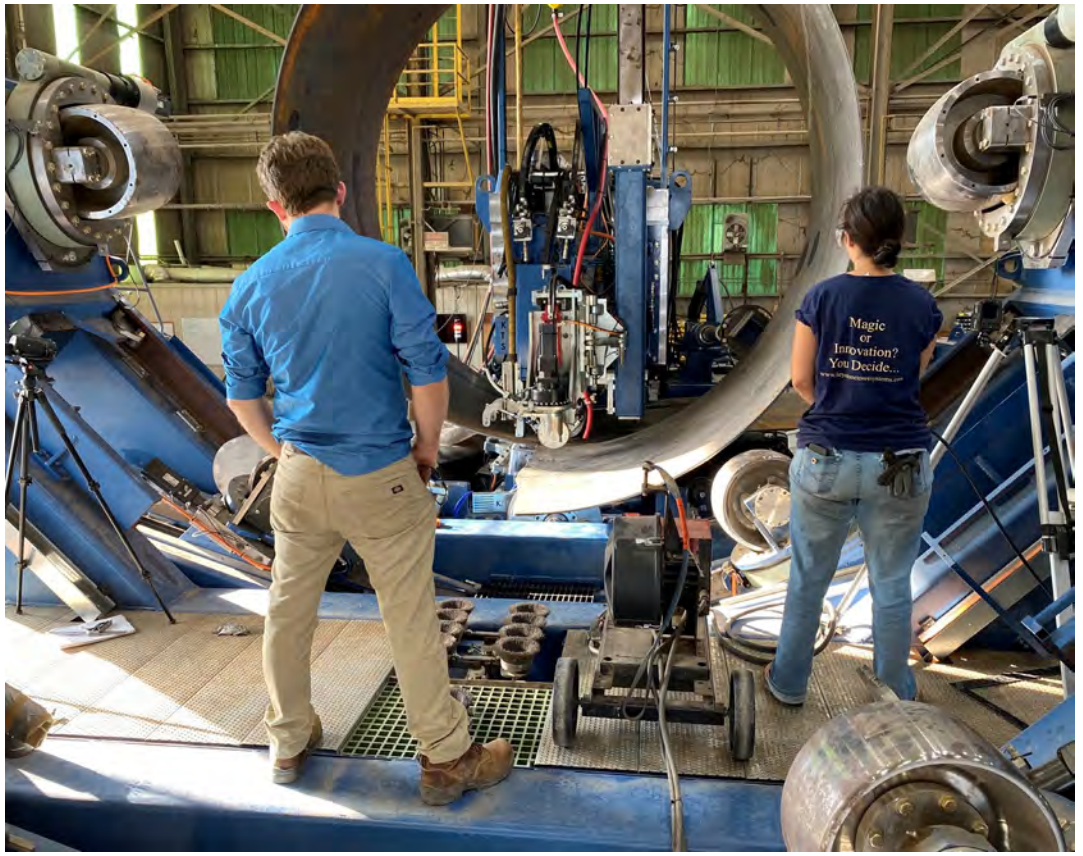



# Building Next-Generation Towers for the Next Generation of Wind Energy

Optimized Tower Design / On Site Manufacturing / Innovative Technology

# Keystone Tower Systems
## 10 years of making cones





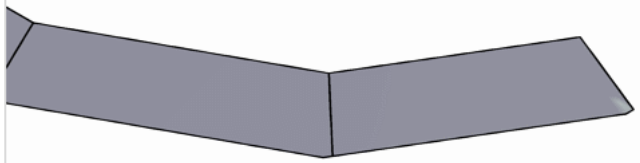
# Our Tapered Technology Brings Spiral Welding To The Wind Industry

Protected globally with over 100 patents issued or pending in 30 countries

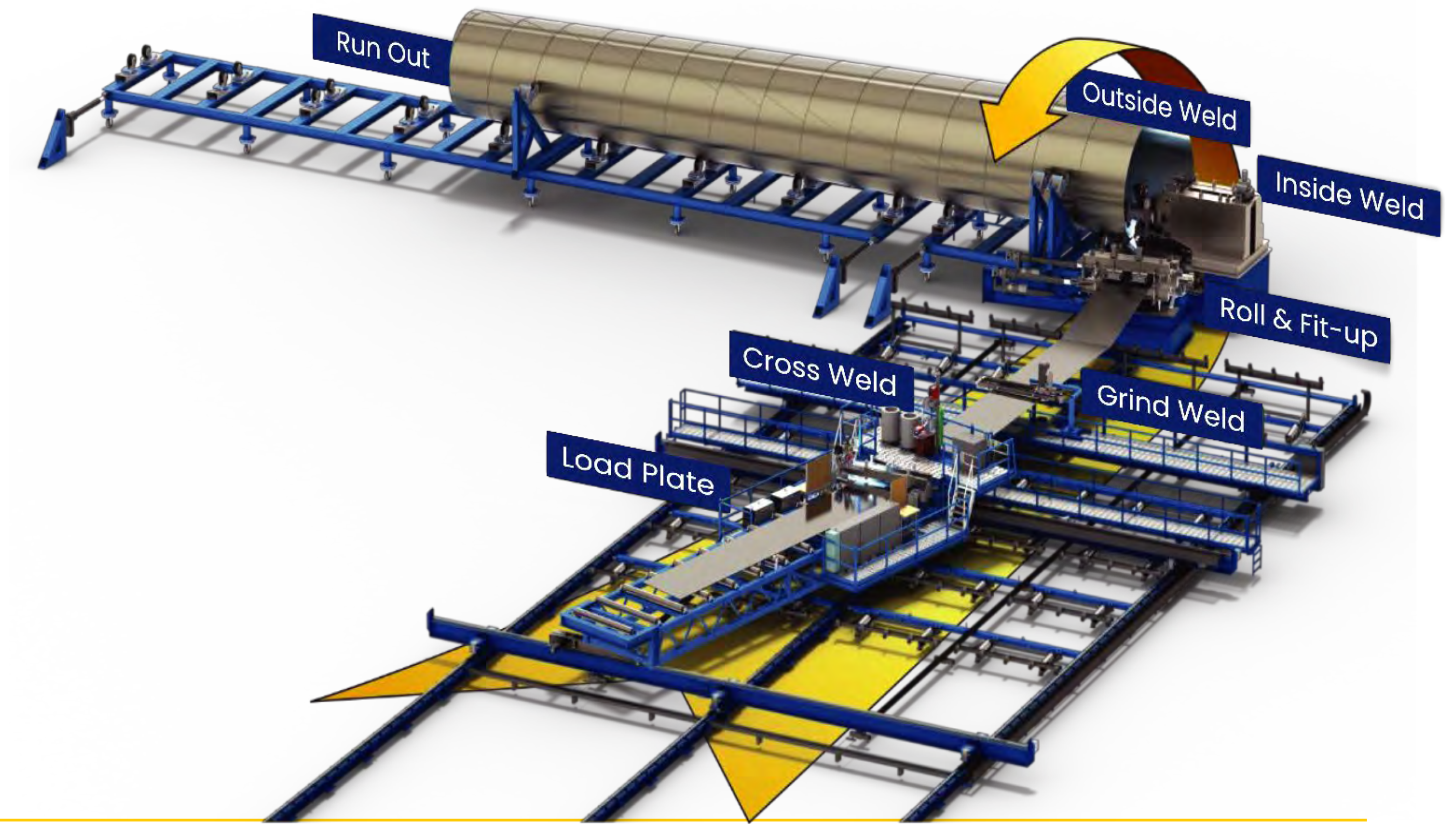
## Keystone's patented manufacturing process:

- Tapers the tower and allows for on-site fabrication
- Can scale to the size needed by next-gen turbines
- Welding is 10x faster than manual tower fabrication
- Offers higher-quality, lower-cost towers

Towers are manufactured using constant-width sheets in a single continuous process.



Link to video: https://vimeo.com/191028513
Password: Keystone



# Video of Keystone Spiral Welding process

Link to video: https://vimeo.com/674261638
Password: Keystone

# Conventional Spiral Welding

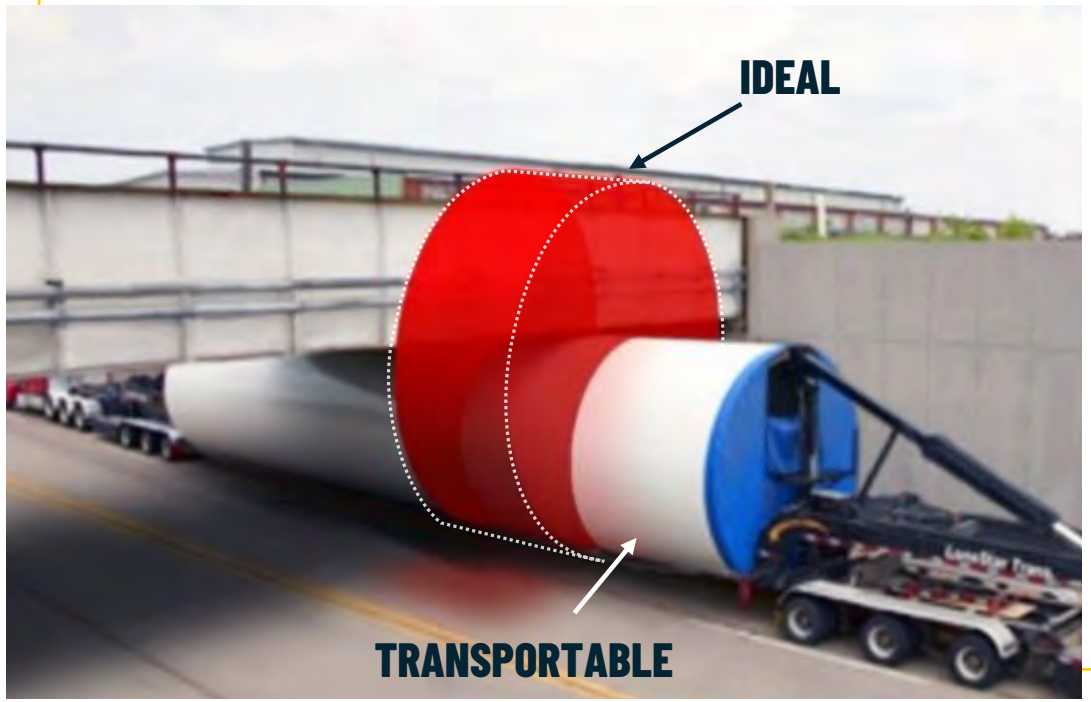
- Mainstream process for 80 years
- Preferred method for large diameter pipe and piles
- Only capable of fixed diameters
- 10x faster than processes used in tower factories
- Proven track record of on-site operation

# In-field Factory

# The challenge and value of diameter

Keystone Tower Systems

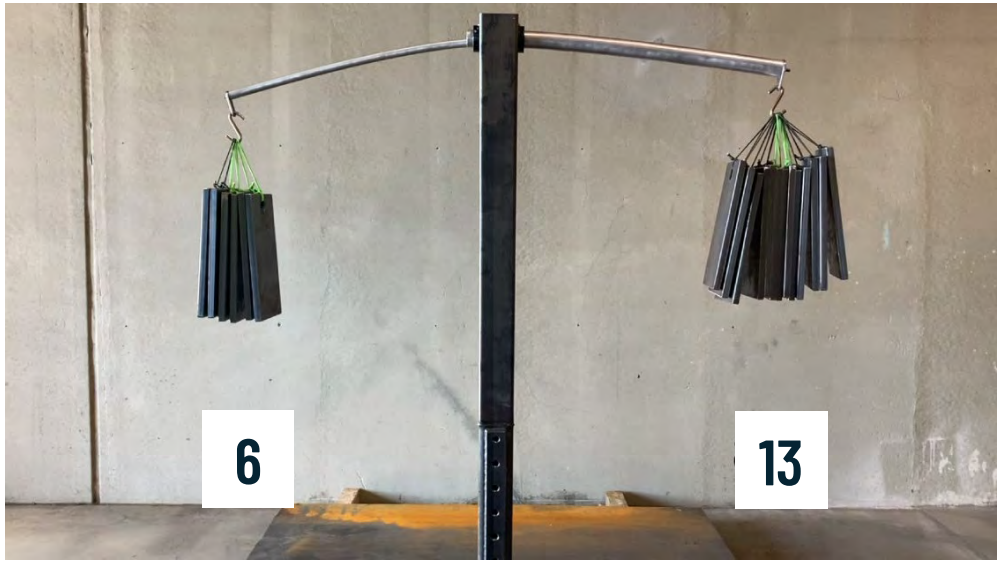
## Tower diameters are determinized by logistics, not structural optimization




## Same Weight

- **2x** the diameter
- **50%** the wall thickness

- **>2x** as strong
- **>>2x** as stiff



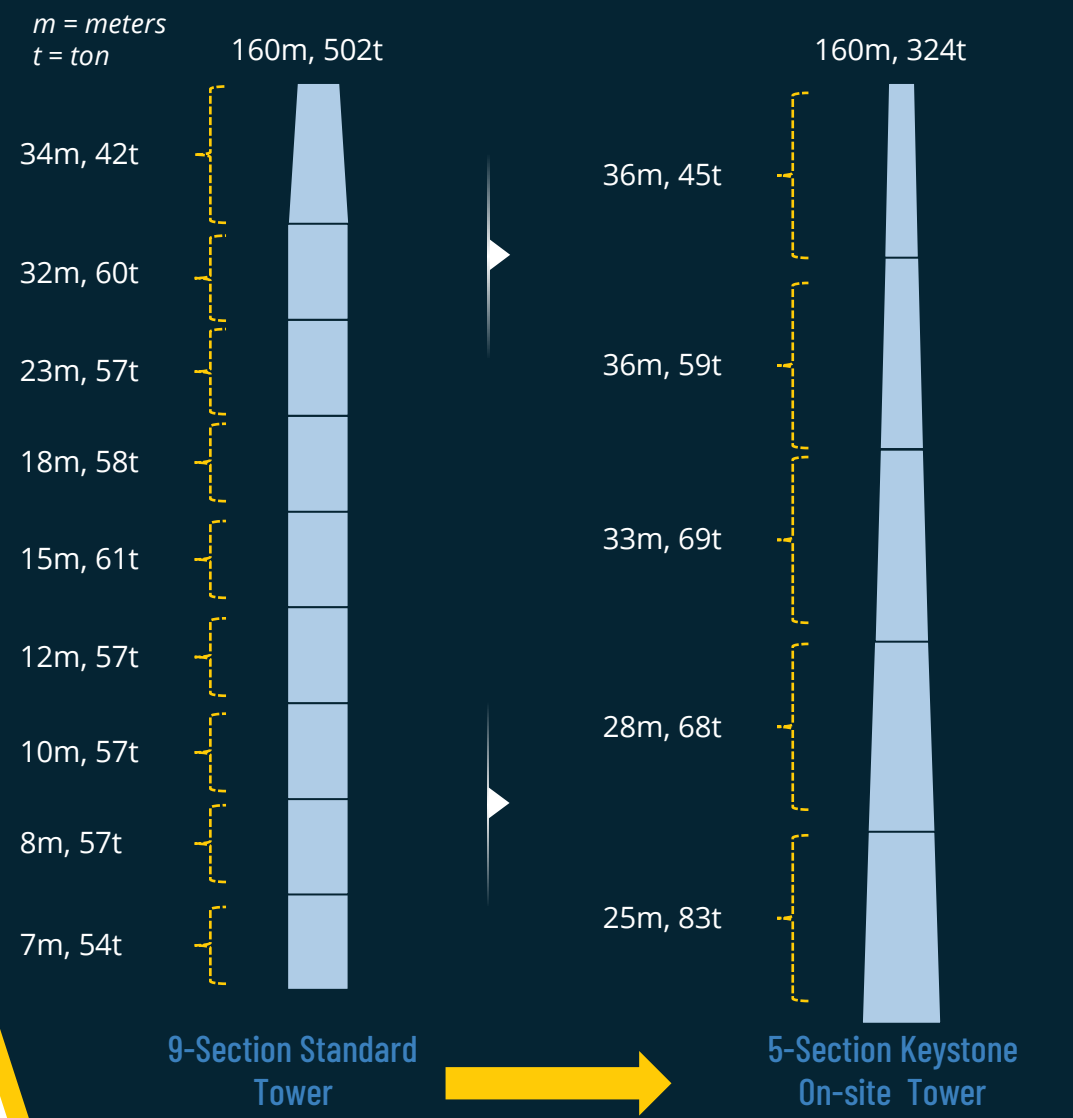
# On-Site Advantages vs. Current Towers

## Example: 150 – 170m class towers
Future design for expansion into new regions

Elimination of transport constraint enables:

- Less steel due to larger diameter sections
- Longer and heavier sections
- Fewer sections:
  - ✓ Faster installation
  - ✓ Elimination of a platform
  - ✓ Elimination of a flange set

**Example:**
**160m class towers**
**5MW turbine**



# Market Expansion with Tall Towers

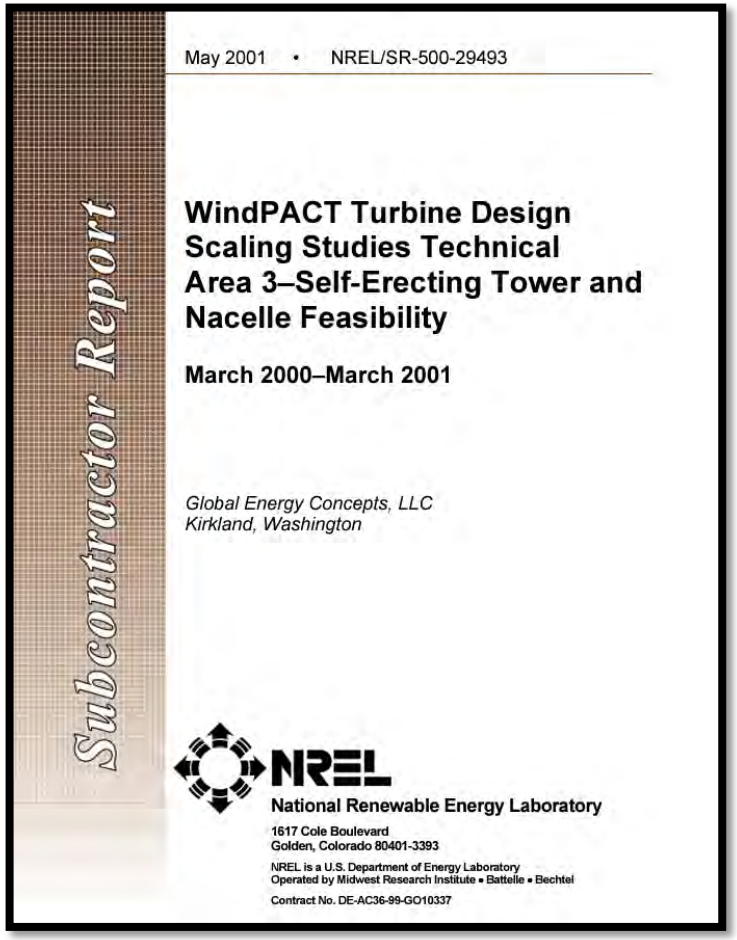
## 3x developable area /
## 3TW of new potential capacity /
## 10% reduction in nationwide LCOE

### Wind Development at 80m


### Wind Development at 160m

# The Keystone Journey

# Systems Engineering based Technology Search (2007-2008)

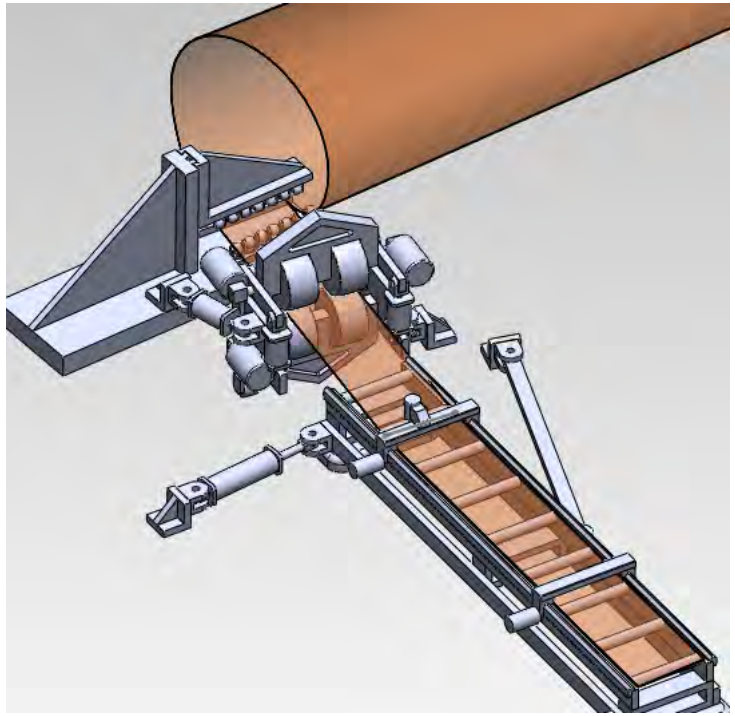


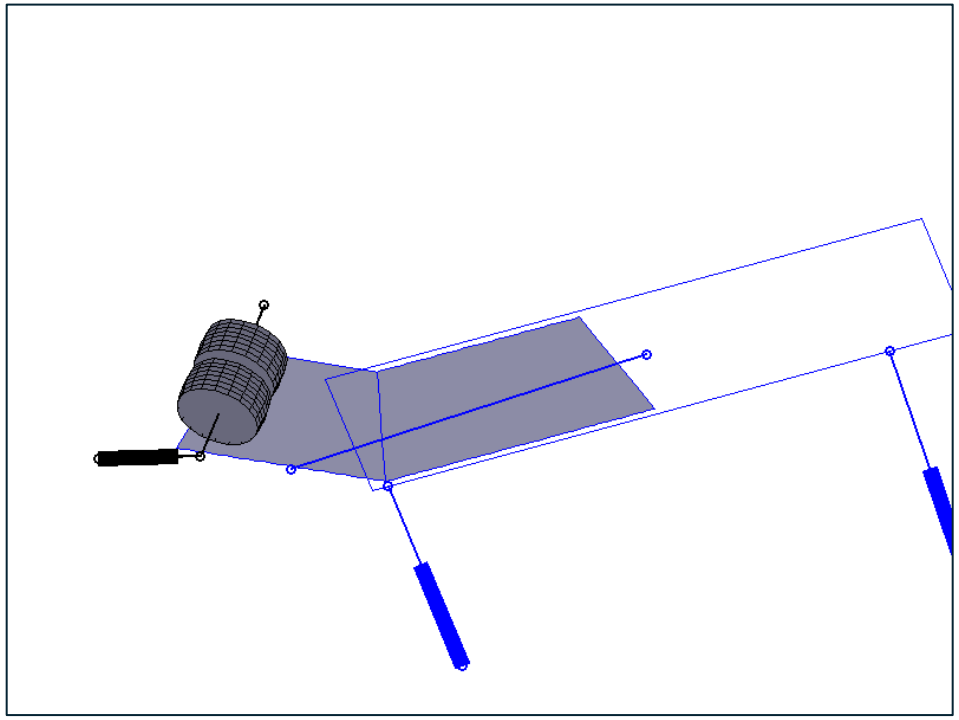

Consulting work:

Evaluating value of innovation for 5MW scale turbines

- Alternative drivetrains
- Advanced controls
- Blade manufacturing
- **Tower Logistics**

# Founding – DOE SBIR 2010-2011

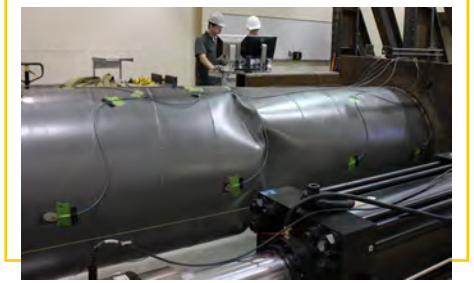




# First Bent Steel

# Proven Technology


**TESTED Process**



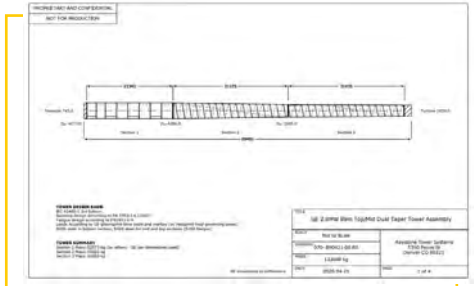
**PROVEN Structural Performance**

**PROTOTYPE running for 5 years**

- First full-scale mill, with 1 GW per year capacity, built in 2021 in Pampa, Texas
- Tower design approved; shipments to first major OEM customer in 2022
- Demonstration of on-site fabrication with industry leaders secured for 2023

# Industry Acceptance


**3RD PARTY CERTIFICATION, bankable**



**Designed with LEADING TURBINE OEMs**

**Long term sales to LARGEST US TOWER BUYER**

# Machine Build in Pecos - 2020

# Technology roll out

## 2021

**ON-SHORE TOWERS**

Cost-out of standard size towers

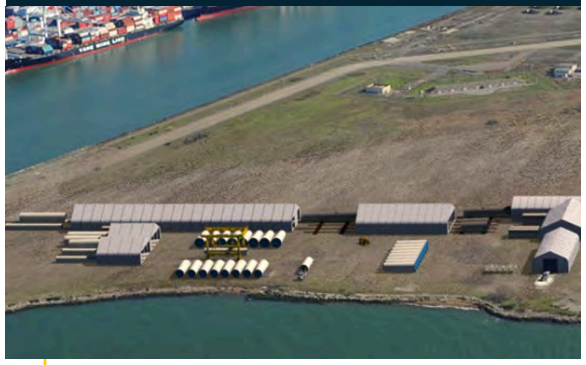
## 2023

**ON-SITE FABRICATION**

Scale-up to larger towers

## 2025

**OFF-SHORE TOWERS**



Apply technology to Off-Shore

# Technology roll out

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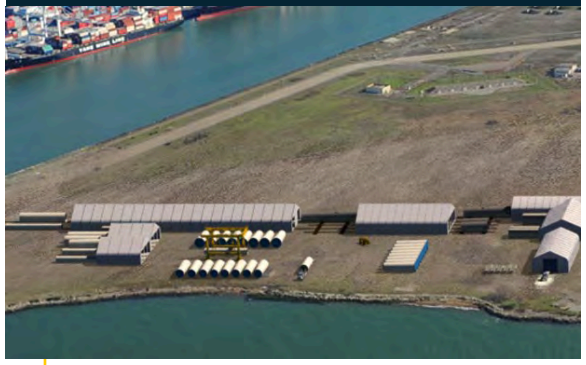

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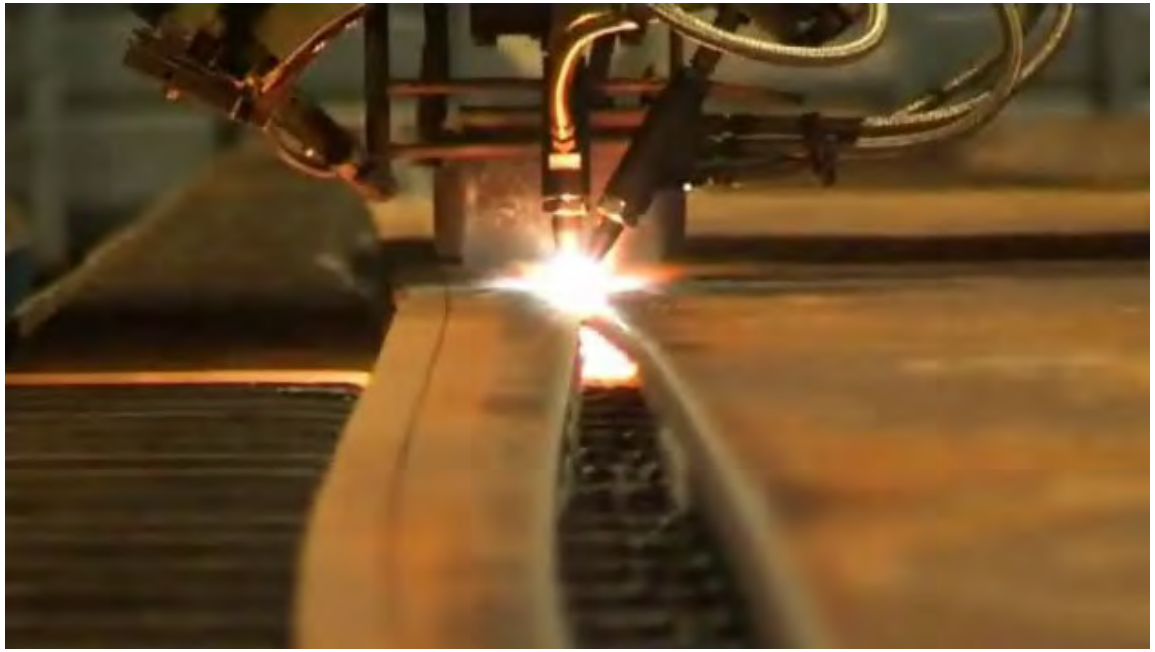
# Efficient and Cost-Effective Continuous Manufacturing

## Traditional Tower Manufacturing

50+ hours per section



## Spiral Welding

<5 hours per section

# Technology roll out

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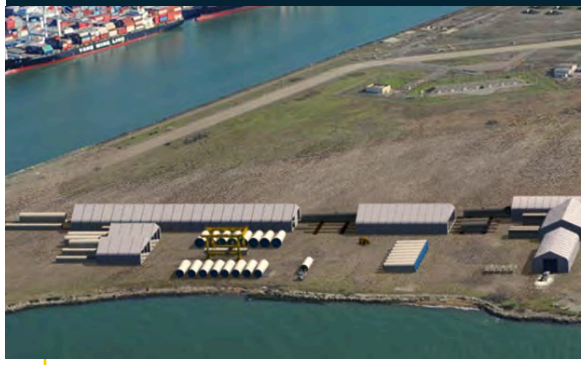

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# Keystone Solutions

## On-Site Demonstration


Detailed Design
Proof of SE business case

Phase 1 2020-2022:
Techno-Economic analysis of site-produced, high hub-height spiral welded towers in US South-East

Technology Demonstration

Phase 2 2022-2023:
Complete regulatory approval, on-site fabrication, and installation of two turbine demonstration project

# Industry Trends

## Large Projects

- Transmission driven wind development results in clusters wind construction
- logistics costs can be greatly reduced with regional manufacturing

MidAmerican unveils 2.1GW Iowa clean power project

reNEWS.BIZ

PCW submits permit application for 3GW wind project in Wyoming

POWER TECHNOLOGY

Xcel proposes $1.7B transmission investment in Colorado to unlock nearly 5.5 GW new renewables

UTILITY DIVE

## Large Turbines

- Larger turbines exert greater forces on towers, requiring greater strength
- Existing tower designs have reached manufacturing and transport limits
- Next generation turbines will require a new tower solution


Siemens Gamesa boosts SG 5.X-170 onshore wind turbine to 6.6MW

WINDPOWER MONTHLY

Dane Vestas unveils 'next level' 7MW class EnVentus onshore wind turbine

RECHARGE

## Tall Towers

- Current towers do not cost effectively scale beyond 120m
- Tall towers enable turbines to reach good wind resources outside of the plains states, bringing wind generation closer to demand

Georgia Power plan confirms move from coal to renewables

The company, which operates no wind generation in Georgia, will seek a pilot program to test supertall wind turbines in the state, Georgia Power CEO Chris Womack said.

AP AP NEWS

Energy Dept.: Taller Wind Turbines, Longer Blades Will Make Wind Power Ubiquitous in the U.S.

POWER

# Technology roll out

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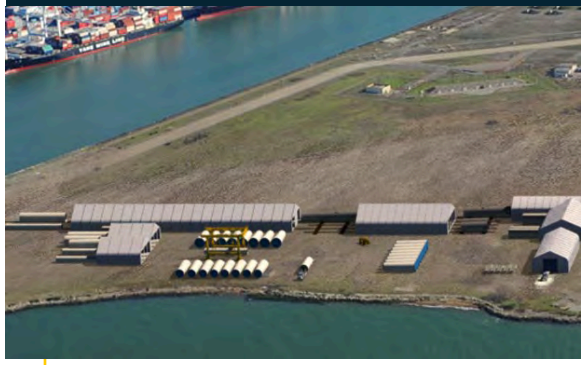

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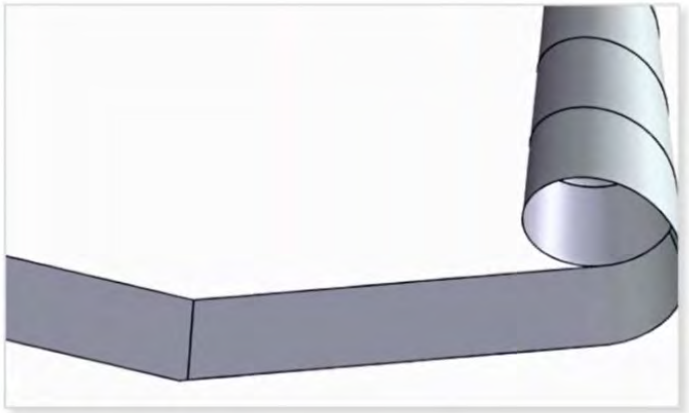
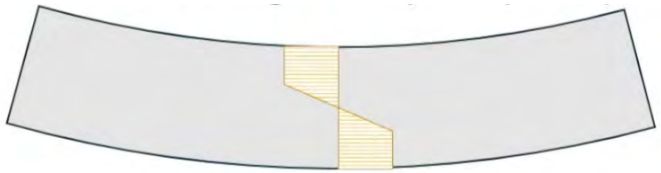
# Technology Scale-up

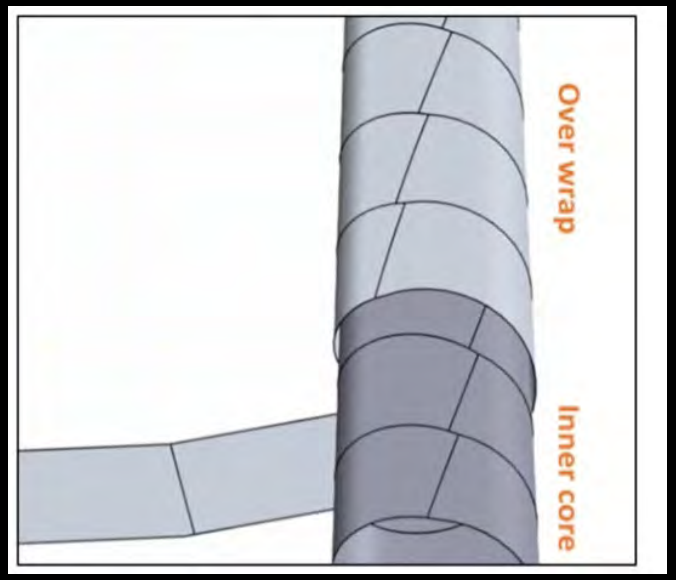
## Two paths for Adapting to Offshore Tower Sizes

### Single wrap

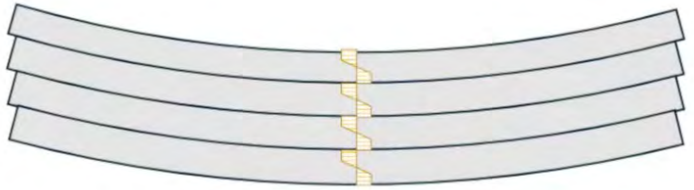




### Multi-wrap




30X less bending force required ($t^2$ to $t^3$)



# Technology De-risking

**Tailwinds:**

- Known manufacturing technology from pipes
- Similar structure to current tower designs

- Clear path to design and certification
- Easy integration – technical (no changes to turbine)
- Easy integration – business (outsourced component)

- Proven at partial scale

**Challenges:**

- Physical scale
- Production volume
- Minimum viable product

- Capital and time to revenue
- Customer integration (many stake holders)

# Execution De-risking

**Functionally identical towers**

- Same dimensions as current designs

**Easily substituted towers**

- Regional production
- Matched hub-heights
- Matched foundation interface?

**Differentiated tower designs**

- Greatest value creation (increased hub height)
- Alternatives very challenging

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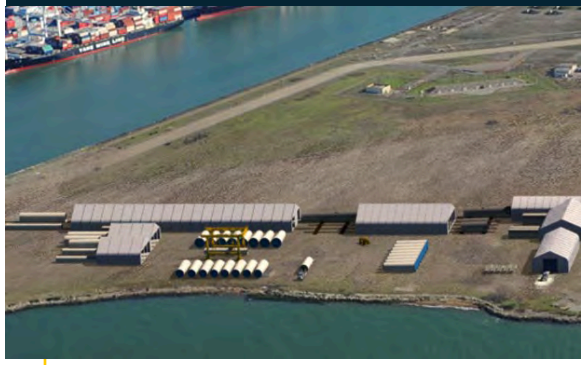

Apply technology to Off-Shore

# THANK YOU

## CONTACT

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