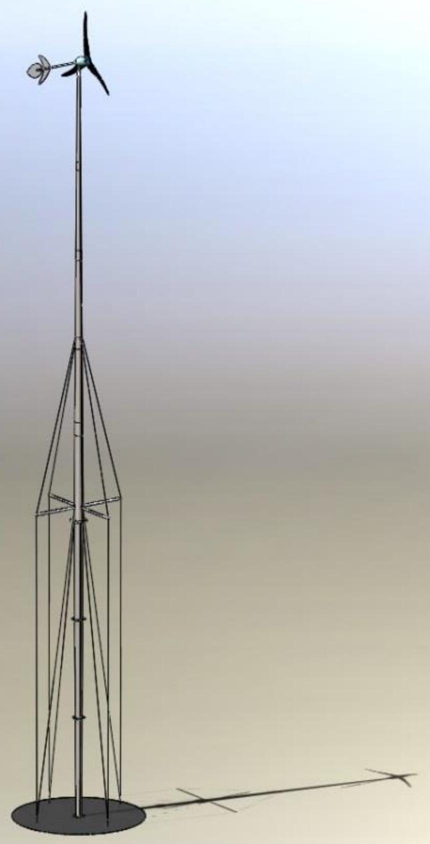
Getting High: Lighter, Taller, Monopole Towers!
AnemErgonics Reduces Small Wind Turbine Energy Costs with Exoskeleton Tower



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About AnemErgonics

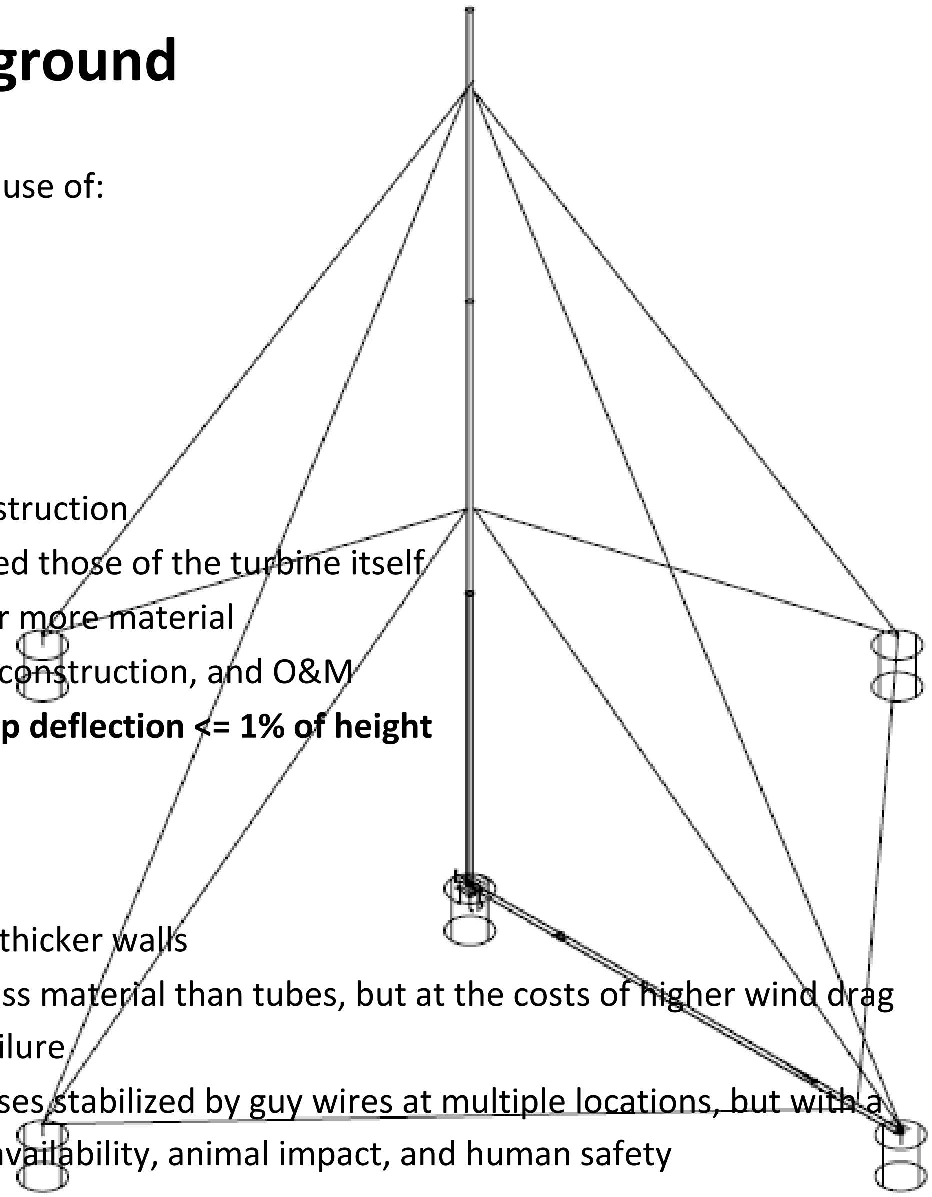
- Mission: to enable small wind by reducing installation costs
- Foundation Kit: Simple Modular Technology (SMarT)
  - Build foundation in one day
- Fiberglass Towers: Up to 70’ monopole with ginpole installation
- Turbine Sizes: up to 3 kW so far; working on 6 kW
- Location: Arvada, Colorado (Denver area)
- Founded: 2005

Introduction

It's hard to get high when you're worried about TIA-222-G!

- Telecommunications Industry Association
- Maximum deflection: 1% of the tower height at the service load (60 mph, 3-sec gust)
- That means 12" max for a 100' tower
- Several small wind towers we've looked at approach 1.5-2.0%
- Weights will have to go up to comply
- FAST alternative possible; may need more work

Background



Premise: Higher wind turbines produce more energy, because of:

- Higher windspeeds
- Less obstructions
- Less turbulence

Challenges: Costs go up with wind turbine height:

- For both towers and foundations; materials and construction
- Tower, foundation, and installation costs often exceed those of the turbine itself
- Requires some combination of larger sections and/or more material
- Increased weight and burden on shipping, handling, construction, and O&M
- **Stringent new TIA-222-G requirements for tower top deflection <= 1% of height**
- 66-yo climbers…

Traditional Approaches:

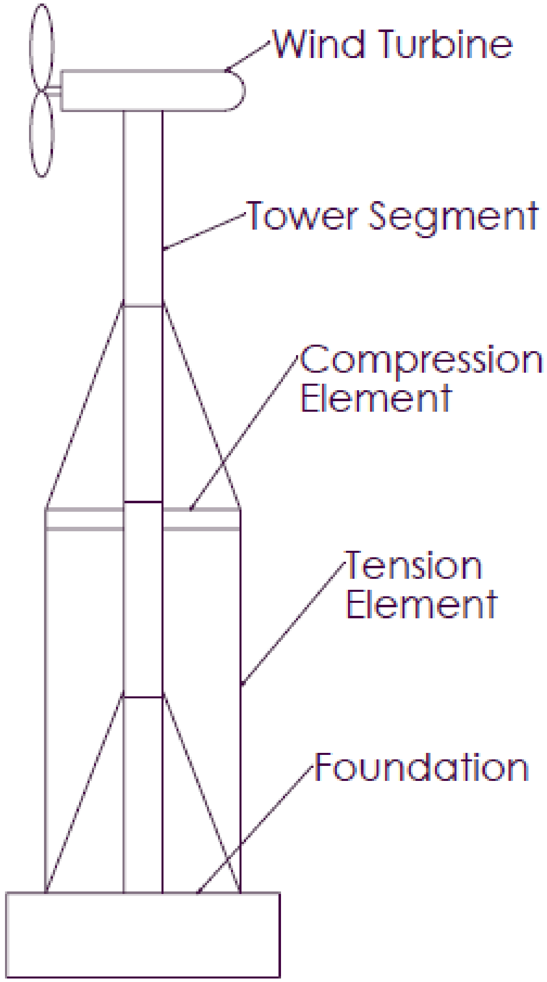
- Monopole (free-standing tube) with wider base and thicker walls
- Free-standing truss to achieve larger sections with less material than tubes, but at the costs of higher wind drag and more parts for assembly, O&M, and potential failure
- Guyed towers with relatively thin, light tubes or trusses stabilized by guy wires at multiple locations, but with a very large footprint of land, with challenges of land availability, animal impact, and human safety

Exoskeleton Tall Tower (ETT)

(US Patent Pending)

New Application: AnemErgonics is developing a tower system that transforms the fundamental nature of a typical monopole tower from a cantilevered bending design to a hybrid tension/compression/bending design by the following approach:

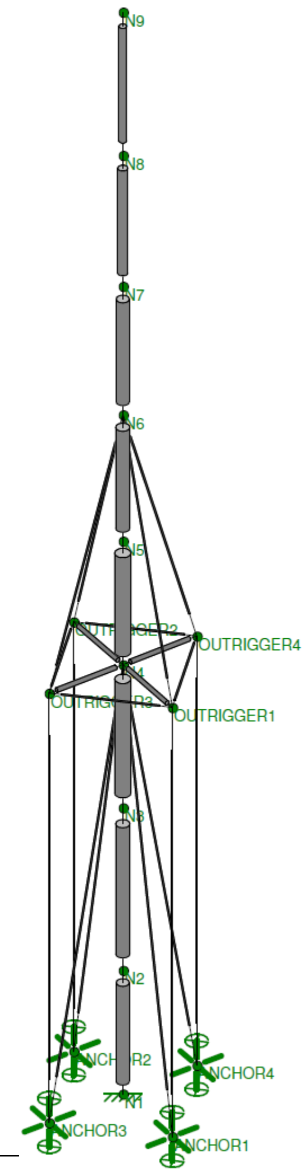
- Stabilize a lighter central tube with external tension and compression elements
- Similar to sailboat masts using "stays" and "spreaders"



Exoskeleton Tall Tower (ETT) Advantages

<u>New Application</u>: The ETT approach aims to achieve the following:

- Reach tower heights up to 150’ at reduced costs
- Reduce central tube dimensions and thus total weight by 40% over equivalent monopoles for easier shipping, handling, and installation
- Stabilize the central tube with external tension cables and compression arms
- Maintain a small footprint, with diameters less than 25% of tower height
- Reduce bending stresses and increase the structural efficiency of the tower system
- Enhance buckling strength with nodal restraints
- Reduce tower top deflections
- Increase tower stiffness, and thus the frequencies of the three modes of vibration, and the ability of the tower core to resist dynamic loads
- Facilitate installation using a ginpole and winch
- Facilitate modular design for compact, low-cost shipping and easy installation
- Darn socks faster than Greg’s grandmother



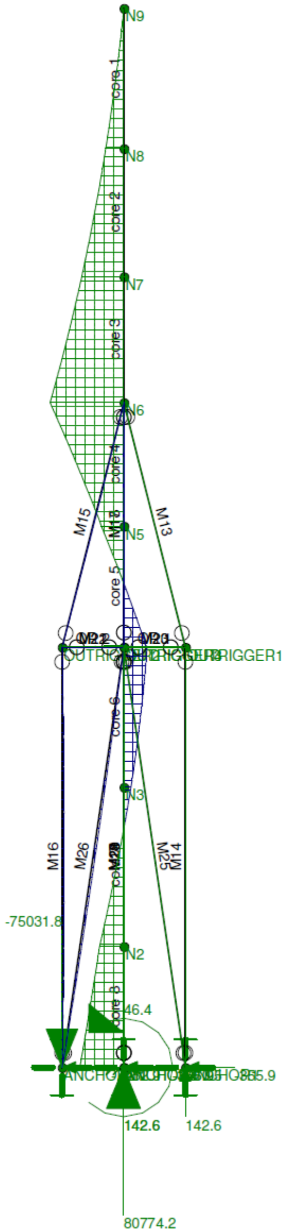
ETT Design and Engineering

Design Inputs:

- Design wind speed
- Rotor diameter and tower top load
- Tower height
- Slip-fit or flanged joints
- Number of cable sets, cable attach points, and compression arm locations
- Inner and outer cable-attachment points
- Base diameter restrictions, anchor separation, and foundation dimensions
- Applicable standards (ie: TIA-222 appears dominant in USA)

Design Outputs:

- Families of towers are anticipated for various turbines at varying heights up to 140’
- Tower segment capacities
- Tower-top deflection
- Guy tensions
- Footprint and foundation design
- Weight
- Packaging and shipping plan
- Installation plan and equipment



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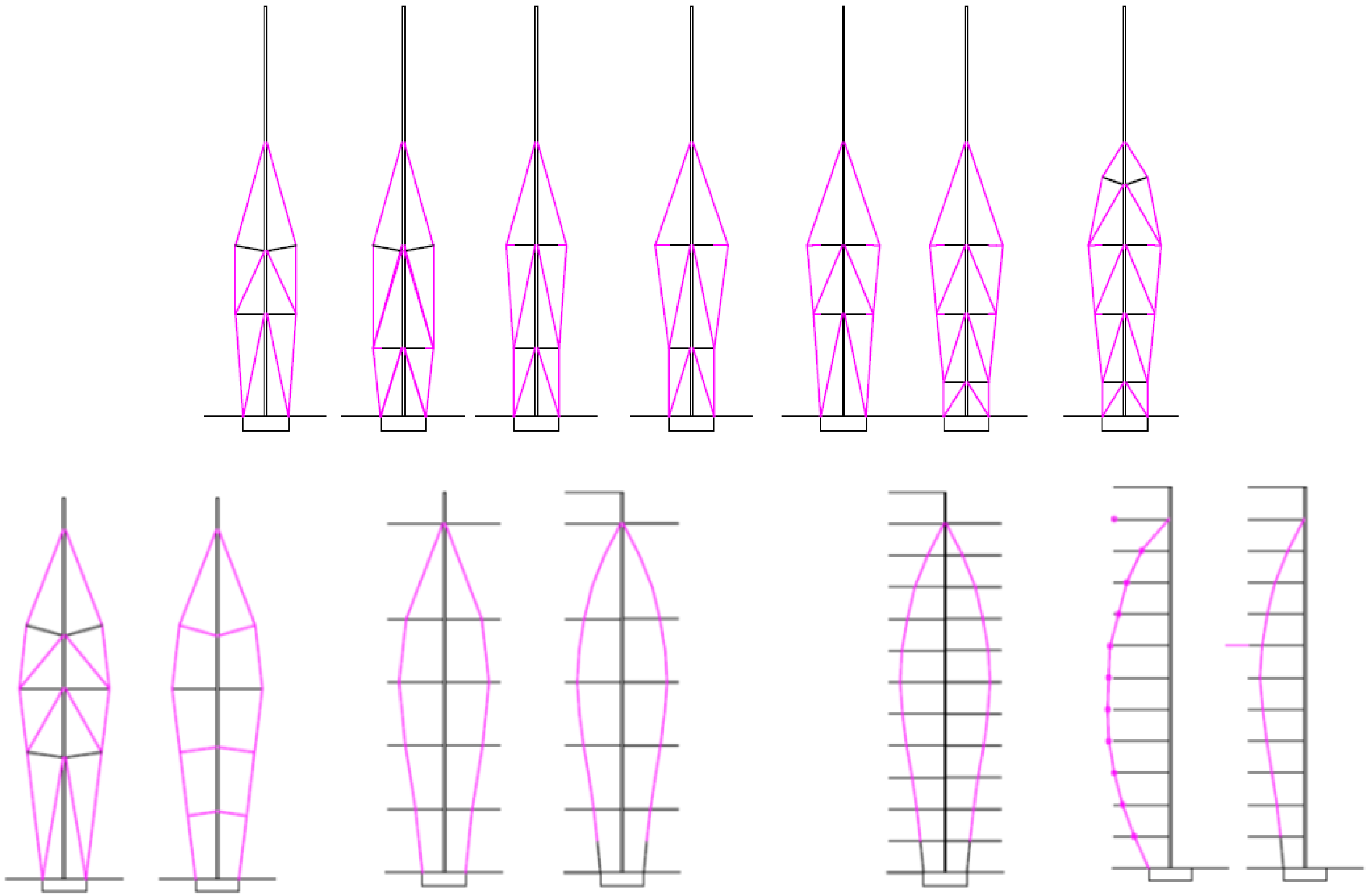
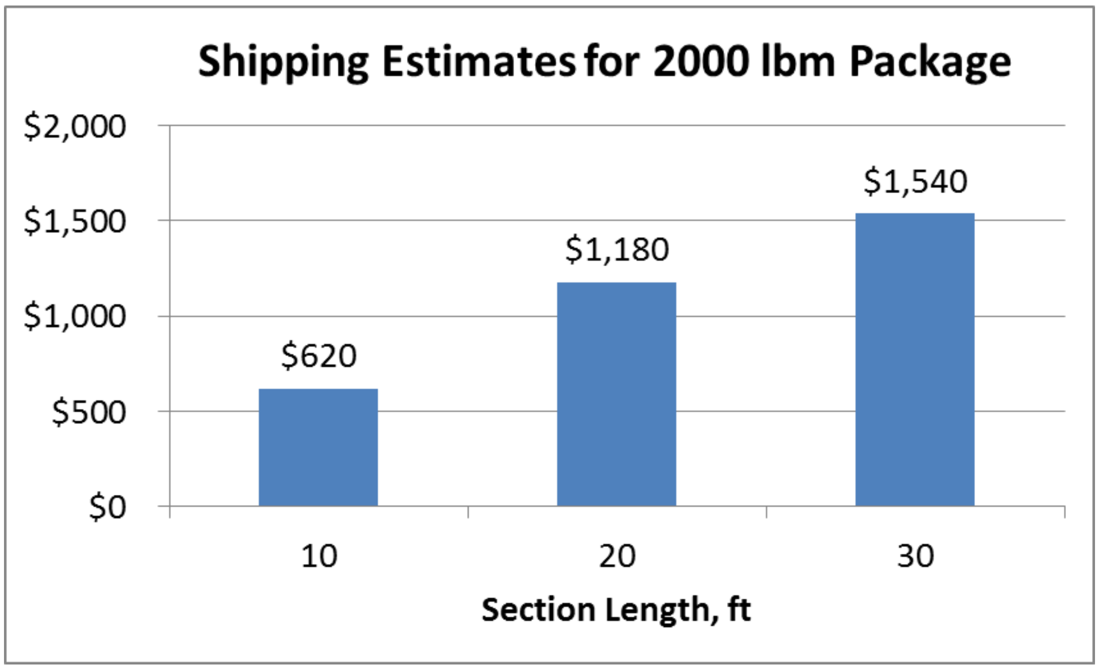
ETT Design Configurations



ETT Shipping Challenges

How Important? Shipping prices vary widely depending on circumstances, and may be important to design choices.

- Compact packaging for LTL shipping and competition among multiple carriers
- Double the weight and double the cost, but it would appear the same applies to section length
- Estimates below are based on price per pound:



Installation Techniques

Installation and Maintenance: An analysis of various installation and maintenance systems indicates a hinge and ginpole system as the lowest cost for labor and equipment:

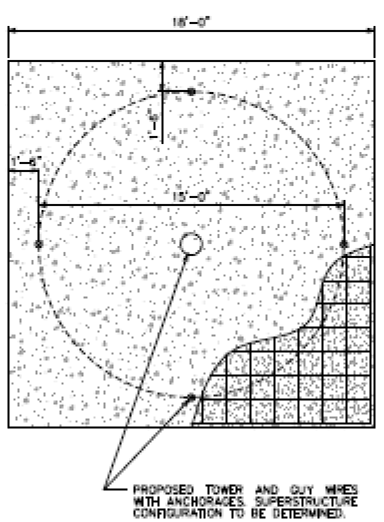
Tower Height: 140'	Erection or Major Maintenance Options		Minor Maintenance Options		
Total Weight: 5800 lbm	**Crane**	**Ginpole (GP)**	**Climb**	**Aerial Lift**	**Ginpole (GP)**
Tower Cost Impact	**$ 80.00**	**$ 80.00**	**$ 1,968.00**	**$ -**	**$ 80.00**
Personnel Quantity	3	3	2	2	2
Hourly Rate, Burdened	$ 31.67	$ 31.67	$ 31.67	$ 31.67	$ 31.67
Erection Time, includes travel	11.5	10			
Total Billable Hours	34.5	30			
Total Labor Cost	$ 1,092.62	$ 950.10			
Insurance Increment	$ 30.92	$ 26.89			
Equipment Rental	$ 4,509.62	$ 312.12			
Equipment, Amortized	$ -	$ 54.67			
Installation Cost Impact	**$ 5,633.16**	**$ 1,343.77**			
Repair Time, includes travel			8.0	8.0	8.0
Total Billable Hours			16	16	16
Total Labor Cost			$ 506.72	$ 506.72	$ 506.72
Insurance Increment			$ 73.22	$ 43.78	$ 14.34
Equipment Rental			$ -	$ 2,320.00	$ -
Equipment, Amortized				$ -	$ 54.67
Repair Cost Impact			**$ 579.94**	**$ 2,870.50**	**$ 575.73**

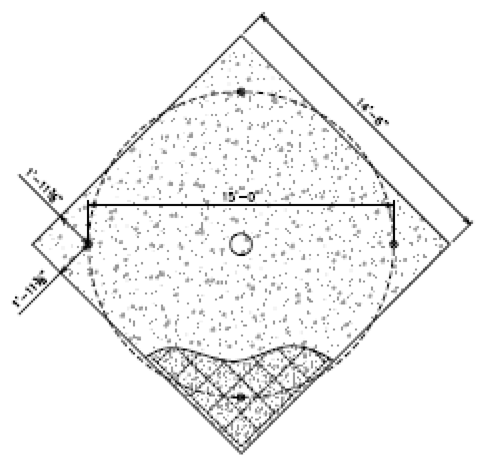
1. Tower = 5500 lbm, turbine = 300 lbm
2. Worker's comp: 2.83% of labor; 14.45% for climbing
3. Foreman @ $45; (2) assistants @ $20
4. Labor Estimate Worksheet
5. Vendor quotes
6. Ginpole amortized over 30 uses

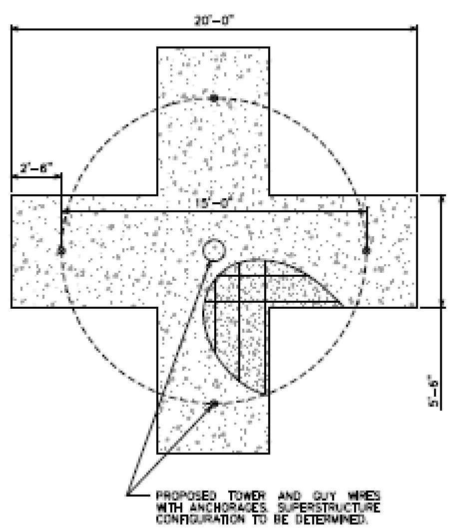
ETT Foundation Options

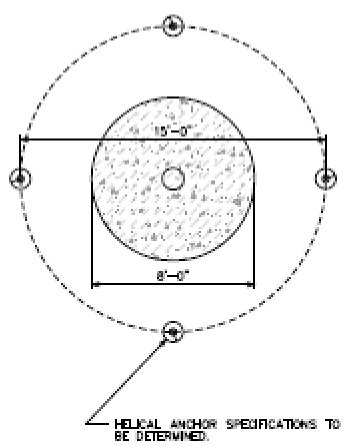
A variety of configurations are under evaluation:

- Monolithic square, lateral anchors
- Monolithic square, diagonal anchors
- Cross shape
- Circular, based on AnemErgonics' patented SMarT foundations









Plans for the Future

Conduct full-scale field testing: In collaboration with industry partners and NREL at NWTC.

Develop multiple families of towers:

- Up to 3 kW: For turbines such as Xzeres SkyStream and Pika T701
- Up to 6 kW: For turbines such as Bergey Excel 6 and Pika Next-Generation
- Larger: Others depending upon interest of industry partners

Thank You

Questions, Recommendations?

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