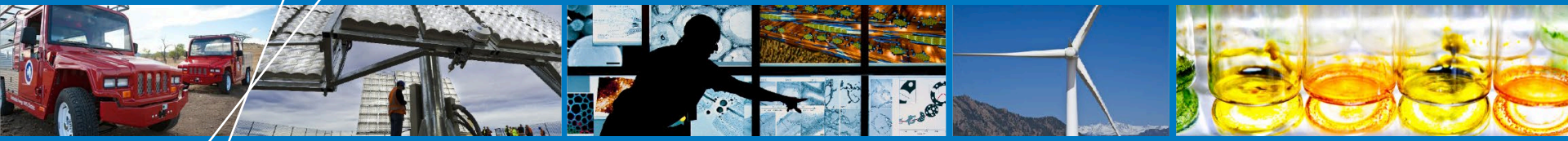
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Marine Hydrokinetic Energy Regulators Workshop:

Lessons from Wind



E. Ian Baring-Gould
NREL
Washington, DC
May 6, 2015

NREL/PR-5000-65125

Then…

705-megawatt Tehachapi Pass Wind Farm. *Photo by David Hicks, NREL 18455-C*

- Limited early acceptance and understanding of potential impacts
- Limited engagement with local stakeholders
- High degree of corporate green energy complex and mistrust.

- Large numbers of small wind turbines installed in tightly packed rows
- Limited deployment experience with high deployment drive
- High corporate turnover

Red-tail hawk taking off from a non-working wind turbine in Altamont Pass, California. *Photo by Shawn Smallwood, NREL 17329*

Now…

- Much larger wind turbines with wide spacing
- Widely dispersed installations
- Much more experience in siting and deployment
- Smaller number of industry leaders

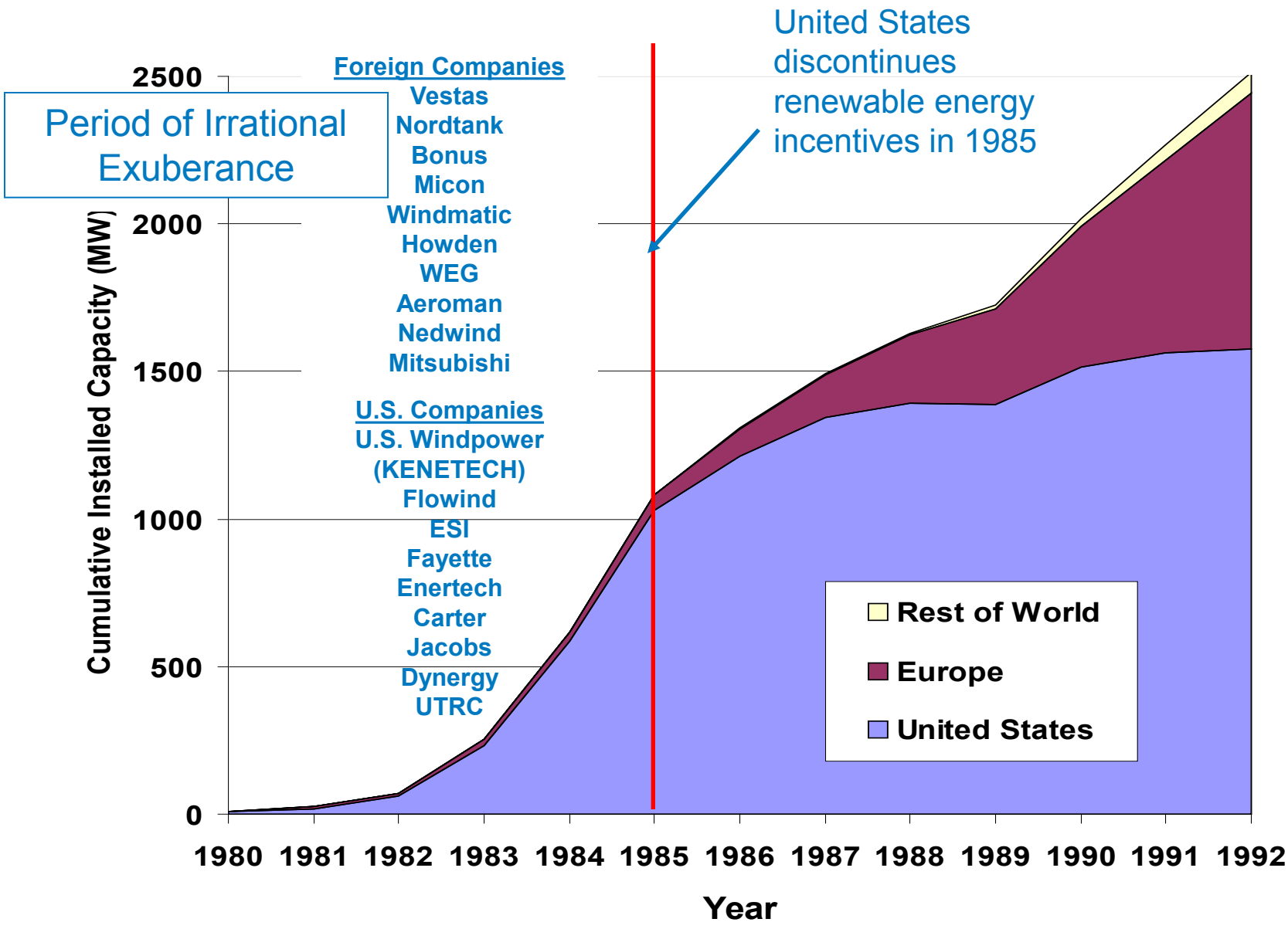
Cedar Creek Wind Farm in Grover, Colorado. *Photo by Dennis Schroeder, NREL 30590*

Forward Wind Energy Center in Fond du Lac and Dodge Counties, Wisconsin. *Photo by Ruth Baranowski, NREL 21208*

- Much better understanding of potential impacts (but still improving)
- Expanded engagement with local stakeholders
- Better-defined regulations
- Expanded collaboration among industry, environmental, and regulatory communities.

First Decade of Wind Energy

10,000 turbines (about 1 gigawatt) were installed in California by 1985



Lessons Learned

- **Use a collaborative approach involving the key stakeholders.**
  - Engage early and often with all parties represented – build trust and collaboration
  - Share data on impacts while respecting IP and issues around sharing
  - Employ quantitative, science-based methods with independent, science-based oversight
  - Good examples: Bats and Wind Energy Cooperative and American Wind Wildlife Institute.
- **Technology needs to evolve to become competitive.**
  - Controlled, small-scale testing allows technology advances.
- **Use baseline studies to measure and prioritize impacts to wildlife.**
  - Developing an "understanding" of impacts from single units is very hard to do; a solid number of units (up to 100?) with enough geographic diversity to allow analysis is required.
- **Look at avoidance and mitigation options early in the process.**
  - Utilize biological and device engineering capabilities to develop lower-impact devices or new avoidance and mitigation solutions
  - Support and fund field-testing of mitigation options.
- **Company size and market potential make a huge difference.**
- **A strong federal role exists in supporting ongoing science, education, and collaboration.**
  - An independent third-party collaborator
  - Ability to look across the whole industry.

Bats and Wind Energy Cooperative

Broad Oversight Committee

- American Wind Energy Association
- U. S. Fish and Wildlife Service
- U.S. Department of Energy
- National Renewable Energy Laboratory
- Bat Conservation International
- U.S. Geological Survey.

Scientific Advisory Committee

Technical Advisory Committee

Partners and Funders

- Acciona
- Adele M. Thomas Charitable Foundation, Inc.
- AES Wind Generation
- American Wind Energy Association
- American Wind Wildlife Institute
- Bass Foundation
- BP Alternative Energy
- Beneficia Foundation
- Clipper Windpower
- Community Foundation for the Alleghenies
- Department of Energy
- Donors to Bat Conservation International
- Duke Energy
- Edison Mission
- Edward Gorey Charitable Trust
- Energy and Environmental Ventures II, LLC
- Erdman Family Foundation
- First Wind
- Gamesa
- General Electric
- Horizon Wind Energy (formerly Zilkha Renewable Energy)
- Iberdrola Renewables (formerly PPM Energy)
- Invenergy
- Massachusetts Technology Collaborative
- Merrill Foundation
- National Fish and Wildlife Foundation
- National Renewable Energy Laboratory
- NedPower
- New York State Energy Research and Development Authority
- NextEra Energy Resources (formerly FPL Energy)
- Noble Environmental
- Offield Family Foundation
- PPM Atlantic Renewable
- Rhode Island Renewable Energy Fund
- Suzlon
- The Hulebak-Rodricks Foundation
- The Leo Model Foundation, Inc.
- The New York Community Trust
- Trans Alta Corporation
- TRF - Sustainable Development Fund
- U.S. Fish and Wildlife Service
- U.S. Forest Service
- U.S. Wind Force
- Vestas
- Wiancko Charitable Foundation Inc.

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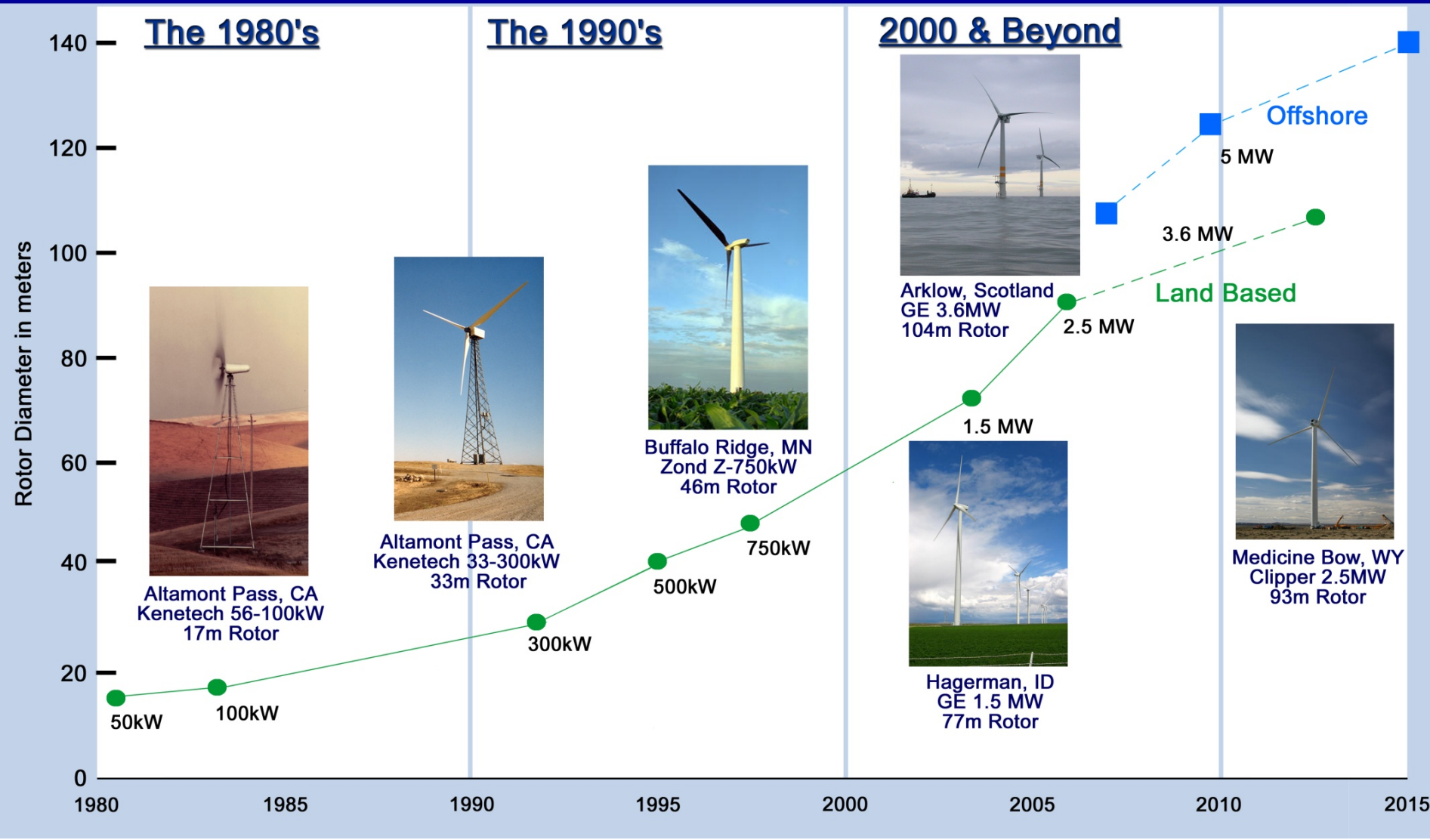
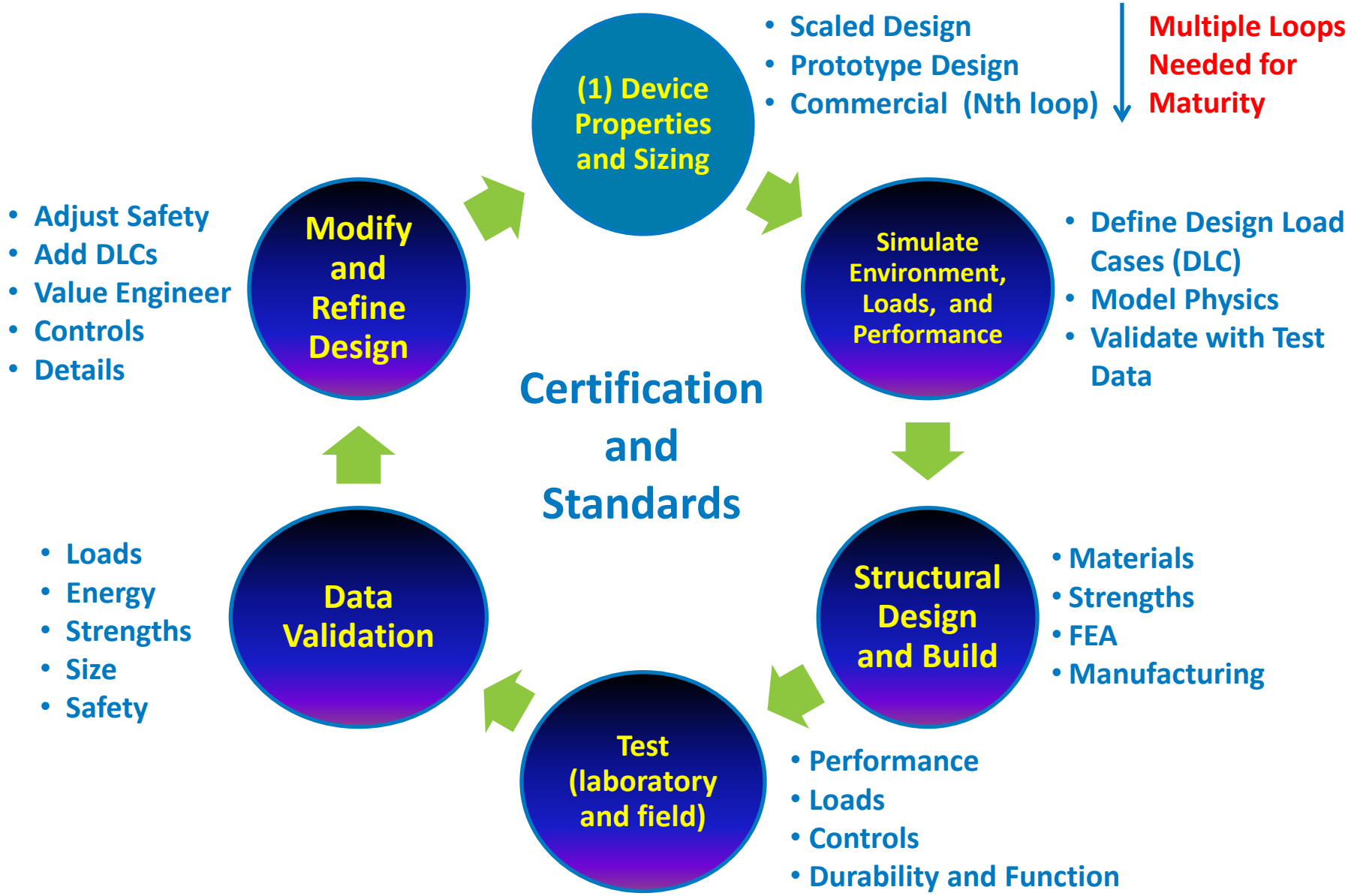
The Technology Has Evolved over Time

Evolution of U.S. Commercial Wind Technology

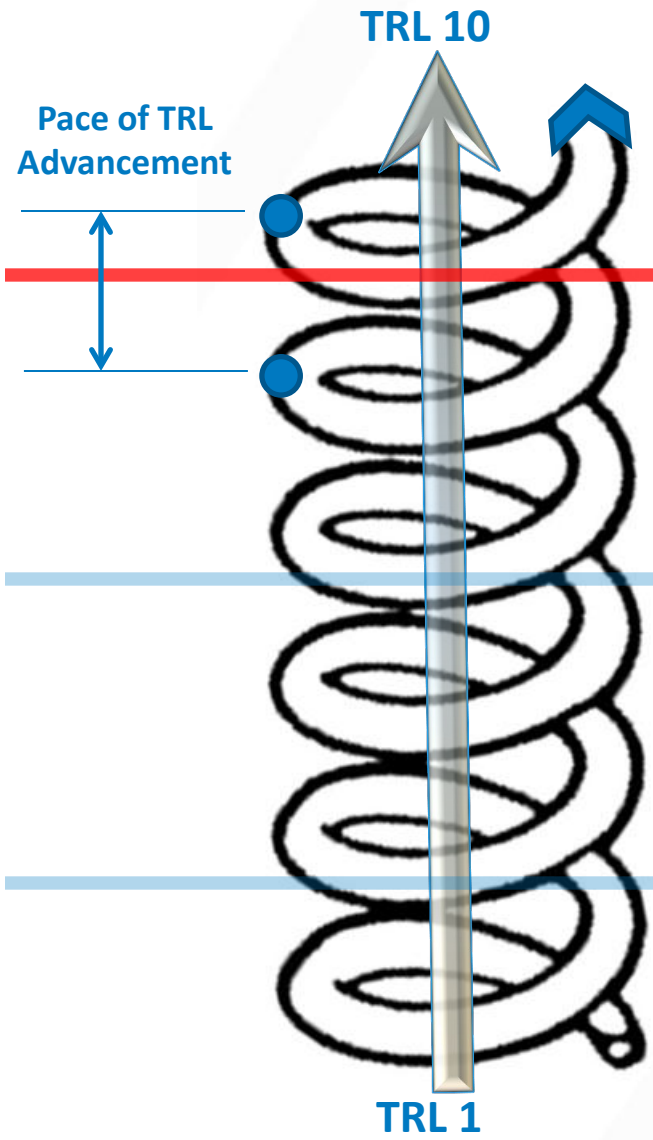


Design Loop Process to Maximize Advancement



Rapid TRL Advancement through Effective Design Loop Iterations

(Design, Simulate, Build, Test, Validate, Refine, Implement, Maintain Repeat)



Key Elements	Phases
Supply Chain Manufacturing Quality Reliability and Operations Market Development	**Commercial Readiness**
Certification and Standards Power Curve Validation Load Validation Power Quality Cost Model Validation	**Open Testing**
Physical Models Scalability Cost Basis Demo Energy Production Proof of Concept	**Controlled Testing**
Desktop Analysis Feasibility Resource Evaluation Potential Impacts	**Research and Analysis**

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The Industry Continues to Learn about Bat Impacts

Photo from Velaia (ParisPeking) (Flickr)

- Initial notice of extensive bat impacts in 2001-2, 30 years after initial deployments in California
- Impacts first noticed in projects in Appalachian Mountains; industry remained quiet
- Bat Conservation International formed the Bats and Wind Energy Cooperative in 2003
- Ongoing assessments revealed a national (and international) issue
- Research continues to develop an understanding of the root cause as well as siting, avoidance, and mitigation options.

Figure 2: Summary of All Bird Mortality Rates at Various Wind Energy Facilities*

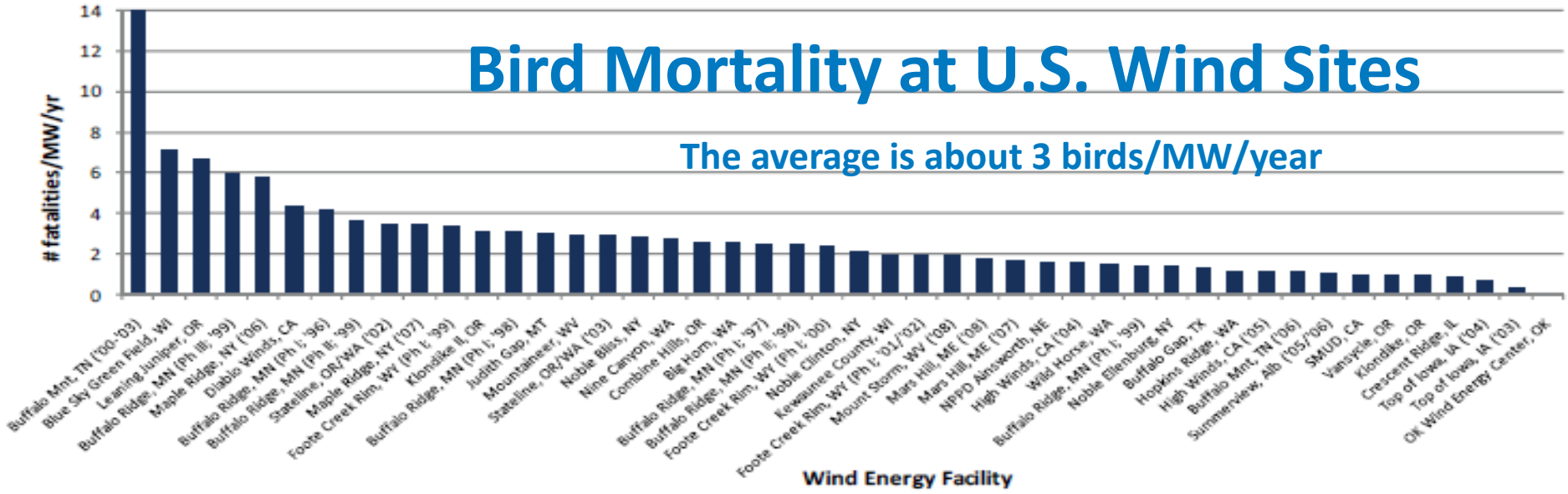
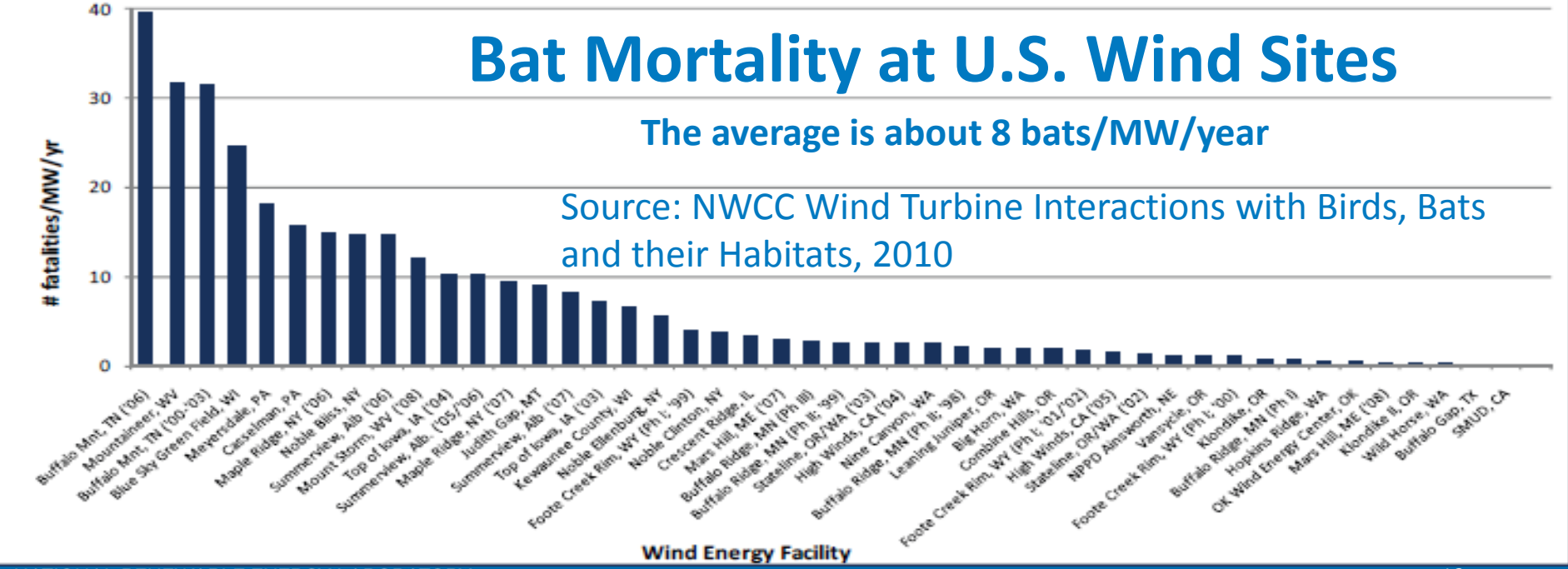


Figure 3: Summary of Bat Mortality Rates at Various Wind Energy Facilities*



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Impact of Different System Designs

Older Technology

19-meter diameter blades on a 100-kW turbine. *Photo by Lee Jay Fingersh, NREL 16392*

Current Generation Scale

Clipper 2.5-MW wind turbine with a 93-meter diameter. *Photo by Alan Laxson, NREL 13886*

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Industry Market Differences

MHK

- Small companies
- Diverse technology
- Short timeframe needs
- Lack of a defined market.

OPT PowerBuoy®.
Photo from Ocean Power Technologies, NREL 22857

Offshore Wind

- Large, diverse companies
- “Understood” technology
- Long development lead times
- Understood market potential.

REpower 5-MW test turbine.
Photo from Gary Norton, NREL 27360

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Photo by Dennis Schroeder, NREL 18891-C

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