Evaluation of a Portfolio of Technologies: Wind Energy

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Presentation Source

This presentation draws on a study nearing completion:

Linkages from DOE's Research and Development in Wind Energy to Commercial Renewable Power Generation

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Study purpose:

to trace how outputs from more than 3 decades of DOE's investment in wind energy R&D are linked to downstream power generation by wind

\+ to assess feasibility of & inform a follow-on benefit-cost evaluation

Study Methods

- interviews with experts
- searches of databases
- review of documents
- analysis of patent and publications

Study challenges

- multiple DOE strategies to advance technology and commercial deployment
- multiple technologies to consider
- multiple markets—utility-scale and distributed
- data issues

Outline for Remainder of Presentation

- Wind Energy Challenges
- Overview of DOE Wind Program budgets & strategies
- Before and after: technology & market snapshots
- Study findings—examples of evidence of direct & indirect linkages
- How historical tracing also has informed feasibility of benefit-cost evaluation

Wind Technology—Technically Challenging

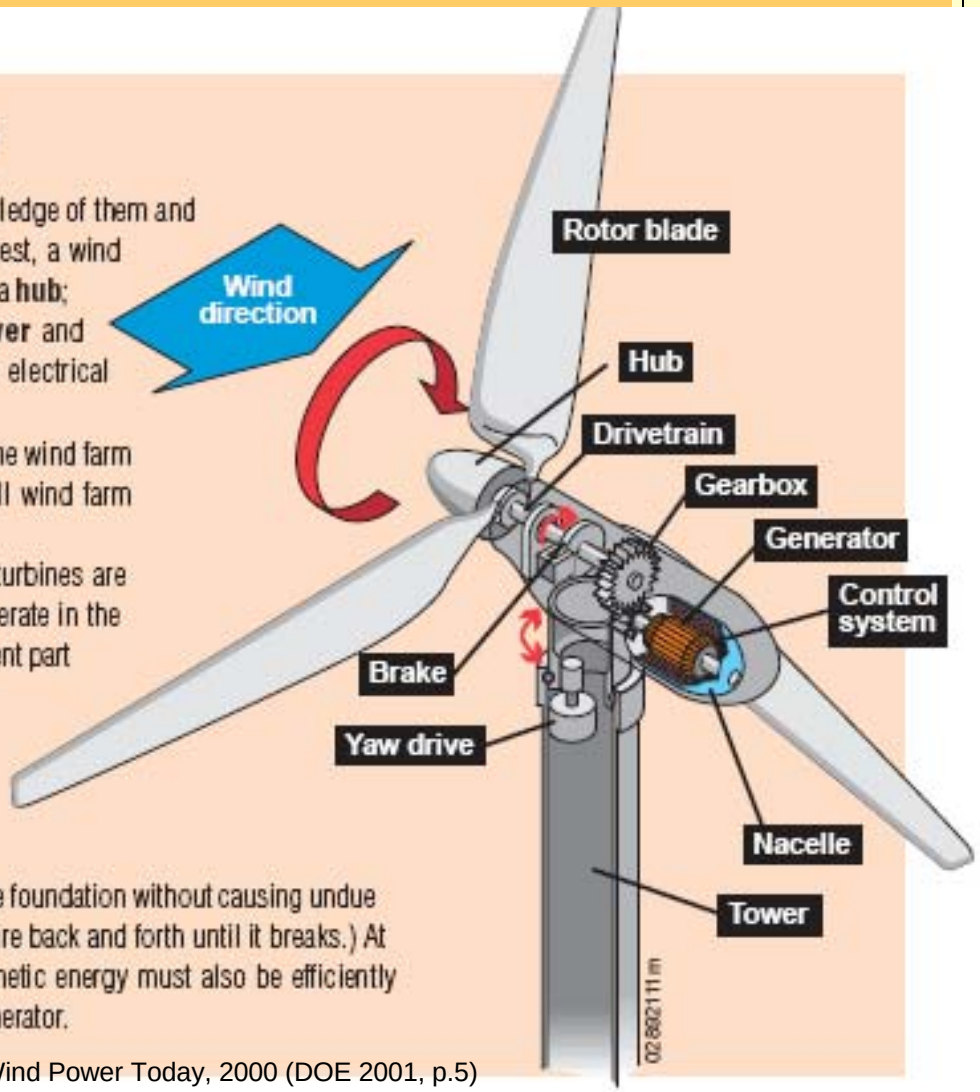
The Parts of a Wind Turbine

Many of the principles used in wind energy are centuries old, yet our knowledge of them and how we apply them has changed dramatically in recent decades. At its simplest, a wind turbine consists of a **rotor** that has aerodynamically shaped **blades** attached to a **hub**; a **drivetrain**, usually consisting of a **gearbox** and a **generator**; a **tower** and foundation that support the structure; a **control system**; and supporting electrical equipment on the ground.

A wind farm is a group of turbines that generate electricity for one owner. The wind farm includes electricity collection grids of wiring and transformers and an overall wind farm control system that monitors the operations of all the turbines in the farm.

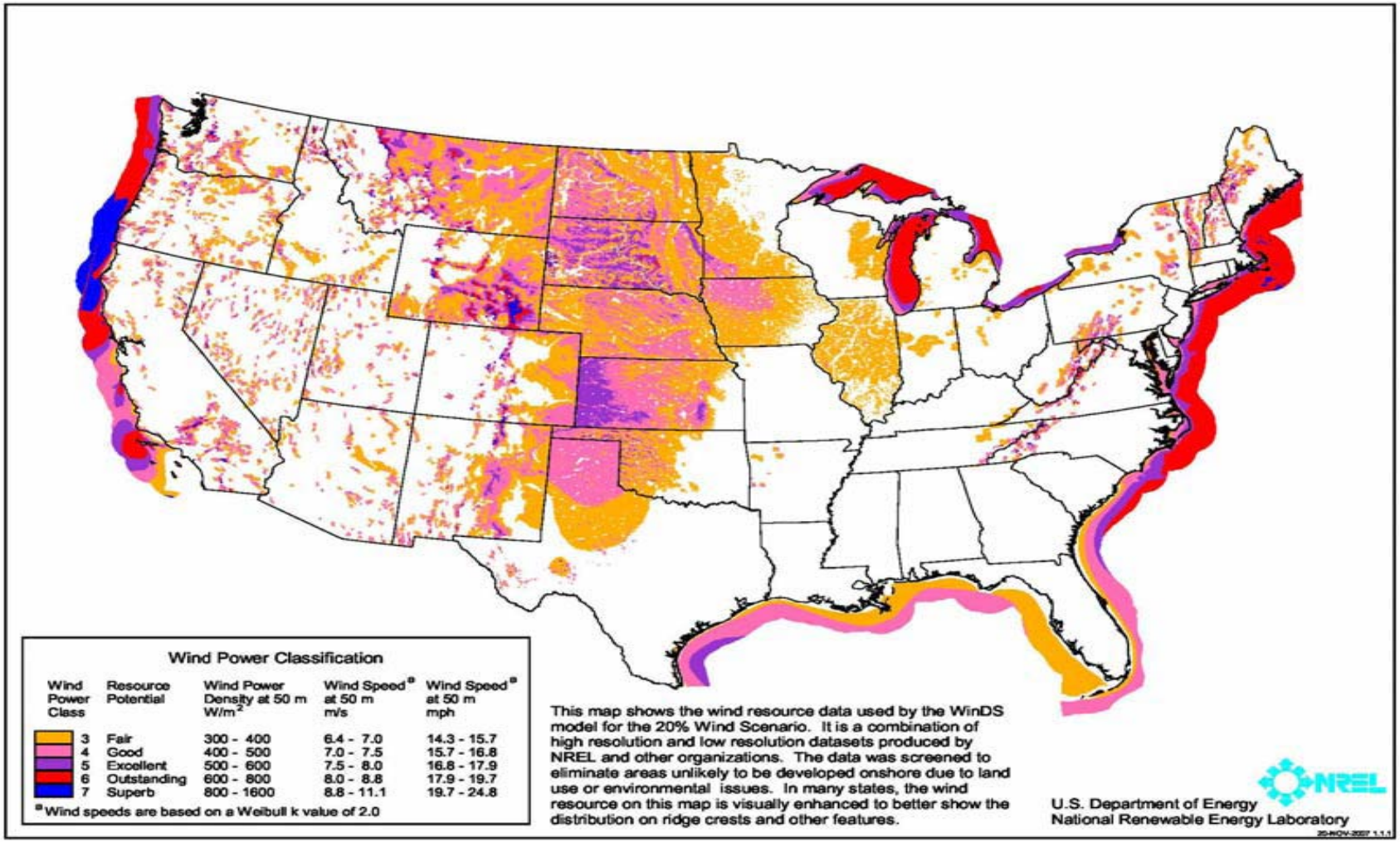
Capturing energy from the wind may appear simple, but in reality, wind turbines are among the most complex and largest moving mechanical structures. They operate in the largely hostile, relatively little understood, and highly unpredictable and turbulent part of the atmosphere near Earth's surface.

Aerodynamic forces on the blades create lift, causing the blades to rotate. These same forces that provide the energy source also flex the blades, bend the towers, and impose forces on the shaft and gearing of the drivetrain as the wind changes direction. The aerodynamic loads transferred from the wind to a wind turbine rotor must be transmitted through the rest of the structure to the foundation without causing undue loading and fatigue damage. (The damage caused when you keep bending a wire back and forth until it breaks.) At the same time these loads are being transferred, the maximum amount of kinetic energy must also be efficiently extracted from the in-flowing mass of air and converted to electricity by the generator.



Source: Wind Power Today, 2000 (DOE 2001, p.5)

Wind Energy—Resource Challenging

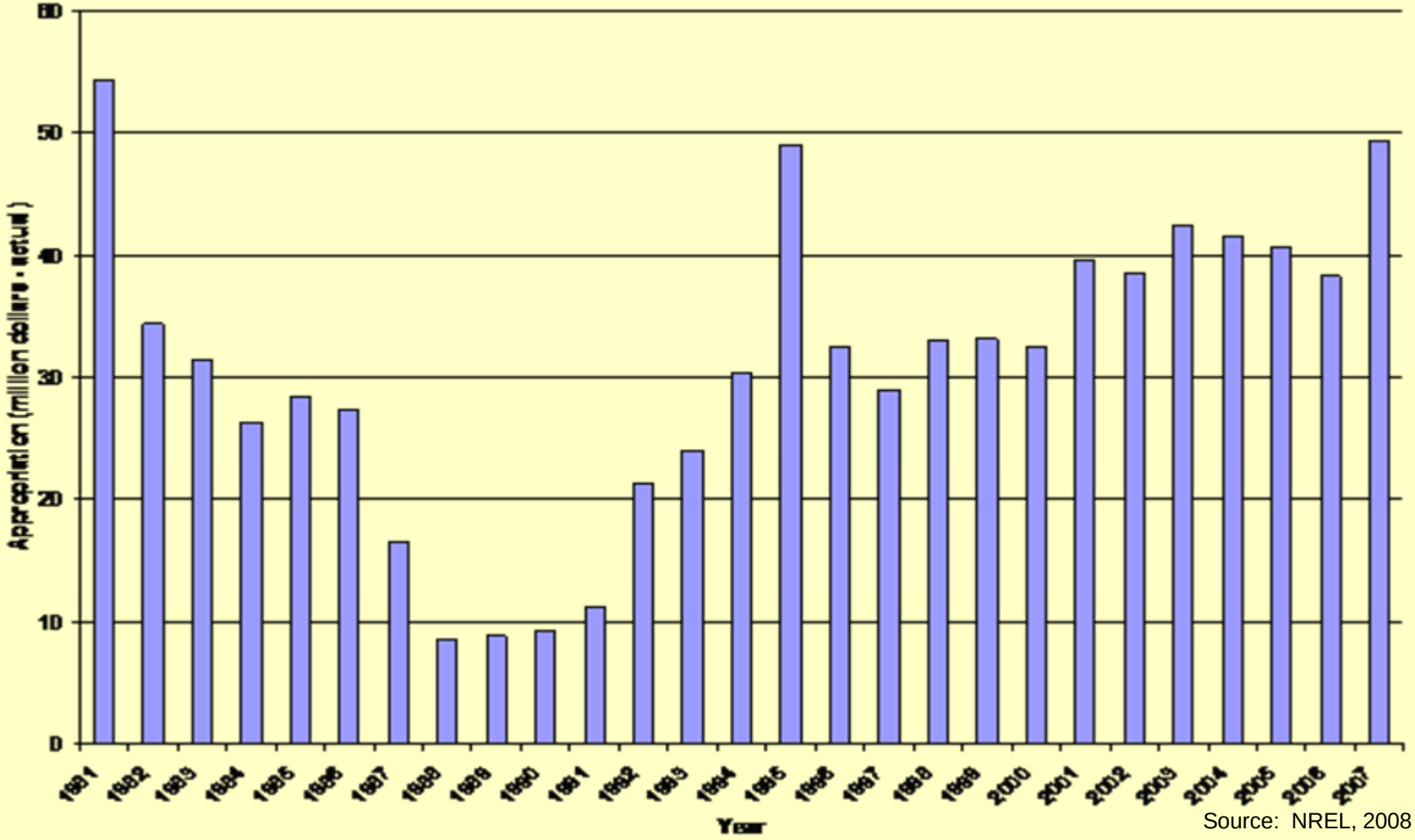


Prior to DOE's Wind Energy Program: High Costs/Short Life/Small Size

Turbines before 1975	
Cost/kWh	$0.50-$1.00
Operating Life	1-5 years
Turbine Size	< 20 kW

Source: NREL In Review, Fall 1995, p.6

National Wind Program Budget is Indicator of Program Intensity



Source: NREL, 2008

DOE's Multiple Strategies to Advance Wind Energy Technology

- Support of testing and industry R&D
- R&D partnerships with industry
- Support of university research
- In-house laboratory R&D
- Provision of specialized testing facilities
- Other

DOE's Multiple Strategies to Foster Commercial Deployment

- Advancing the technology also advanced deployment
- Certification and standards development
- Incentives for utilities to invest in wind energy
- Mapping Wind Resources
- Initiatives & collaborations with associations and other organizations to promote markets for wind energy (e.g., Wind Powering America)

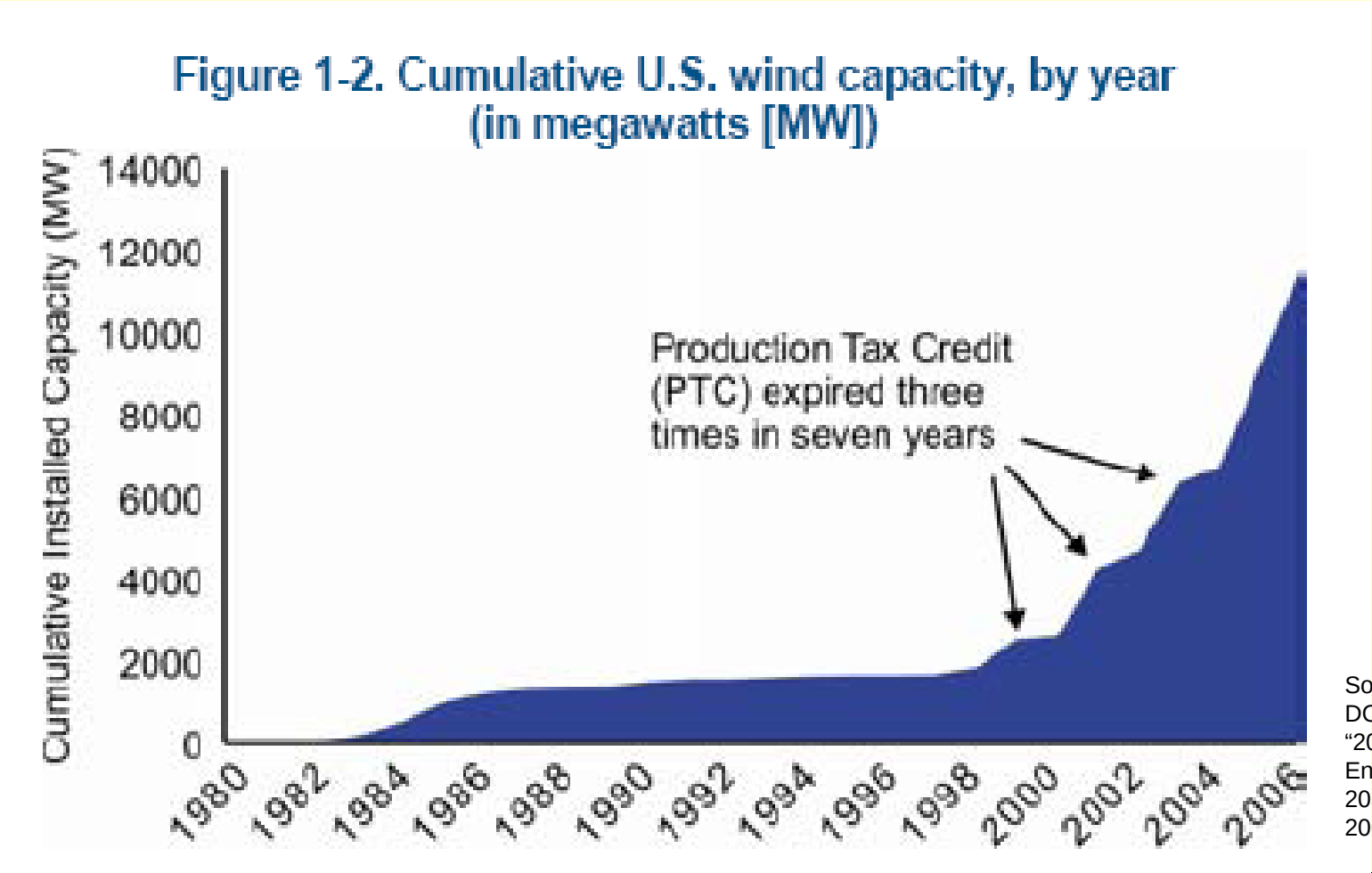
Study: Is the DOE Wind Program Linked to Desired Technical & Market Changes in the Wind Industry?

1. Consider before-and-after:

   i.e., an action is taken & change is observed -- a necessary, but insufficient condition for attributing impact

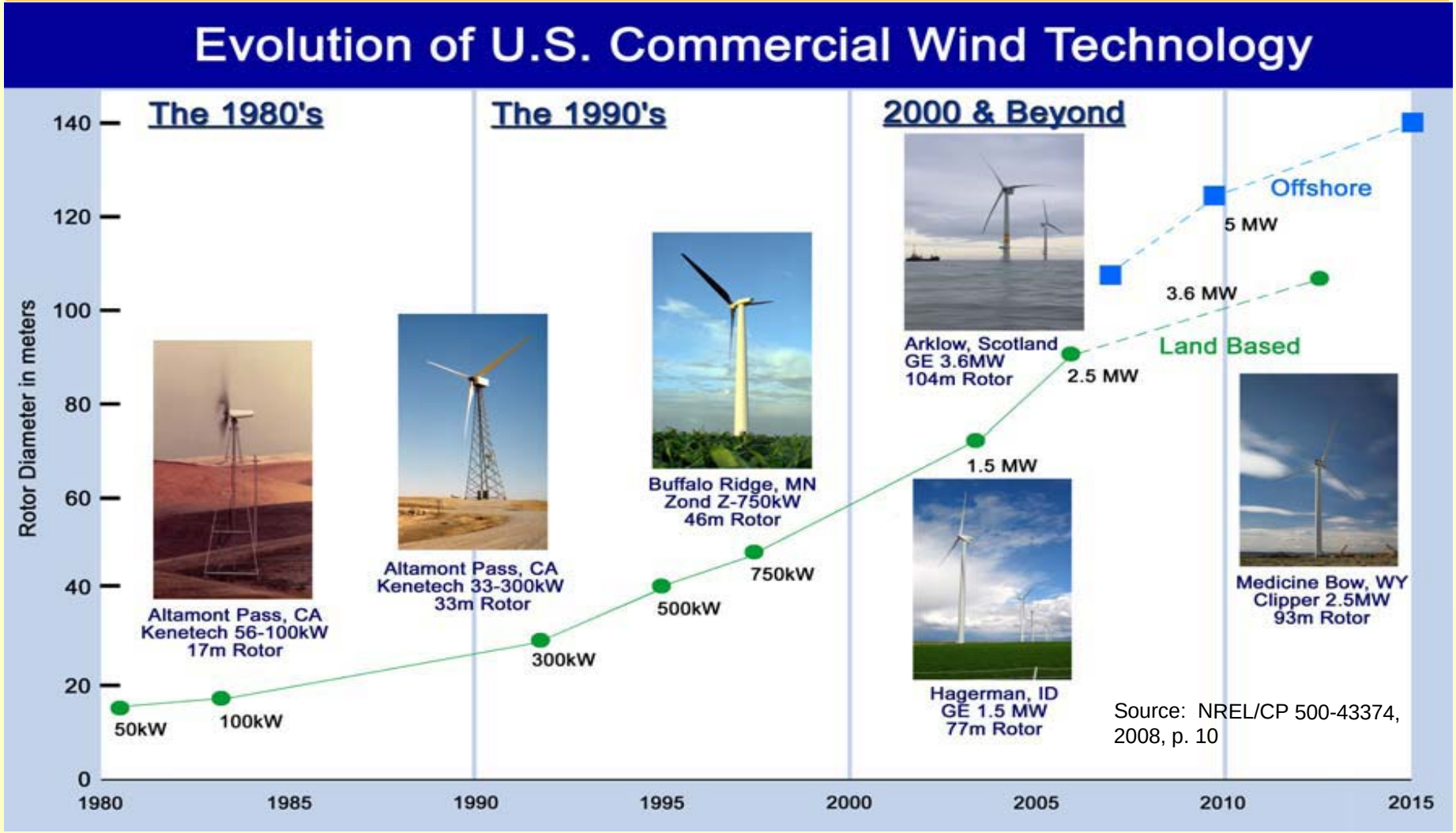
2. Consider other specific evidence compiled from historical tracing & patent/publication analysis

Changes in Installed US Wind Capacity



Source: DOE's "20% Wind Energy by 2030," 2008, p.5

Increasing Size of Turbines



Source: NREL/CP 500-43374, 2008, p. 10

Dramatic Cost Reductions

	1981	2006	2014
Land-based:	0.40/kWh	$0.03-.06/kWh	
Offshore:		$0.095/kWh	$0.050/kWh

A Look at Some Study Findings:

Examples of linkages from DOE's support of R&D to technology and market developments found by

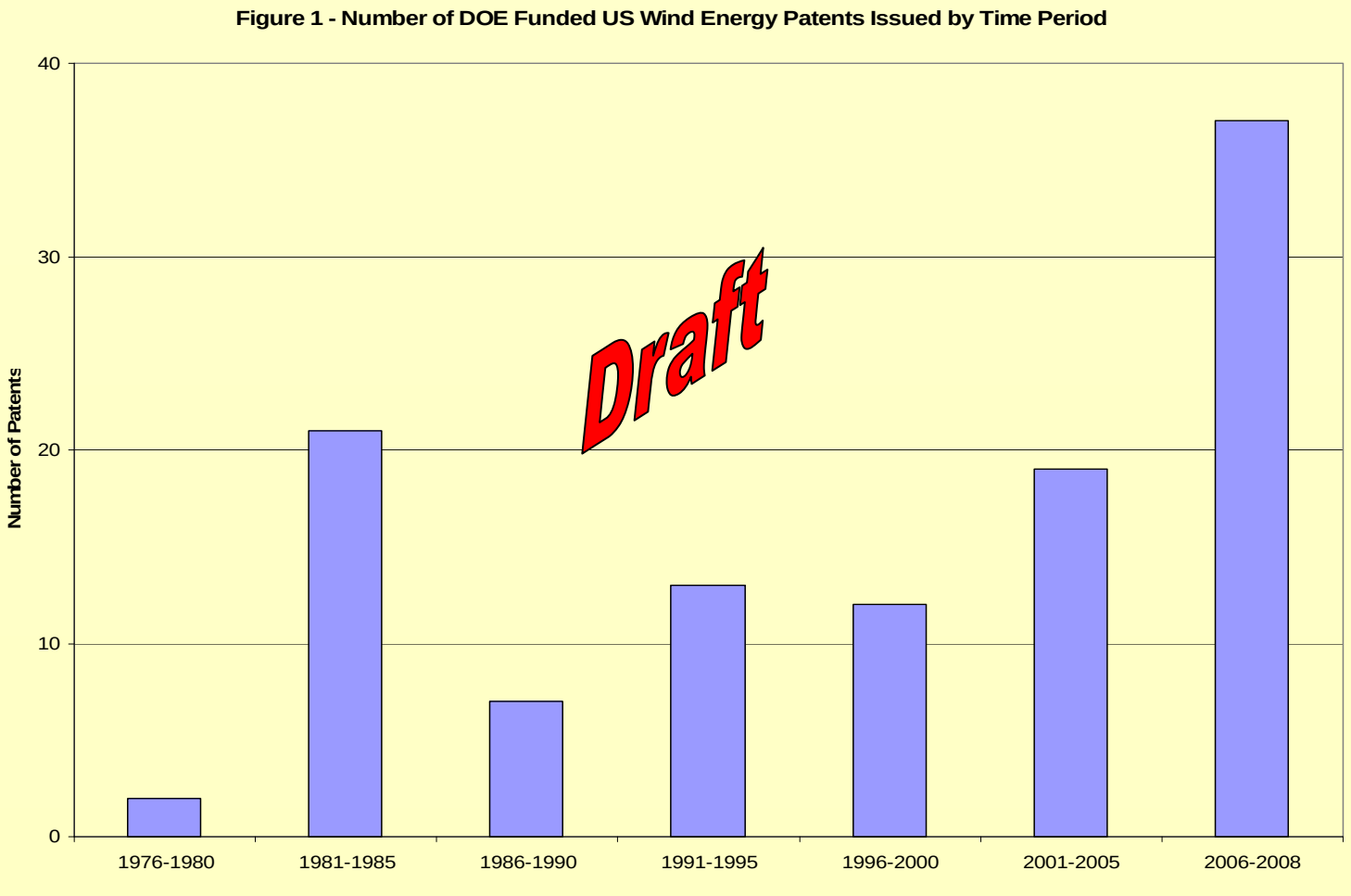
Example 1: patent analysis & document review and interview

Example 2: publication analysis

DOE's Partnerships with Companies

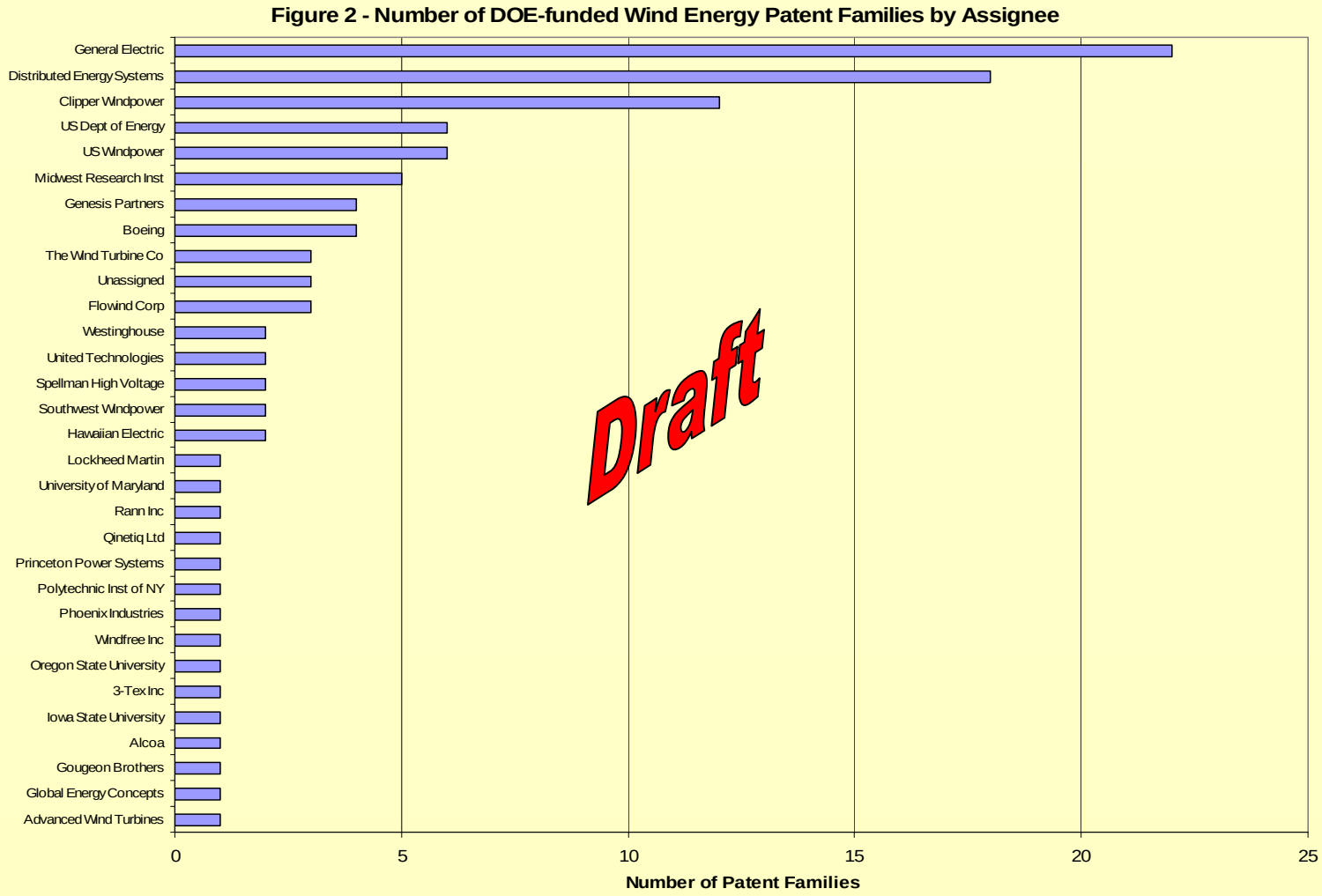
- DOE funded >80 companies to develop new wind energy technology
- DOE supported many more companies in testing and deployment projects

e.g., Evidence of Technology Advancements



Source: Ruegg and Thomas, Draft Wind Report, 2008

About the Patents—an example



Source: Ruegg and Thomas, Draft Wind Report, 2008

Evidence of Technology & Market Advance via Clipper from Document Review

Clipper Windpower receives U.S. DOE award for research and innovation
Tuesday, September 11, 2007

Clipper Windpower, based in Carpineria, Calif. received an Outstanding Research and Development Partnership Award from the U.S. Department of Energy for the design and development of its 2.5 MW Liberty Wind Turbine, the largest wind turbine manufactured in the U.S.
Acknowledging Clipper for its "outstanding contribution toward industry advancements", the award recognizes "the Liberty wind turbine, which attained unparalleled levels of efficiency and reliability and reduced cost of energy."
The turbine was developed under a partnership with DOE and its National Renewable Energy Laboratory (NREL).

Commercial sales efforts kicked-off in June 2006 for the new Liberty wind turbine and account for more than 5,600 MW (2,240 units) of firm and contingent orders for deliveries in 2007 through 2011.

Evidence of market advance from Interview with Clipper MGT

Draft

- "…leadership in the industry is with companies that have partnered with DOE—e.g., GE, Clipper, …"
- "…the partnership approach has been very effective. The program of NREL with Clipper was one where we won a $9 million grant for an $18 million program, and within 5 years we were producing over $1 billion in benefits—and that's a pretty fantastic payback. …we just would not have been able to engage in the technology development without that support."
- "I think the success of the global wind industry can be traced directly to the work that DOE has taken a leadership in. Yes, it got off to a bit of a rocky start…but when it started directly supporting emerging companies and new technology ideas in the 1990s, it really made a huge difference to the industry—by taking it from the level that wind energy production was not very economic to where it really enabled the industry to produce at a true utility scale, high efficiency, very competitive level."

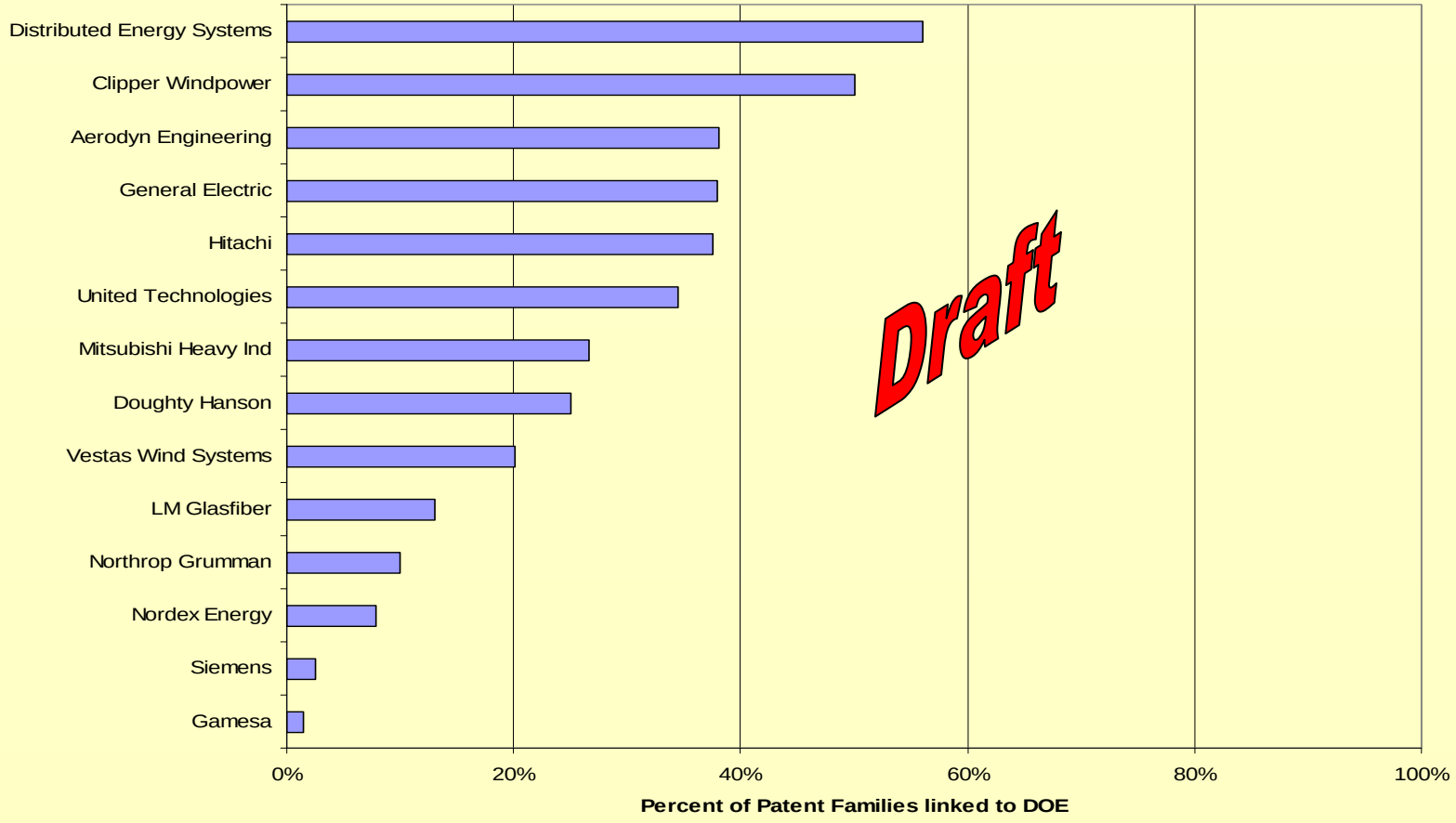
More Evidence of Link to Market Developments via Clipper from Document Review & Interview

- In April, 2008 Clipper Wind announced plans to develop the World's largest wind energy turbine in the UK. Being developed for Offshore use each turbine would be rated at around 7.5MW and would be roughly double the size of the largest turbines used in commercial offshore wind farms today (GE's 3.6MW turbine) As reported by the British Wind Energy Association "as few as 20 of these turbines could satisfy the domestic consumption of a city the size of Newcastle upon Tyne" a city with a population of around 250,000. (Reuters, Jan. 21, 2008)

- "…[DOE funding] led to the development of an innovative turbine which we currently have in production. Now we have 300 of those machines, up from 137 last year and 8 the year before. That technology has enabled us to go to an even greater machine for offshore deployment. While DOE's funding for wind has been limited in the last few years, the Brits have meanwhile really opened up their support for renewables in the UK, so they are supporting us now to develop a 10 MW machine for the offshore market. The machine is based on the same technology as the 2.5 MW machine. This will be the largest in the world—7.5 MW for land and 10 MW for offshore. The Brits have provided support for testing and the Crown has bought the machines for offshore installation. (Interview with Clipper Mgt, Oct. 2008)

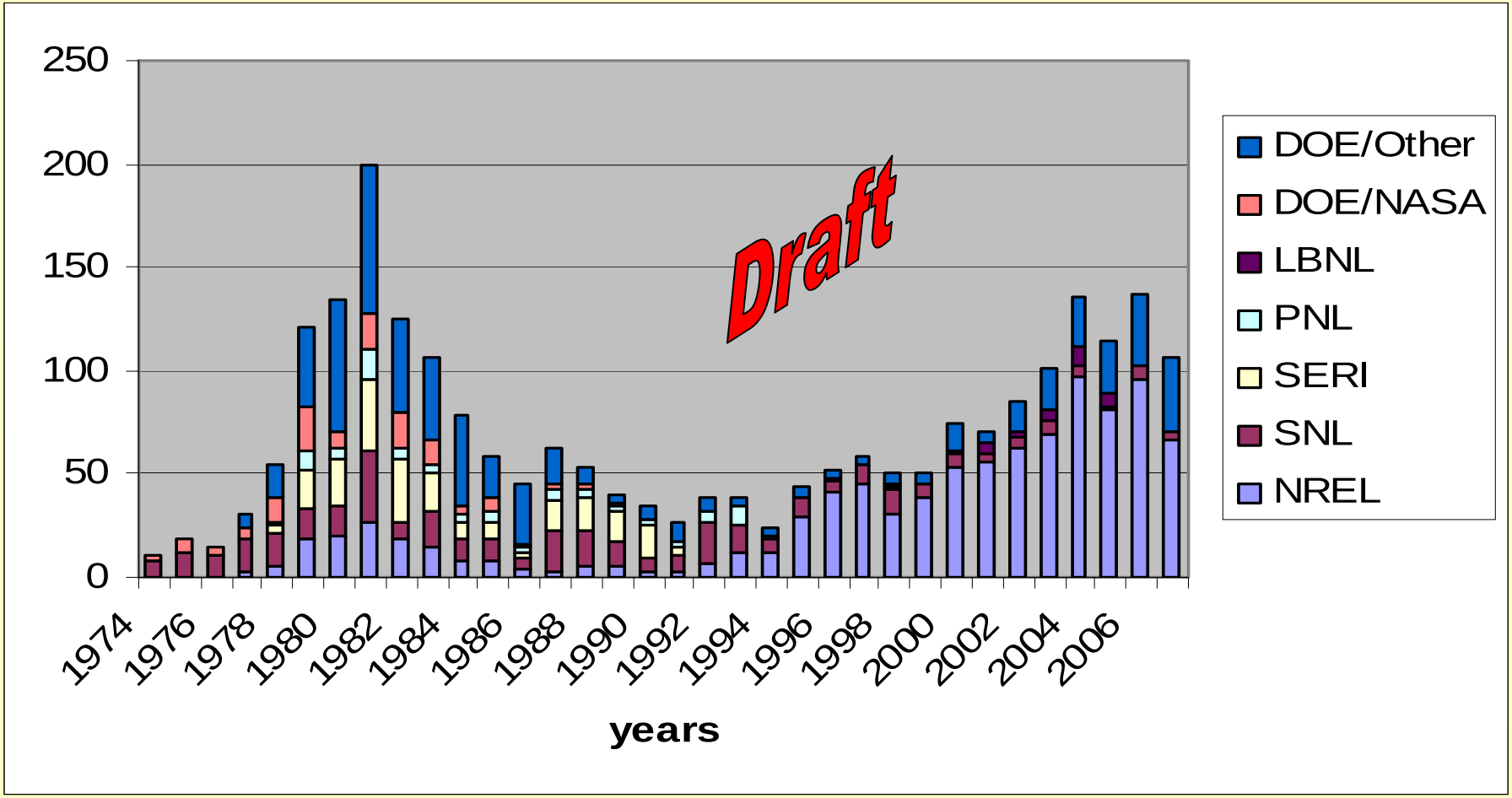
We found leading wind companies globally to have their wind energy patents linked to DOE

Figure 6 - Percentage of Wind Energy Patent Families from Leading Organizations linked Directly/Indirectly to DOE-funded Wind Energy Patents/Papers



Source: Ruegg and Thomas, Draft Wind Report, 2008

Evidence from Publication Analysis



Evidence of Linkages from DOE Wind Publications to

- Generally, publications add to the knowledge base from which researchers draw—upstream of commercial applications

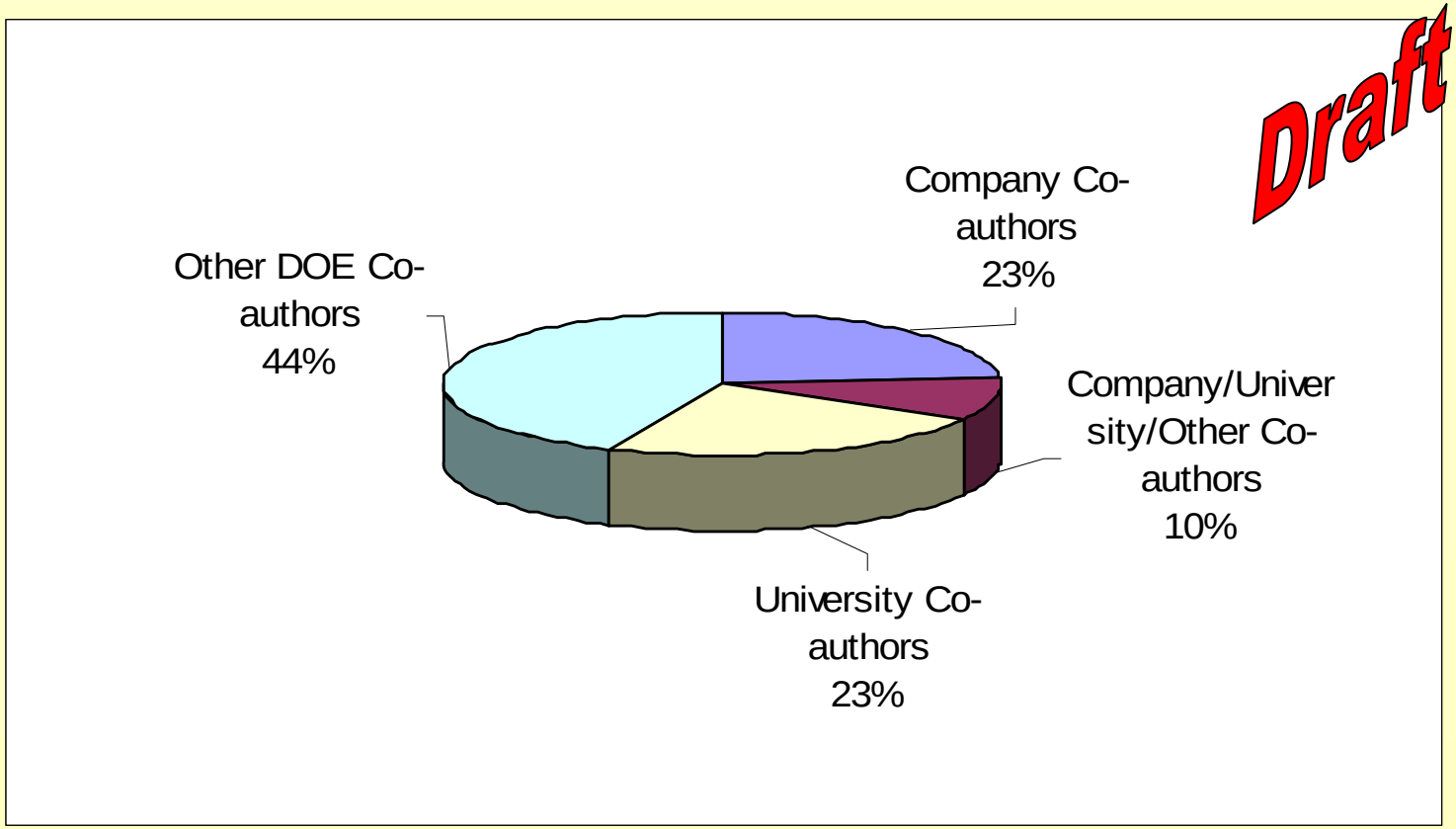
- Here, a direct connection was found from DOE publications to commercial developers and suppliers of wind power turbines

  – DOE researchers often co-authored with others affiliated with manufacturers of turbines, providers of technical services in wind, wind farm developers, and utilities which supply electricity produced by wind.

  – DOE publications were cited early and often by wind energy companies, domestic and foreign universities, foreign research laboratories, as well as by other government laboratories.

Many DOE Wind Publications Are Coauthored with Companies

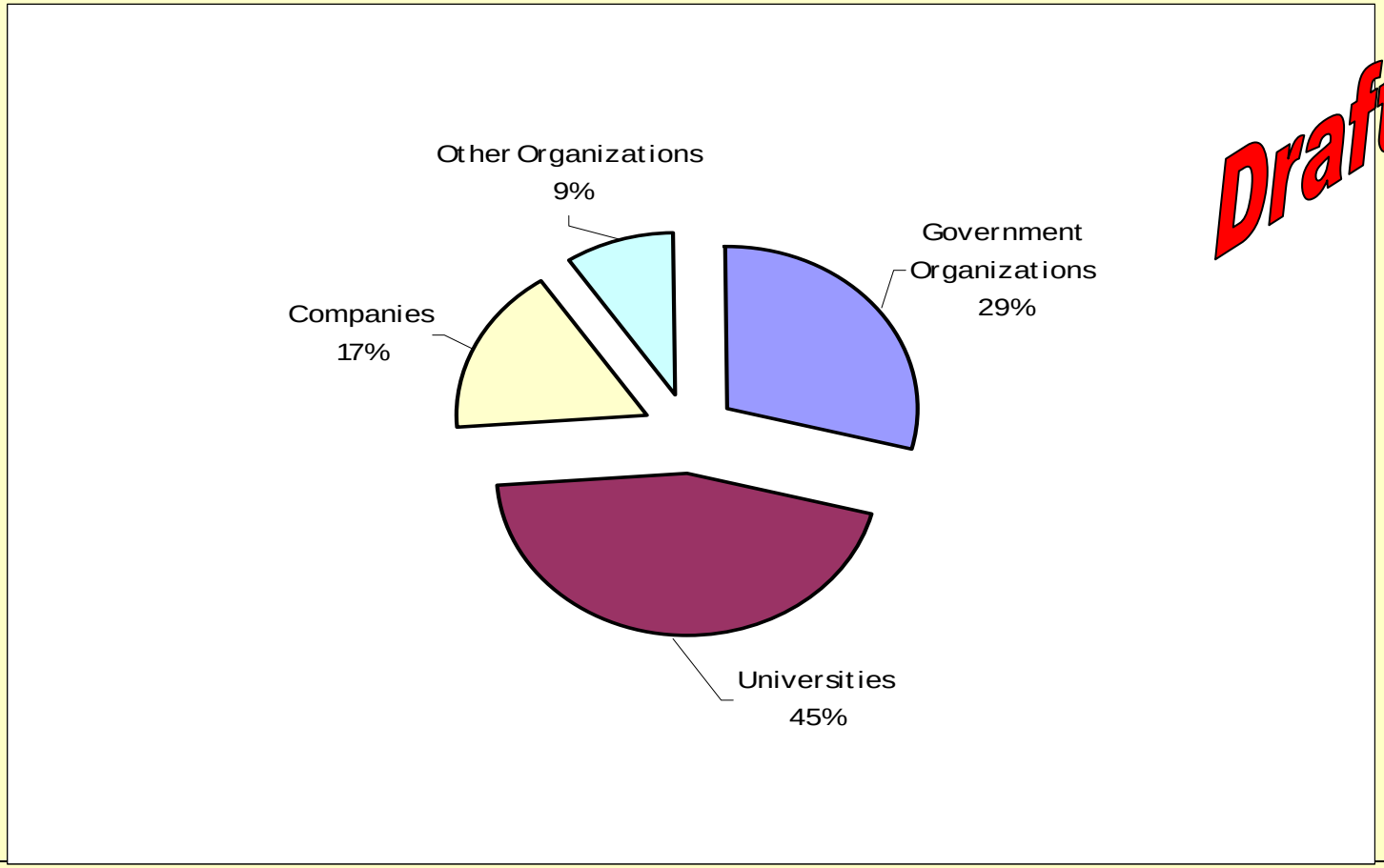
Of a sample of 33 NREL Conference Papers, 30 were co-authored as shown here:



Source: Ruegg and Thomas, Draft Wind Report, 2008

Many DOE Wind Publications Are Cited by Companies

For a sample of SNL publications, the affiliations of citing organizations are as shown:



Source: Ruegg and Thomas, Draft Wind Report, 2008

Another Finding: Historical Tracing/Citation Analysis Informs Benefit-Cost Evaluation

- In the past, these have been considered separate evaluation approaches used for different purposes

- But this effort has found that Historical Tracing with Citation Analysis performed in advance of Benefit-Cost Analysis can inform the Benefit-Cost study:

  - It shows how public research is linked to downstream innovations

  - It suggests who is using a program's outputs & often for what purpose

  - It suggests areas of knowledge spillovers

  - It identifies useful documents and people for the benefit-cost evaluation

  - It suggests where to concentrate attention for the benefit-cost evaluation

For additional information about the study and to obtain a copy of the published report, contact:

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