Sources of experience in wind energy technology

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Agenda of this presentation

This presentation is based on

- **Chapter 3 in the EXTOOL final report**
- **Paper distributed for this workshop**

Contents of the presentation

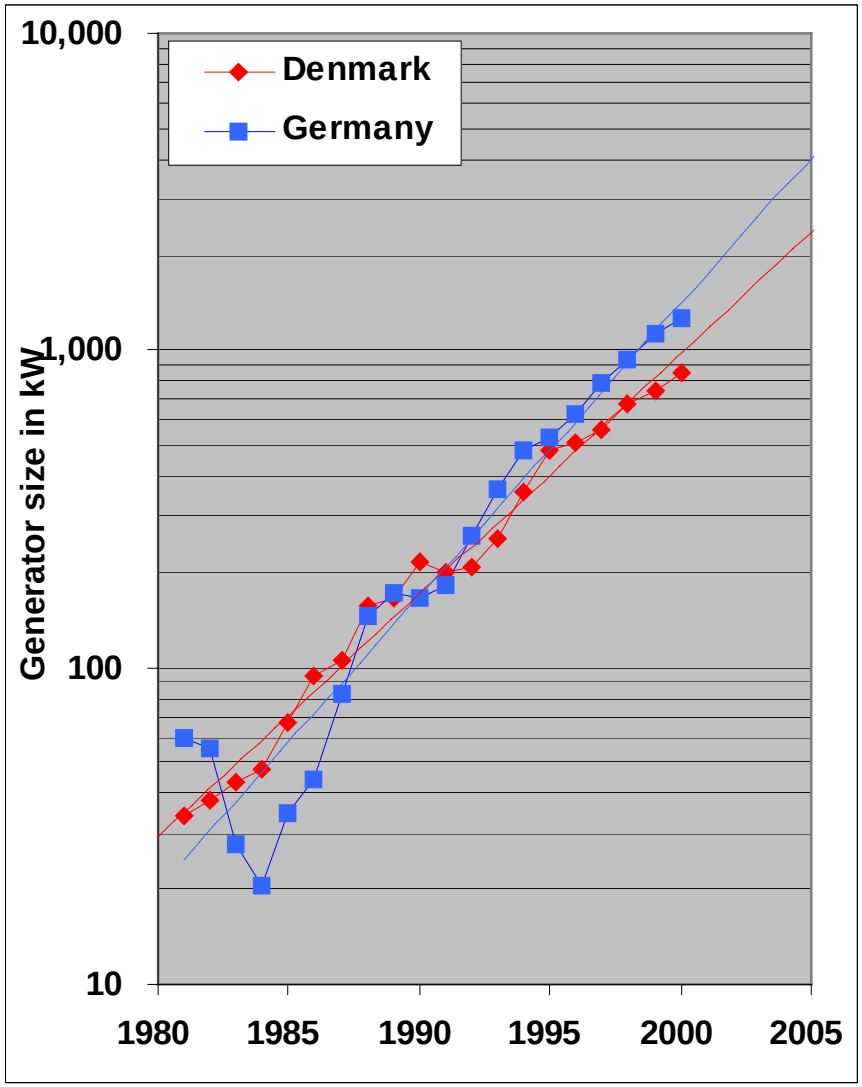
- **Characteristics of wind power technology and their affects on experience curves**
- **Innovation theory revisited and consideration on experience curves and Progress Ratio**

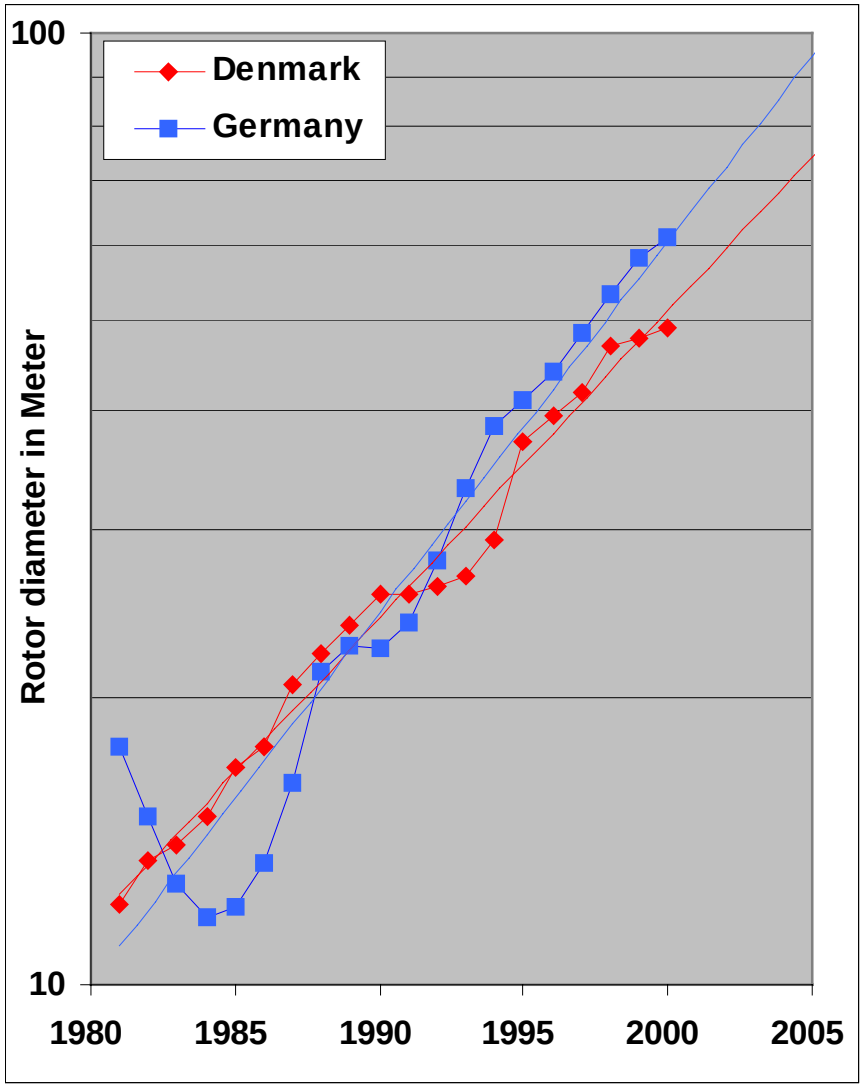
Characteristics of technical changes in wind power technology

- **Up-scaling of turbines**
- **Improved efficiency**
- **Generations for technology / turbines**
- **Types of innovation**
  - Innovations as improvements of one size of machine (same generation and same platform)
  - Innovation as up-scaling on a platform (within a generation)
  - Introduction of a new platform (a new generation)

➔ **Affects on experience curve and Progress Ratio**

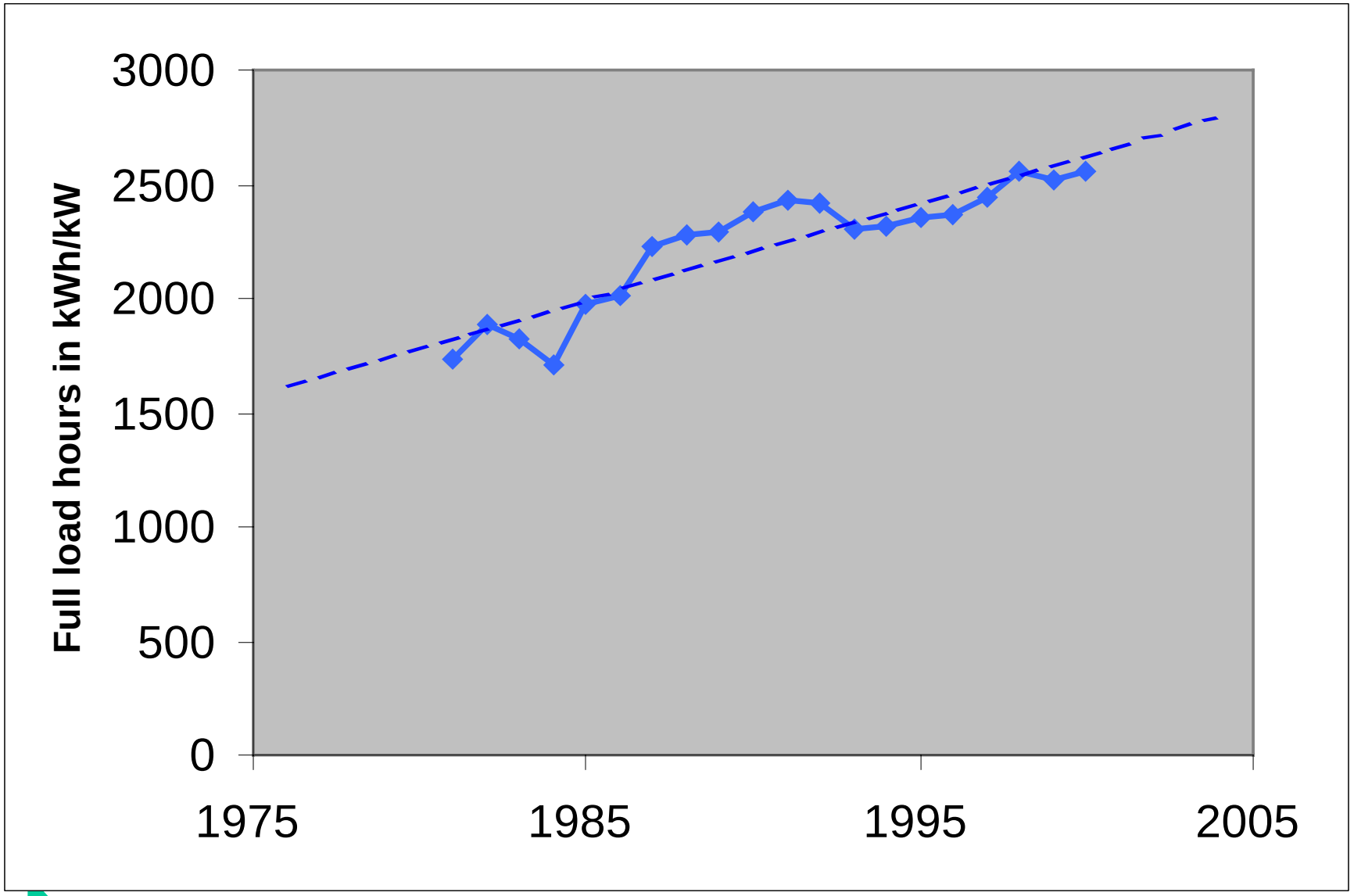
Up-scaling of wind turbines





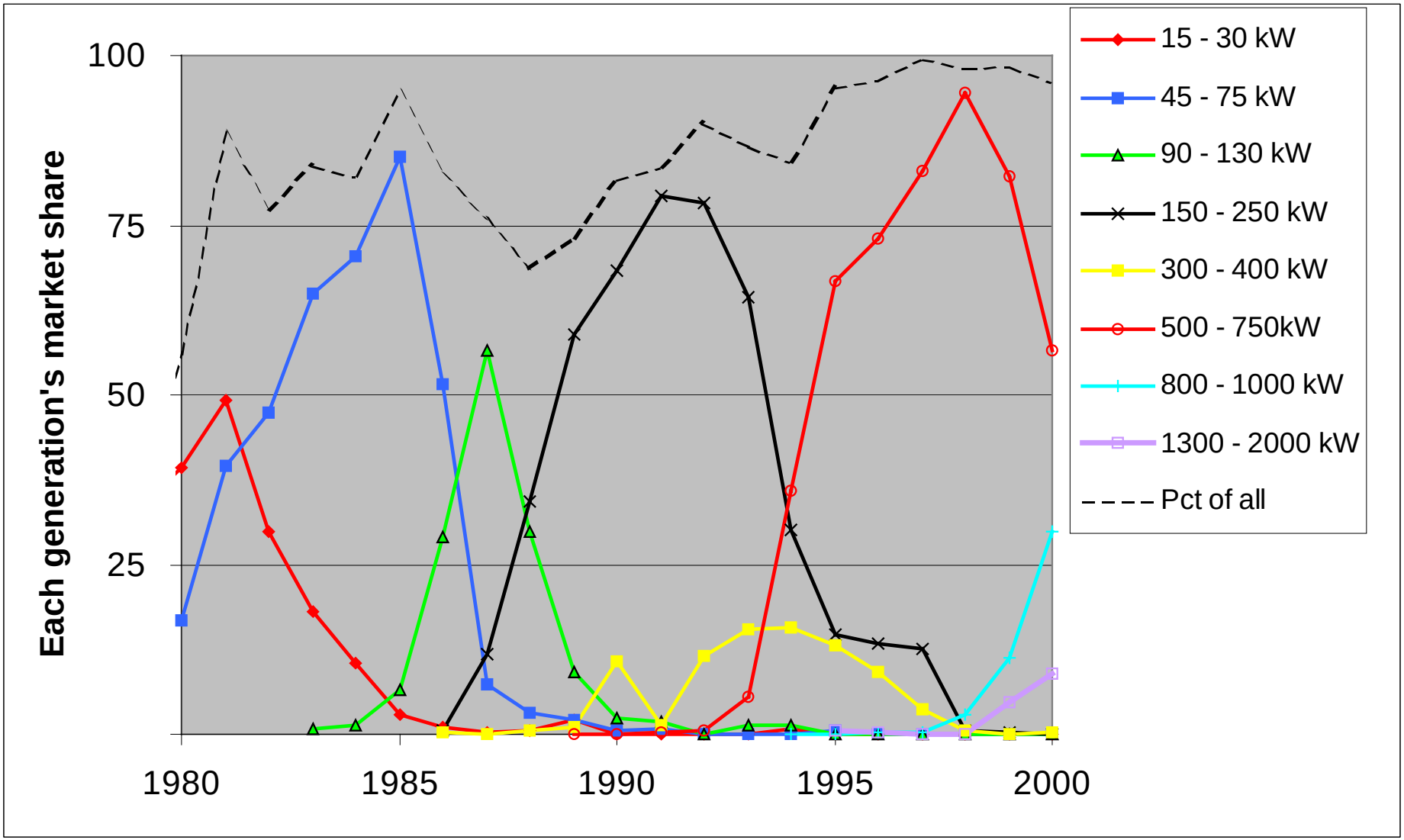
Improved technical efficiency

Partly an affect of the up-scaling (Danish data)



Generations of technology

Only 3-bladed machines from largest Danish firms

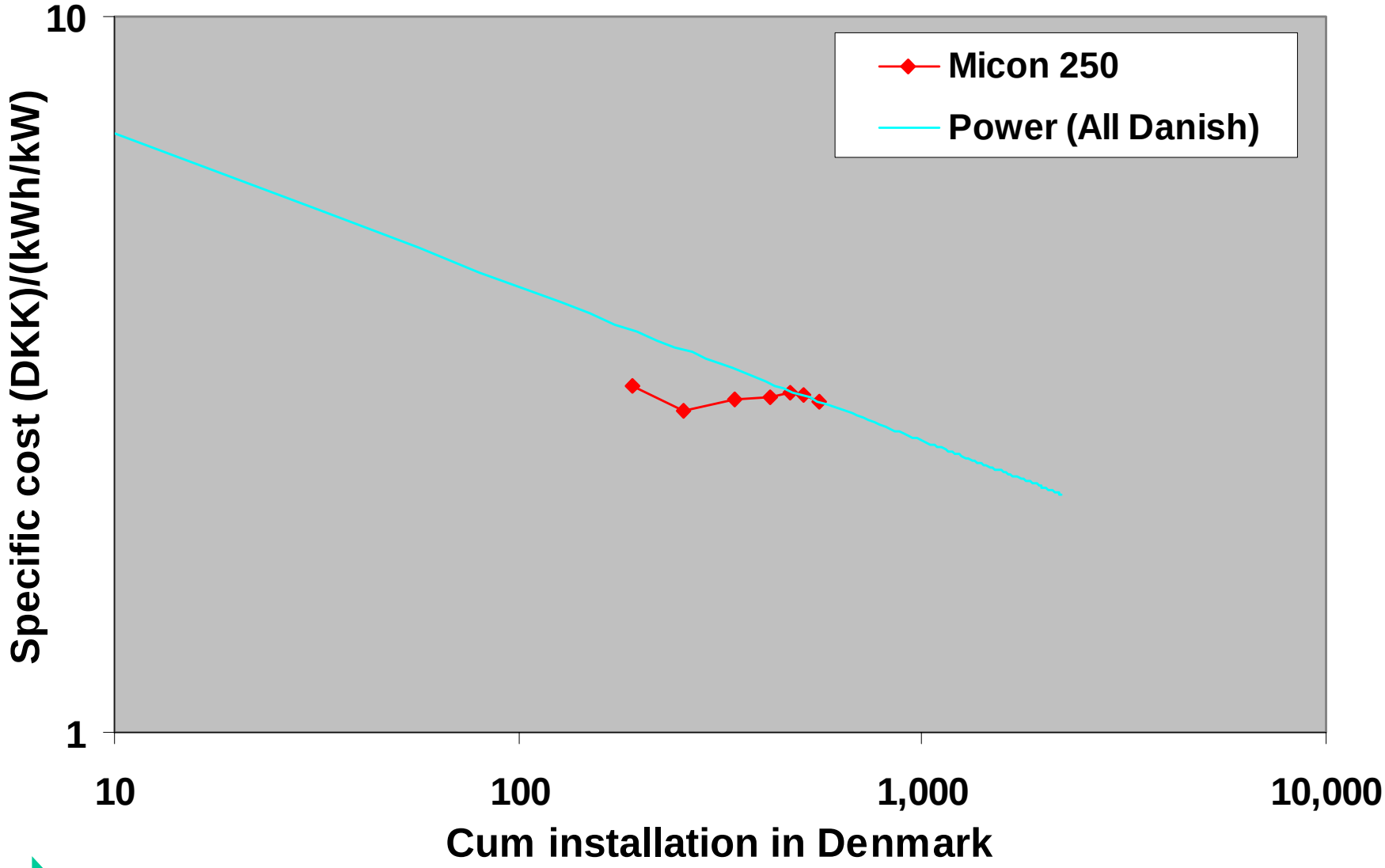


Types of innovations on wind turbines

- **Innovations as improvements of one size of machine (same generation and same platform)**
- **Innovation as up-scaling on a platform (within a generation)**
- **Introduction of a new platform (a new generation)**

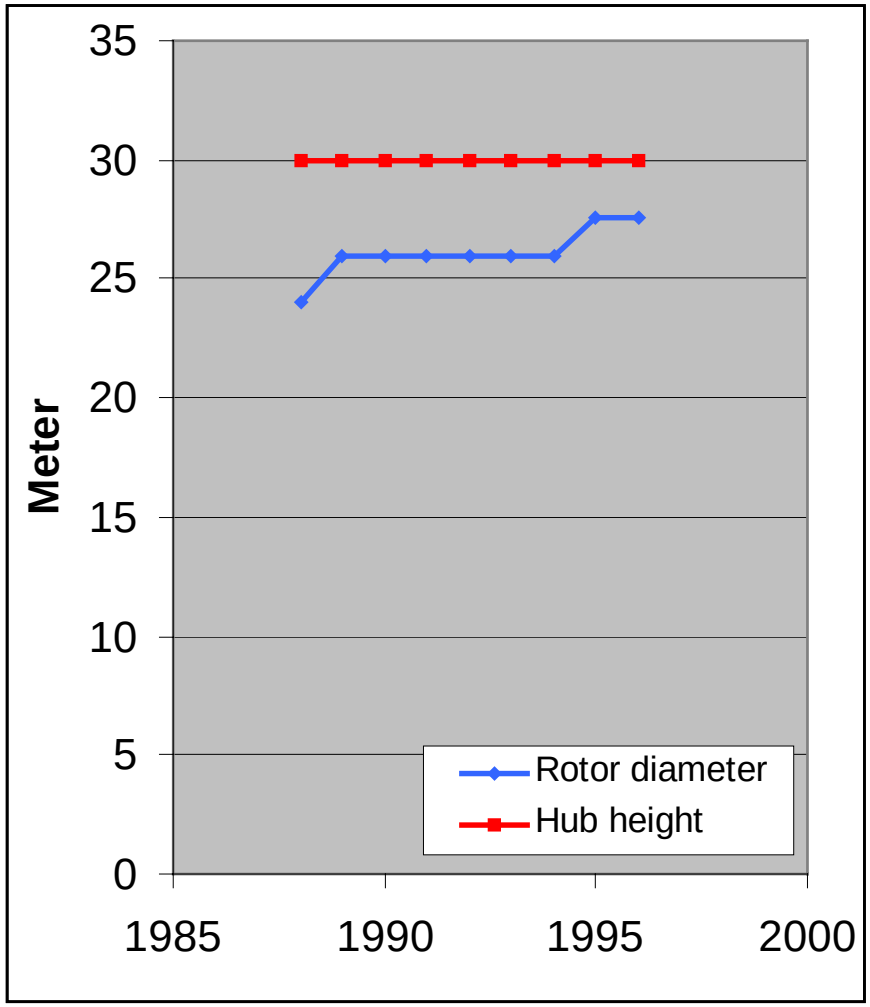
Innovation as improvements of a machine

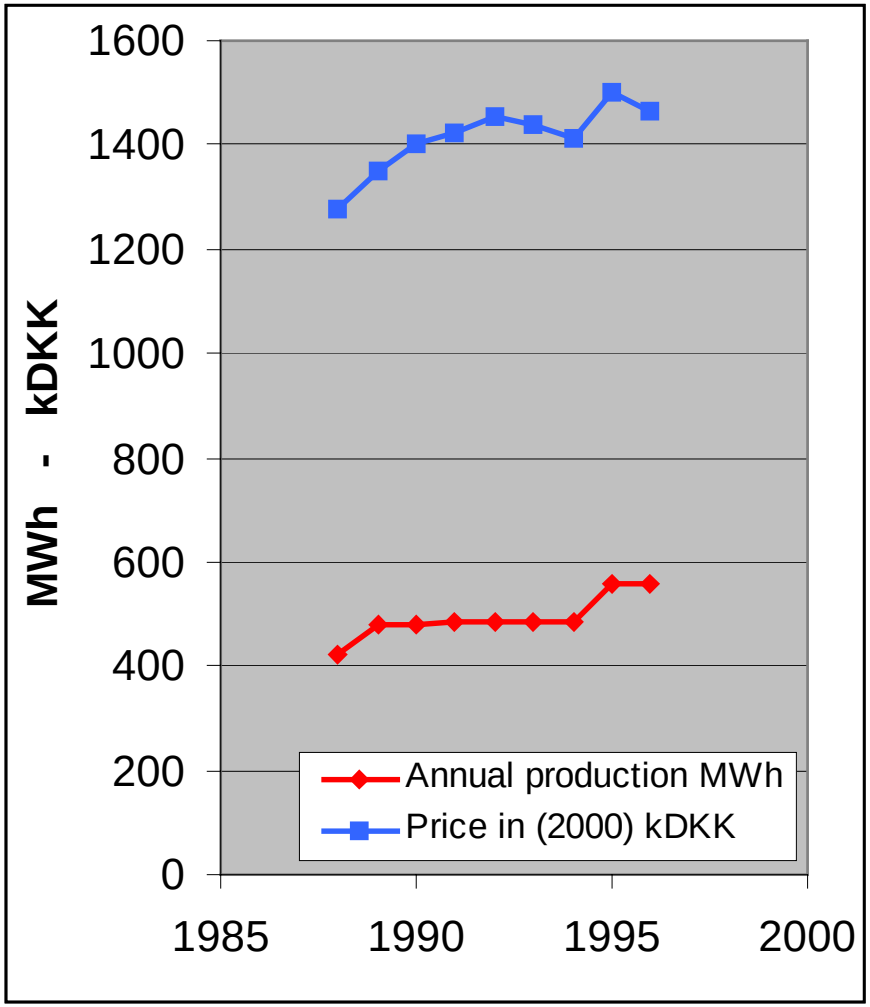
Micon 250 machine



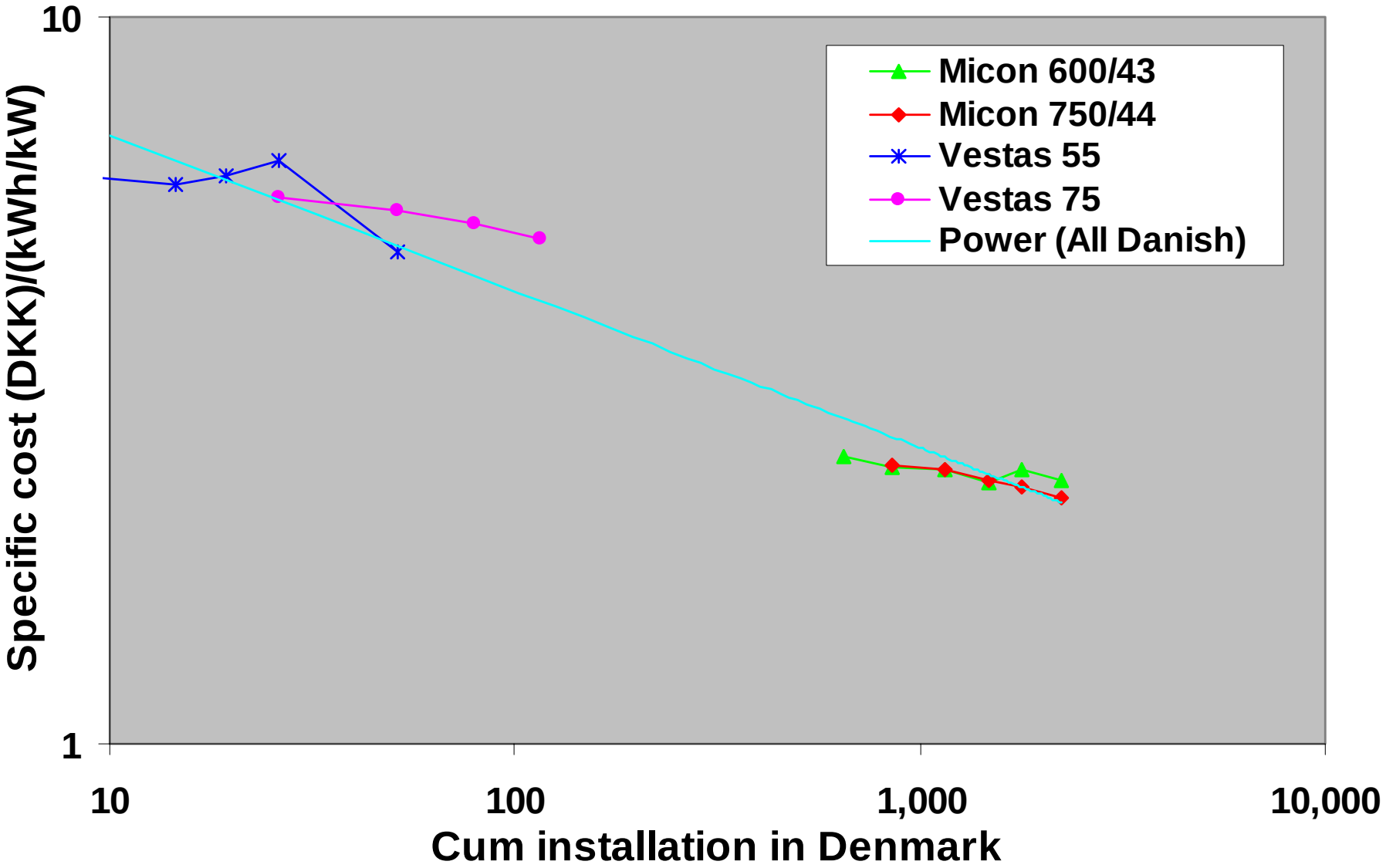
Innovation as improvements of a machine

Micon 250 machine

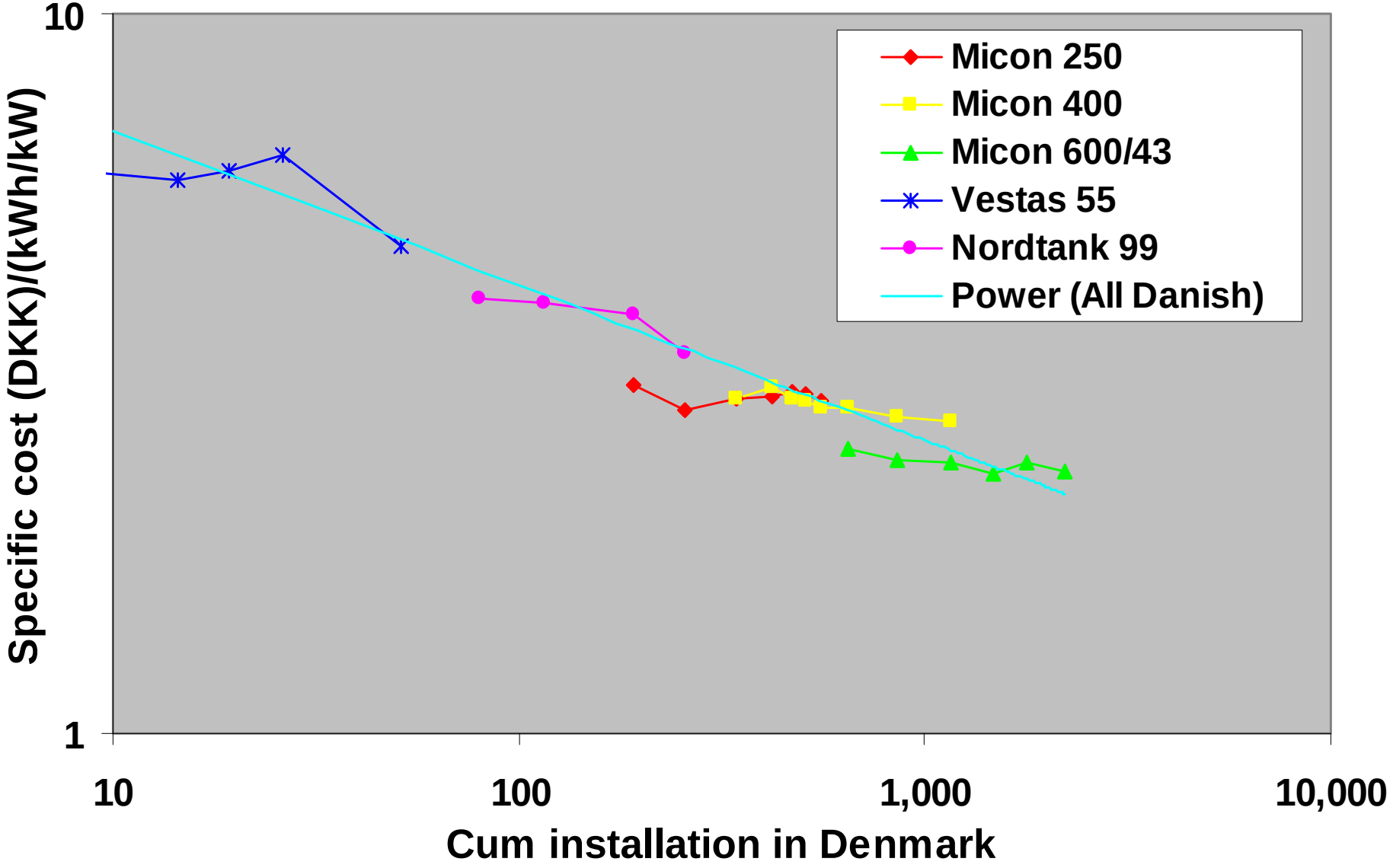




Innovation as up-scaling on a platform



Innovation as a new platform (generation)



Innovation theory revisited

Scientific challenges

- **Better theoretical understanding of what experience curves actually express**
  - y-axis: cost of equipment, total cost of installation, electricity production cost, ?

- **Better theoretical understanding and concepts of learning in contemporary use of "experience curve"**
  - Often only focus on "learning-by-doing" or "learning-by-producing"

➔ **Open up the black box of industrial learning and innovation**

Innovation theory revisited

Some approaches to learning

- **Innovation theory (evolutionary economy)**
  - technological paradigms and trajectories
- **Innovation theory (technology sociology)**
  - taxonomies of technology and innovation
- **Knowledge management (more recent paradigm)**
  - concepts of knowledge and learning
- **Science sociology**
  - concepts of knowledge/learning and technology/innovation
  - new concepts and paradigms in science and technology (”the new science”)

Innovation theory revisited

Some terms

- **Technology: artefact and knowledge**

- **Technology and knowledge**
  - product and process (Woodward, Perrow, etc)
  - concept knowledge and manufacturing or process knowledge
  - learning-by-doing and learning-by-using (Rosenberg)
  - design knowledge and production knowledge (Vincenti)

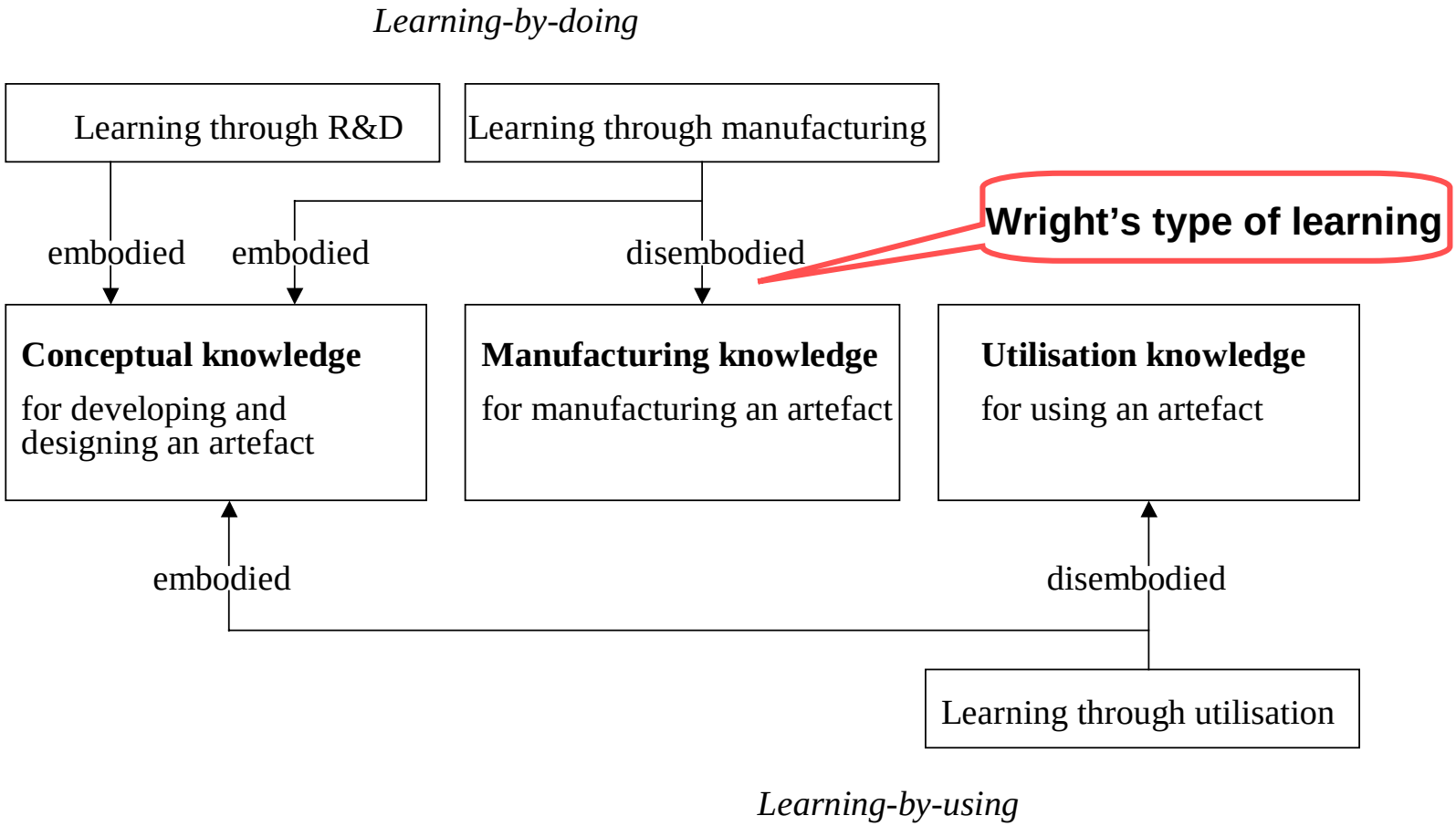
- **Codified knowledge and tacit knowledge (Polanyi, Vincenti)**

- **Embodied knowledge and disembodied knowledge (Rosenberg)**

- **Experience based and science based learning (Burns&Stalker, Rosenberg, Gibbons, Nowotny)**

Innovation theory revisited

A model for sources of knowledge and learning



Sources of cost reduction (and learning)

- **Total installation cost**
  - Ex works turbine costs (price/cost data available)
    - Costs of individual components: blades, generator, tower, etc. (data not available)
  - Additional costs (some data available – model for estimation available)
- **O&M costs (models for estimation available)**
  - Regular maintenance, spare parts, insurance, interest rate, administration, land lease, etc.
- **Energy production**
  - Efficiency (ability to extract energy from the wind – data available)
  - Siting (few data available - but not used)

➔ **Cost of electricity (estimate possible)**

Implications for experience curves (y-axis)

- **Learning traditional only linked to changes in manufacturing knowledge**
  - improvement in cost of equipment: EUR/kW
  - PR = f(cost of turbines, *additional costs*)

- **Also learning linked to changes in concept knowledge**
  - improvement in cost of equipment's ability to produce electricity EUR/(annual kWh)
  - PR = f(cost of turbines, *additional costs*, annual production at standard site)

- **Also learning to changes in utilisation knowledge**
  - improvement in cost of electricity (EUR/kWh)
  - PR = f(cost of turbine, additional cost, O&M, ability to micro-siting)
  - interest rates and insurance rates could be added as they reflects the financial community's learning on the area

Affects on experience curve and PR

Type of cost applied on the y-axis of the experience curves	Progress ratio	Types of experience included	Organizational boundary
a) Ex-works prices of wind turbines.	91%	Experience embodied and disembodied as cost reduction of equipment	Manufacturing industry
b) Total installation costs.	90%	Experience embodied and disembodied as cost reduction of equipment and installations	The whole business cluster except that related to operations
c) Specific electricity cost (or specific) ex-works prices.	86%	Experience embodied and disembodied as cost reduction of equipment and as improvements in efficiency	Manufacturing industry
d) Levelised cost of electricity.	83%	Experience embodied and disembodied as cost reduction of equipment and installation, as improvements in efficiency and disembodied utilization experience	The whole business cluster

Estimate of future cost reduction of wind electricity

Reductions 2000 to 2004: 15%

Source	Relative share
Design improvements – weight reductions of wind turbines (*and larger rotors?*)	35%
Improved conversion efficiency - aerodynamic and electric efficiency	5%
Economy of scale – gains from steady serial production and optimisation of logistics	50%
Other contributions – foundations, grid connection, O&M	10%
Total	100 %

Sources:

•IEA R&D Wind, Ad Hoc Group report on Long-term R&D Needs for Wind Energy for the time Frame 2000 tp 2020.

• BTM Consult, World Market Updata 1999.