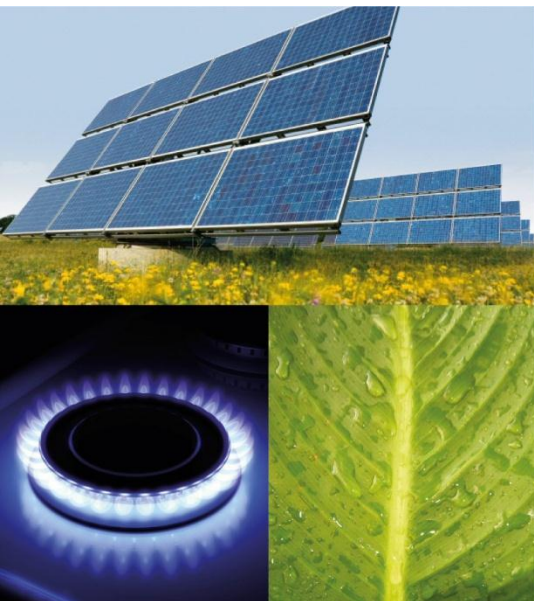


Innovation for Accelerated Deployment and Learning Curves

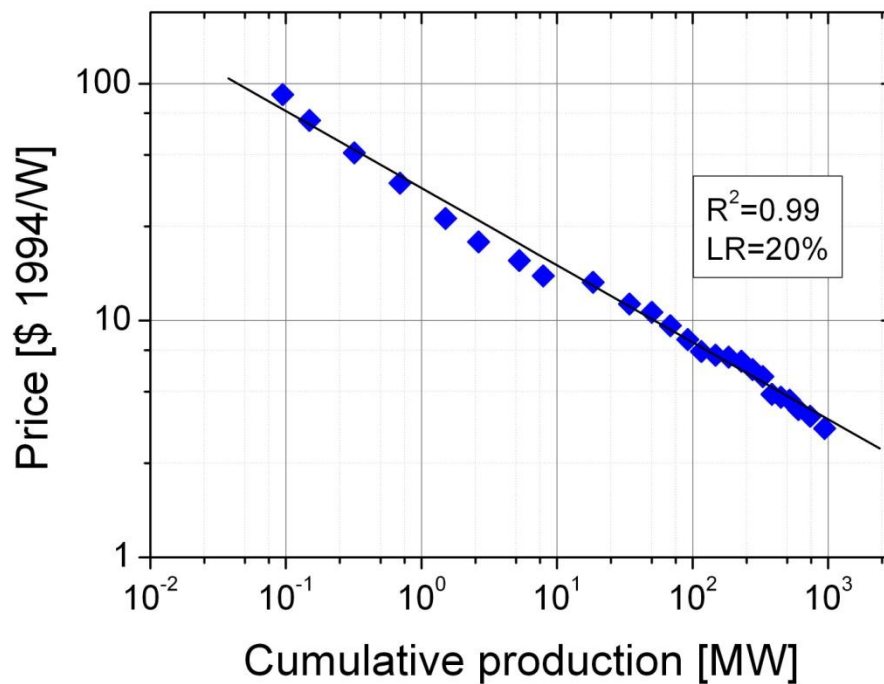
IRENA, IITC Inaugural Workshop, “Renewables: Competitiveness and Innovation”

Bonn, 6 October 2011

Bob van der Zwaan

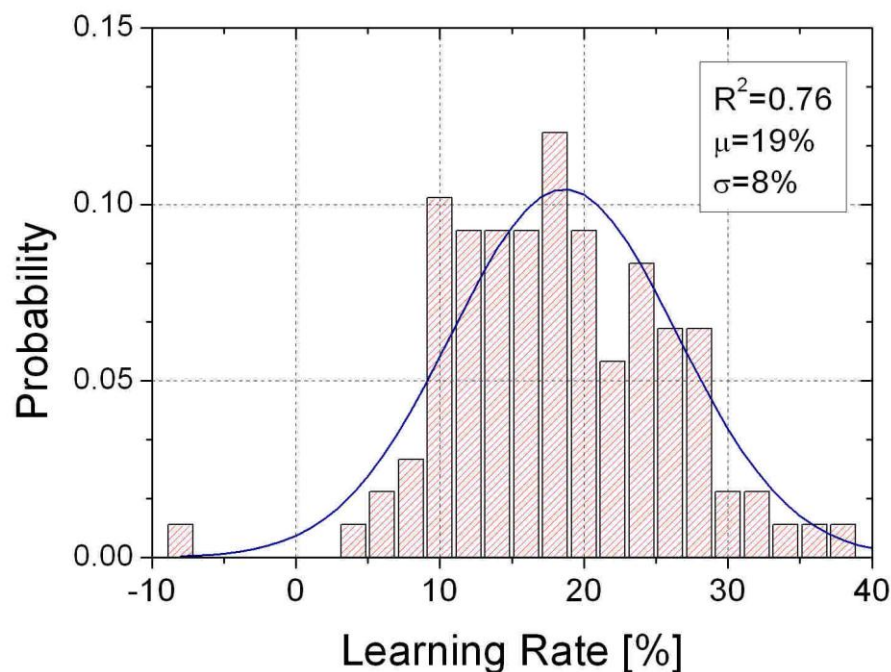


Learning curve



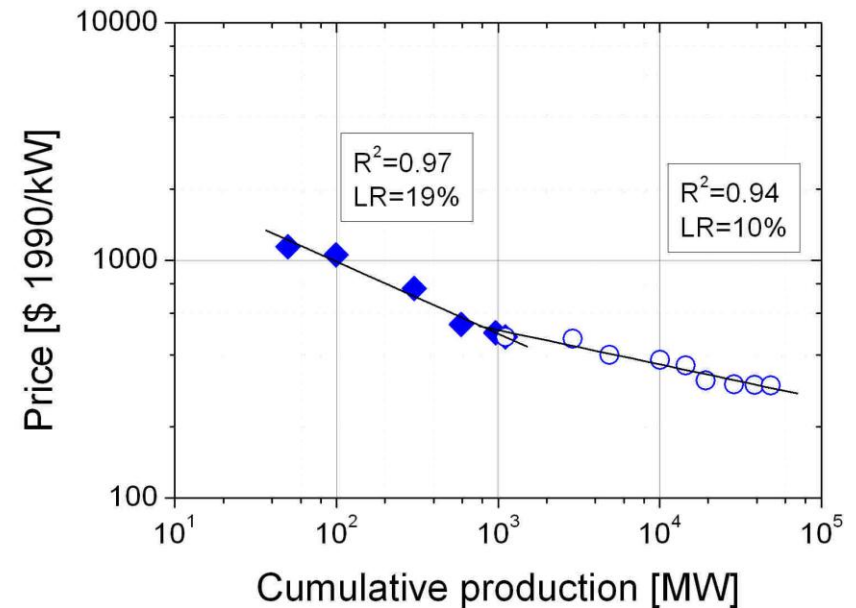
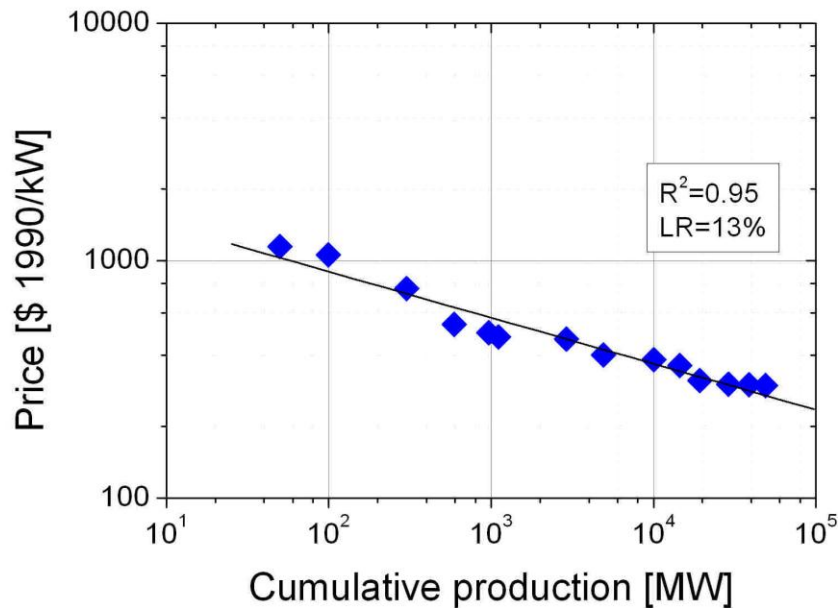
Price data for PV modules with learning curve (Harmon, 2000).

Learning rate distribution



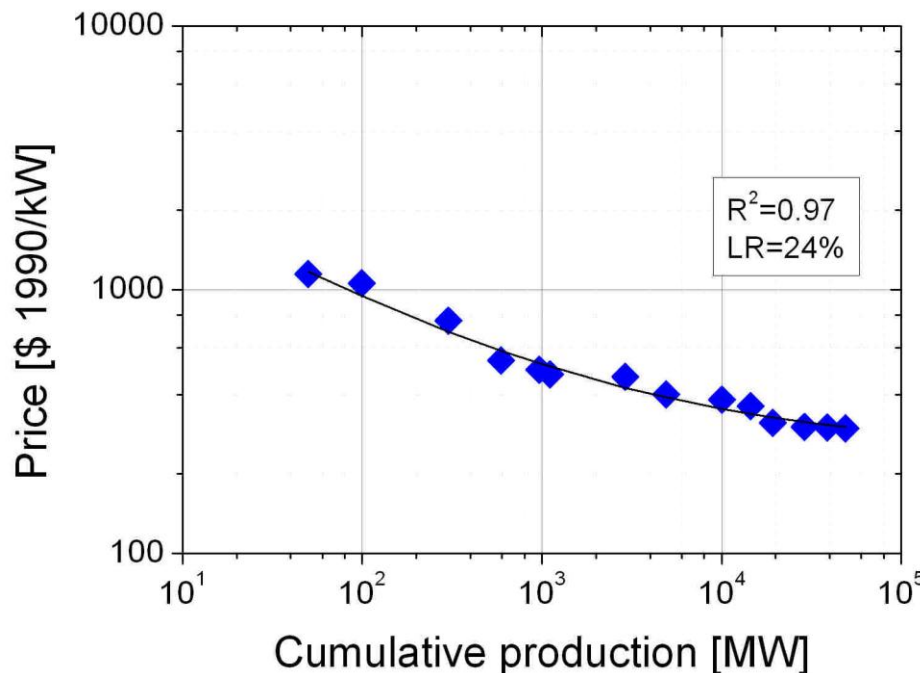
Learning rate distribution for over 100 technologies (data: Dutton and Thomas, 1984; Gaussian: Ferioli et al., 2009).

Traditional learning



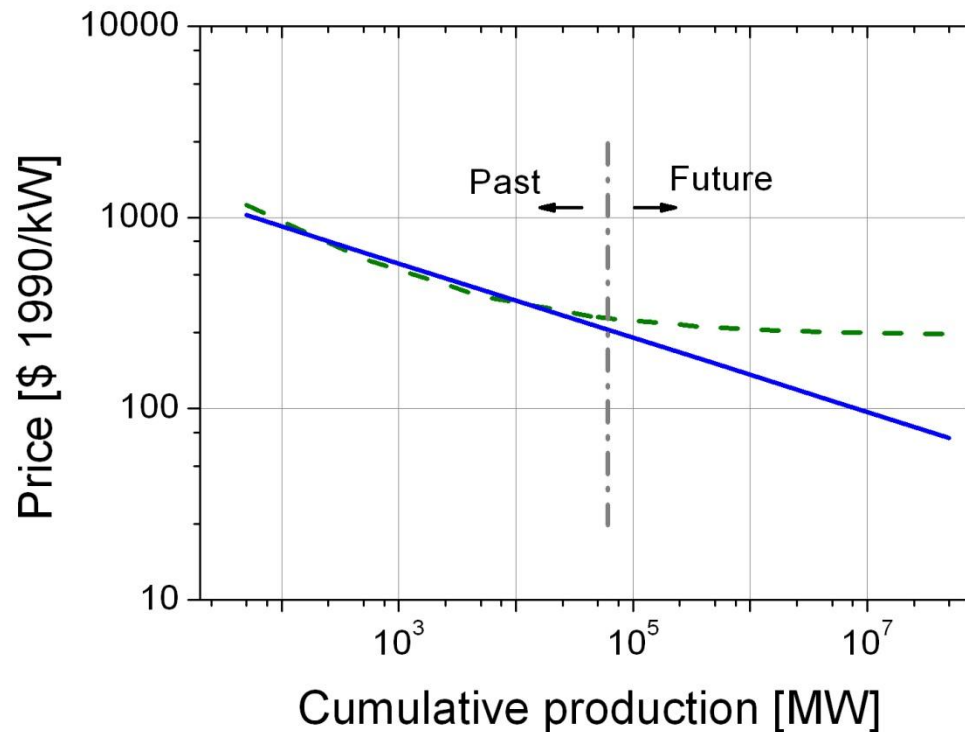
Price data for gas turbines fitted linearly and piece-wise linearly (data from MacGregor et al., 1991).

Component learning: gas turbines



Price data for gas turbines and fit under the assumption that only one of two components learns, $\alpha=0.8$ (Ferioli et al., 2009).

Component learning: implications



Traditional versus component-learning (Ferioli et al., 2009).

On- and offshore wind power



Learning rates from 4% to 15%:
Neij et al., 2003.

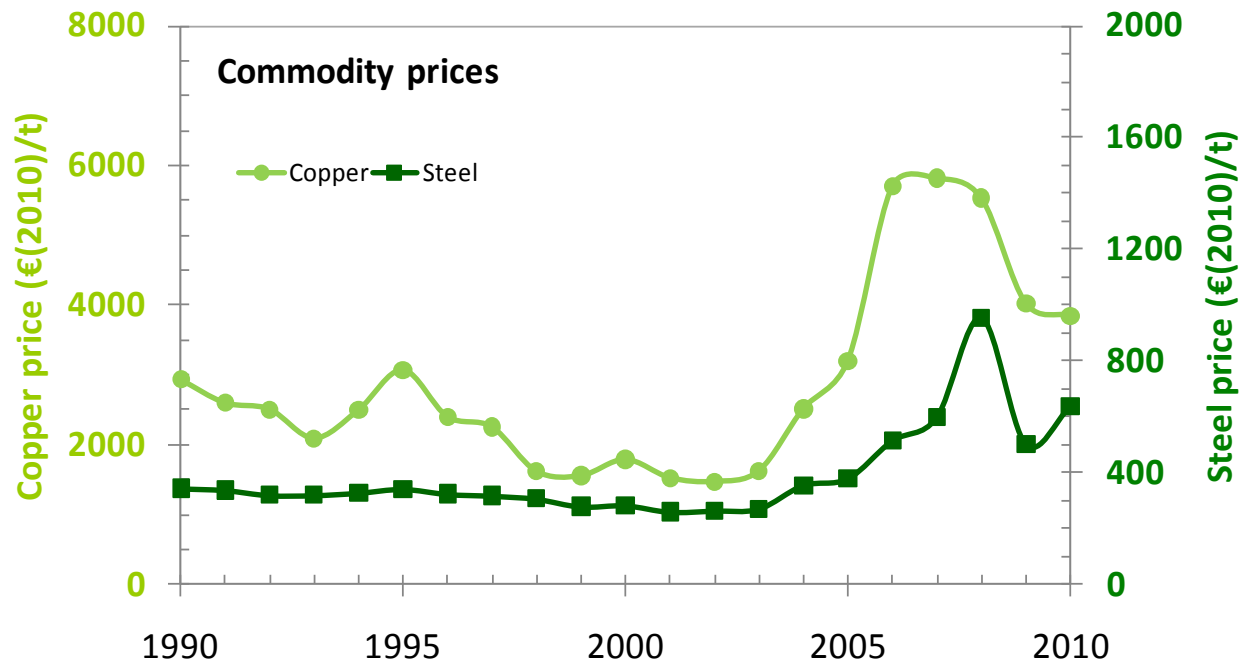
Offshore wind gains in popularity:
space and speed.



Learning for offshore wind?

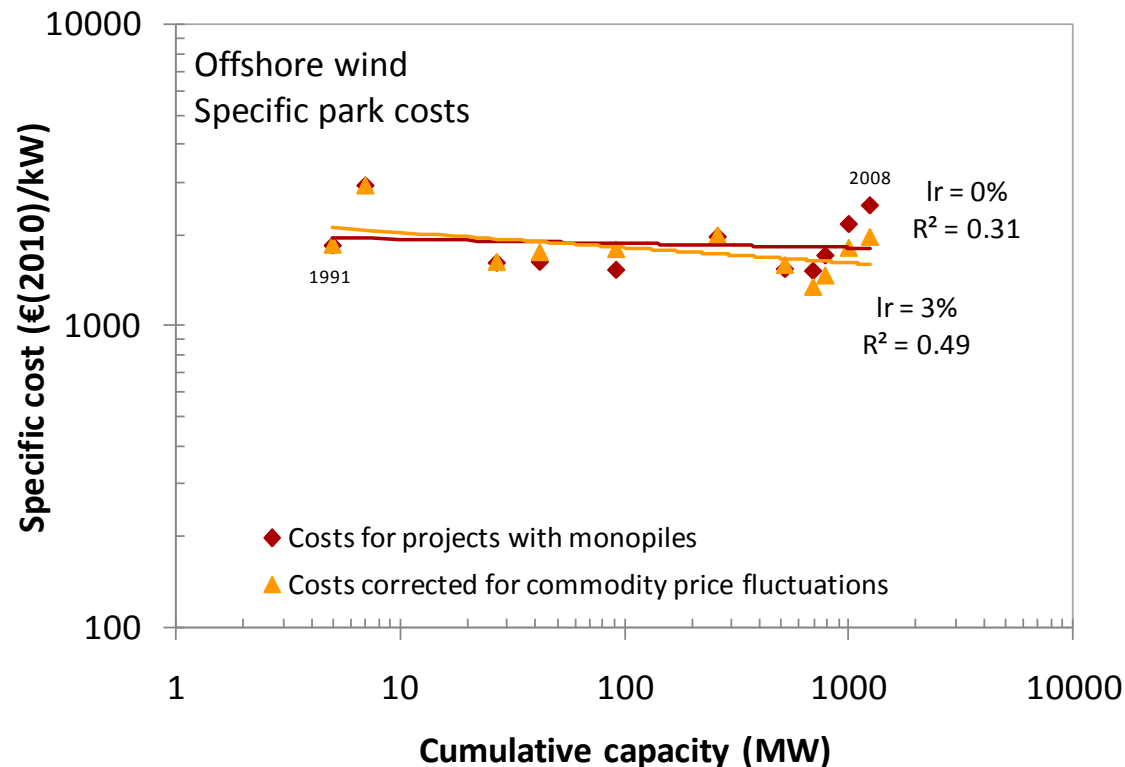
- Cost increasing effects:
 - Commodity prices
 - Market tightness
 - Sea depth
 - Shore distance
- Cost decreasing effects:
 - Economies-of-scale for turbines
 - Economies-of-scale for wind parks
 - Learning-by-doing for manufacturing
 - Learning-by-doing for installation

Prices of materials



Commodity price development (van der Zwaan et al., 2011).

Offshore wind learning



Learning for offshore wind (van der Zwaan et al., 2011).

Learning curve merits

- Clean energy technology is key to address the problem of global climate change.
- Among the largest challenges is the high cost of innovative (renewable) energy technology.
- Learning curves can be useful tools for analyzing potential cost reductions.
- But they have to be handled with care and considered in juxtaposition to understanding technology features.
- Opening up the 'black box' of learning curves needs to be elaborated, including on the lines suggested.

Learning curve caveats

- Learning-by-doing seems rather universal, so should be used to justify investing in e.g. renewables.
- Prices of indispensable material input, however, may constitute a lower bound, or even reverse learning.
- Often only technology components learn, rather than the technology as a whole, which may be bad news.
- Costs are among the many factors determining the deployability of new / renewable energy technologies.
- 21st century society should probably be prepared to pay more for its energy services.

Publications

- Ferioli, F. and B.C.C. van der Zwaan, “Learning in Times of Change: a Dynamic Explanation for Technological Progress”, *Environmental Science and Technology*, 43, 11, 2009, 4002-4008.
- Ferioli, F., K. Schoots and B.C.C. van der Zwaan, “Use and Limitations of Learning Curves for Energy Technology Policy: a Component-Learning Hypothesis”, *Energy Policy*, 37, 2009, 2525-2535.
- Ferioli, F., K. Schoots and B.C.C. van der Zwaan, “Component-Learning for Energy Technologies: the Case of Hydrogen Production”, *International Journal of Innovation and Learning*, 6, 6, 2009, 625-640.
- Schoots, K., F. Ferioli, G.J. Kramer and B.C.C. van der Zwaan, “Learning Curves for Hydrogen Production Technology: an Assessment of Observed Cost Reductions”, *International Journal of Hydrogen Energy*, 33, 11, 2008, 2630-2645.
- Schoots, K., G.J. Kramer and B.C.C. van der Zwaan, “Technology Learning for Fuel Cells: an Assessment of Past and Potential Cost Reductions”, *Energy Policy*, 38, 2010, pp.2887-2897.
- van der Zwaan, B.C.C., K. Schoots, R. Rivera-Tinoco and G.P.J. Verbong, “The Cost of Pipelining Climate Change Mitigation: an overview of the economics of CH₄, CO₂ and H₂ transportation”, *Applied Energy*, 8, 2011, pp.3821-3831.
- Rivera-Tinoco, R., K. Schoots and B.C.C. van der Zwaan, “Learning Curves for Solid Oxide Fuel Cells”, *under review*.
- van der Zwaan, B.C.C., R. Rivera-Tinoco, S. Lensink, P. van den Oosterkamp, 2011, “Evolving Economics of Offshore Wind Power: Cost Reductions from Scaling and Learning”, *under review*.