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The Sailing Ship Effect and its Potential Influence on Energy Transitions and Policy

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Aim / Outline

- To explore
  - The origins of the contested *Sailing Ship Effect / Last Gasp Effect* hypothesis/es
  - Explanations for it - how can it arise?
  - Claims of its existence and non-existence
  - Its potential relevance for innovation policies and transitions to a low-carbon economy

The hypothesis of the *Sailing Ship Effect*

- The advent of a competing new technology may stimulate innovation in an incumbent technology
  - for some mature technologies, in some circumstances
- This ‘Sailing Ship effect’/ ‘Last Gasp Effect’ makes the incumbent technology more efficient and competitive
- Before being ultimately superseded
- Cited SSE/LGE examples include:
  - Improvements in sailing ships after the introduction of the steam ship in late C19
  - The response of gas lighting, via the Welsbach incandescent mantle, to the 1880s arrival of the incandescent lamp
  - The response of carburettors to the introduction of electronic fuel ignition in the 1980s (Snow)

Potential Significance of the SSE Hypothesis for Lower Carbon Transitions & Policy

- Significantly increased (price/quality) competitiveness of the incumbents could :
  - Slow the newcomers' sales
  - Delay their travel down their experience curves
  - As they chase the incumbents' shifting experience curves
- Slowing the transition: reducing newcomer penetration rates below what they would have been
- And raising policy costs – through higher subsidy levels needed for price/quality competitiveness & penetration
- And forecasts, to the extent that they fail to allow for the SSE, will overestimate new technology penetration
- So understanding SSEs/Last Gasps matters, in a context where there are mature technologies and we seek radical innovation

Background and Literature

- Early work on sailing vs. steamships by Gilfillan (1935), Graham (1956) & Harley (1971)
  - Also discussed in Geels (2002) – a complex 'mosaic' of mostly qualitative evidence
- Rothwell & Zegfeld (1985) claimed the existence of the SSE in the C19 alkali industry
- Utterback (1996) cited two C19 US cases: gas vs. electric lighting ('The gas companies came back against the Edison lamp … with the Welsbach mantle') and mechanical versus harvested ice.
- Tripsas (2001) identified the effect as the 'last gasp' of a technology
- But the existence, frequency and scale of the SSE disputed by Howells (2002):
  - "Detailed re-examination of two cases thought to be exemplars of the effect reveals that it existed in neither. […] if the phenomenon occurs, it is likely to be rare."
- Recent re-examination by Snow (2004), the carburettor's 'Last gasp':
  - Defines the LGE as: 'An extraordinary *efficiency* improvement in a technology immediately preceding the death of the technology'
  - Because he wants to allow for more than narrowl technological improvement

Three Explanations (1): Trying harder

1. Response to a threat

- Rosenberg (1976):
  - 'The imminent threat to a firm's profit margins […from] the rise of a new competing technology seems often in history to have served as a more effective agent in generating improvements in efficiency than the more diffuse pressures of intra-industry competition.'
  - *Counterfactual?* But he accepts that the sailing ship builders' response to the threat of steam can't be asserted with authority, 'because we do not know what the sailing ship of the 1880s would have been like in the absence of such inter-technological competition. But it seems like a reasonable conjecture…'
- **Utterback (1994):** firms 'do not always sit back and watch their markets disappear. Most fight back.'

Trying harder – Qualification & refinement

- *The Red Queen Effect:* from evolutionary biology, : 'in this place it takes all the running you can do, to keep in the same place' - evolve or be selected out (Snow)
- *Qualification:* where's the slack - if there are competitive markets, why is there still room for more? And why not exit or switch instead? (Howells)
- *Refinement:* trying harder is relevant in imperfectly competitive markets that have high exit & switching costs associated with the old technology (Snow)

Three Explanations (2): Selection & Fit

2. Selection and Fit:

- LGE improvements come from a *selection mechanism* which divides the market between new & incumbent technologies
- In ways that allow technologies to be used in areas/niches of comparative advantage
- So the most inefficient uses are selected out first and replaced by the new technology, raising efficiency and leaving the old technology in the most efficient areas
- So even with static technology, the old technology *appears* to improve, by being forced into areas where it retains a comparative advantage (Snow)

Three Explanations (3): Technology Spillovers from the New Entrant

3. **Spillovers:**
   - Component innovations from entrant technologies may spill over to incumbents, enhancing measured incumbent performance
   - In circumstances where the entrant's arrival is a necessary condition for the introduction of the new component technology
     - (or why not do it anyway?)
   - Implicitly in Harley (1971); raised by Schivelbusch (1988)
   - Examples: iron hulls in sailing ships, incandescent gas mantle, electronic components in carburettors, hybrid hard disk drives with flash memory…

Case Study: Carburettors and Electronic Fuel Ignition (EFI) – Snow (2004)

- Until the early 1980s, carburettors were the standard technology for mixing petrol & air
- By the late 970s, carburettor technology seemed to be reaching the limit of its ability to achieve more MPG & accommodate tightening emissions control equipment requirements
- In 1980, Electronic Fuel Injection (EFI) - was offered for the first time as an alternative on mass-produced vehicles
- It used electronic controls and electronically-controlled valves, allowing better control of the ratio of fuel to air
- So car makers could use more advanced emissions control devices and get better fuel economy.

Carburettors and EFI (2)

- There was a gradual ten-year transition from carburettors to EFI
  - Three reasons:
    - Early EFI systems cost $600 more per unit, so were only found on luxury and performance cars
    - Early EFI systems were less reliable than carburettors
    - Even in the early 1980s, observers were unsure that EFI would eventually 'kill' still–improving carburettors
- After EFI introduction, cars equipped with carburettors exhibited dramatically increased fuel efficiency
- Snow uses two EPA datasets plus patent data to explore the three explanations for this last gasp

Carburettors and EFI (3)

Snow's findings: all three explanations played a role

- The *selection effect* was important: as EFI was adopted, selection led to observed fuel efficiency gains *not* caused by technological change in carburettors
- *Spillovers:* the greater rate of fuel efficiency improvement in carburetted cars equipped with FFS suggests that spillovers from EFI technology were responsible for a substantial portion of the fuel efficiency increases in carburetted cars
- *Trying harder:* there is ambiguous evidence that firms that were most committed to carburettors tried harder to generate efficiency improvements in them

Case 2: Falling costs for new and incumbent technologies: Flash memory & hard drives

The Guardian | Thursday August 24 2006

TechnologyGuardian Inside IT

Flash memory ready to put hard drives in a spin

Flash memory is getting cheaper all the time. Does this mean the end of the hard drive as we know it?

George Cole

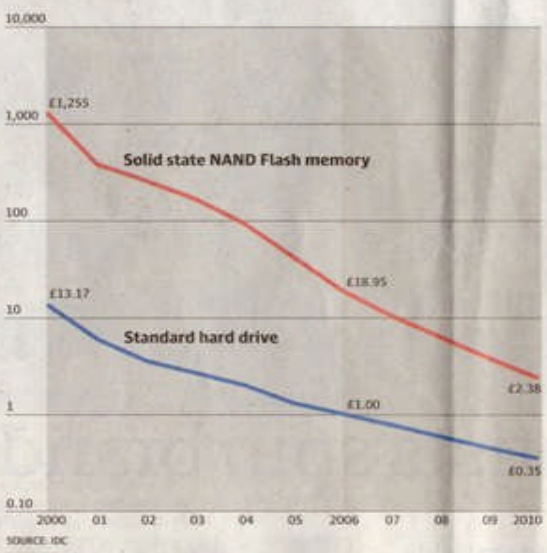
The PC hard drive could soon be an endangered species. As the price of Flash memory crashes, it is being used in areas traditionally occupied by magnetic storage systems. USB Flash keys are fast becoming the portable storage medium of choice, and a growing number of digital music players (such as Apple's iPod nano) use Flash memory rather than miniature hard drives. Flash memory – specifically, that using NAND logic gates in its transistors, rather than NOR gates, which is slower – is frequently used in games consoles, digital cameras, digital camcorders and mobile phones. But could it really replace a computer hard drive?

Some are trying. In Korea, Samsung has launched two computer products that use solid state drives (SSDs) in place of the conventional magnetic version. Both the NT-Q1-SSD ultra mobile PC (about £1,300) and the NT-Q30-SSD (around £1,900), a 12.1-inch screen notebook, have a 32GB NAND Flash drive. Samsung says there are many benefits to putting an SSD inside a computer, claiming an SSD can read data at 57MB/s and write at 32MB/s, significantly faster than a hard drive's typical 24MB/s, thus offering faster access to applications and slicker multi-tasking.

The boot-up time for Windows XP is said to be 25% to 50% faster and an SSD is up to 60% lighter than a comparable 1.8in hard drive. It's also more robust – Samsung claims that the SSD can withstand deceleration forces (that is, being dropped) double what would cripple a

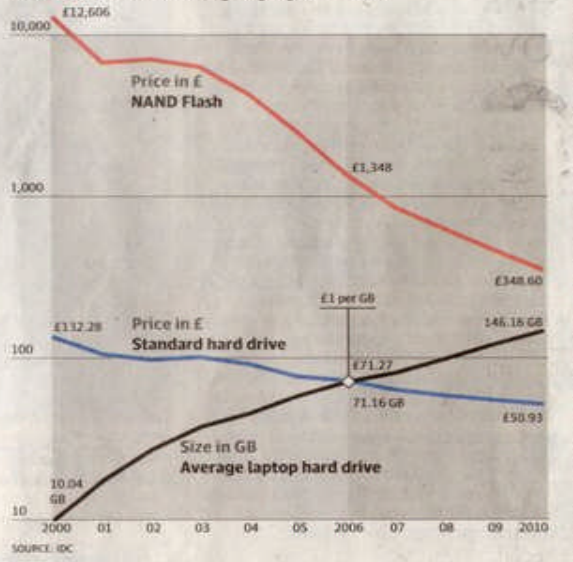
Cost of Flash memory crashes ...

Price of a gigabyte of storage



... while hard drives grow

Price and size of an average laptop hard drive



"Hard drives which measure 1in and less will be under pressure from Flash."
Joe Unsworth, Gartner

each successive generation of PC offers larger storage capacity (see graph 2).

"The disadvantage is cost," admits Richard Walsh, Samsung Europe's senior manager for Flash marketing, "but we're targeting our solid state products at the professional executive who's looking for a smaller computer – a kind of 'super Blackberry'. It's for carrying your business applications and not for storing movies or family photos. But NAND Flash prices are falling every year."

In an article written last November for the International Disk Drive Equipment

disk only needs to spin perhaps once every 10 or 20 minutes, when the solid state cache is full and needs to put some of its contents on to the hard drive.

Joni Clark, Seagate's product marketing manager for notebook drives, says there are three key benefits to using an HHDD: "It's more power efficient, because the hard disk drive hardly spins, and so you get longer battery life. Second, it's faster, so you can expect faster boot-up times, faster resume [from Windows hibernation mode] and faster access to applications. Finally,

the first HHDDs are due in ea
the expected date for the
launch of Microsoft's Windo
because manufacturers have
ing with the software giant f
HHDD technology.

"I believe Microsoft saw cer
tions in the hardware," sa
"Microsoft recognised the b
and saw hybrid disk drives as
improving the computer." W
Sandisk's vice-president for
products, adds: "Vista is abou
bigger than XP, and what co
with that large size is a speed
with faster CPUs. We've bee
with Microsoft on ways to spe
ing and application loading
menting the hard drive with F

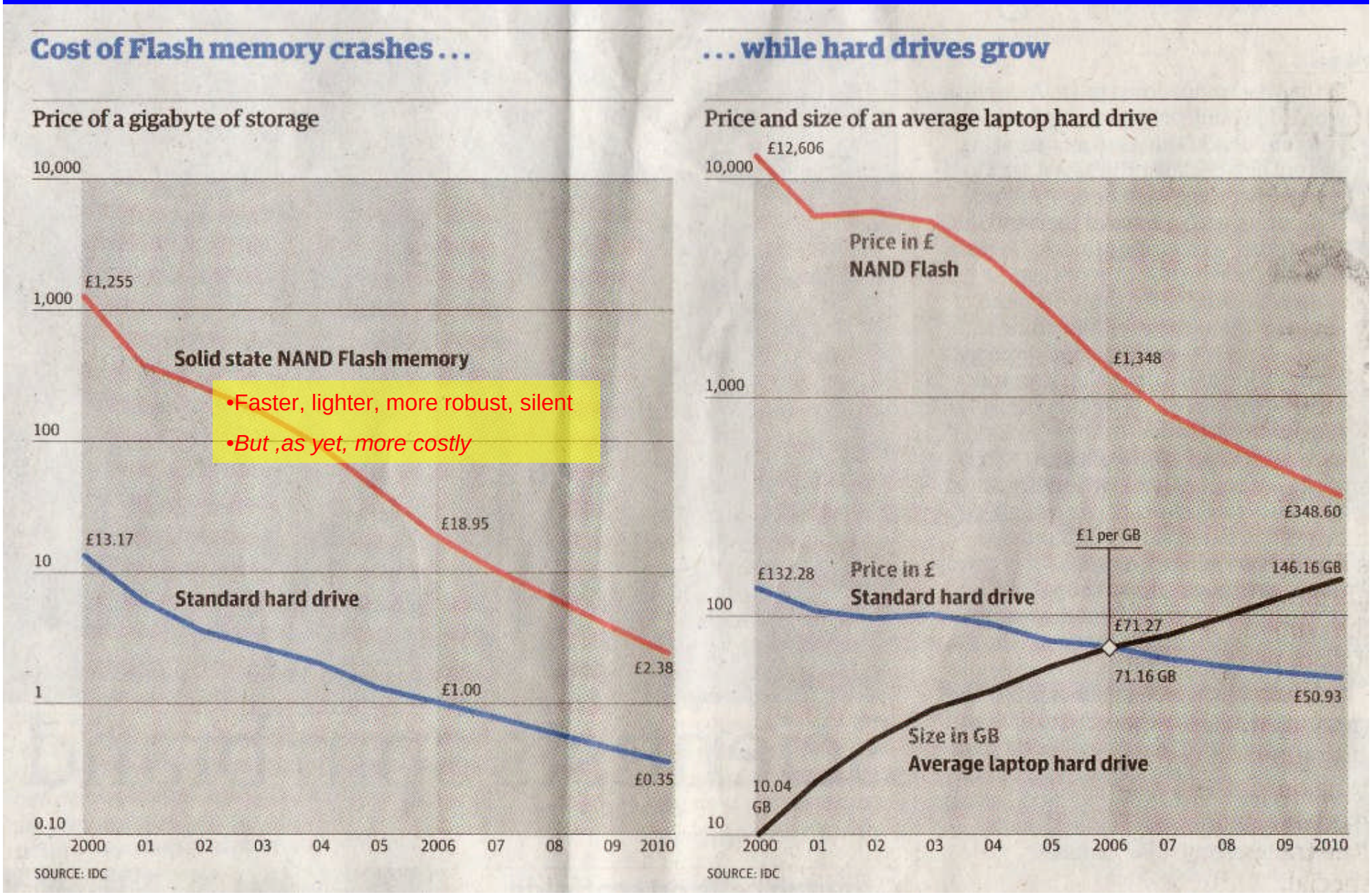
Vista is ready for HHDD

Vista will automatically recog
device is using a HHDD and w
a feature, ReadyDrive, which
to take advantage of the techn
will also offer a feature called R
where a Flash USB key can be u
of additional RAM chips to boo
able amount of PC memory (u

The chip maker Intel also w
Flash memory to improve
mance, but rather than opt for
nology, plans to put Flash me
where on a PC. The company
eration portable platform (
Santa Rosa) will include a
called Robson, which adds u
Flash to the motherboard.

"You're talking about a com
size of a fingernail, so that son
a cell phone today could use
bile PC as an alternative," s
Meanwhile Intel, Sony, the m
ufacturer Micron and others h
the Open NAND Flash Interfa
Group, which aims to develo
tions to make it easier for ma
to integrate NAND Flash wi

Flash memory & hard drives (cont.)



- Faster, lighter, more robust, silent
- *But ,as yet, more costly*

Flash memory & hard drives (cont.)

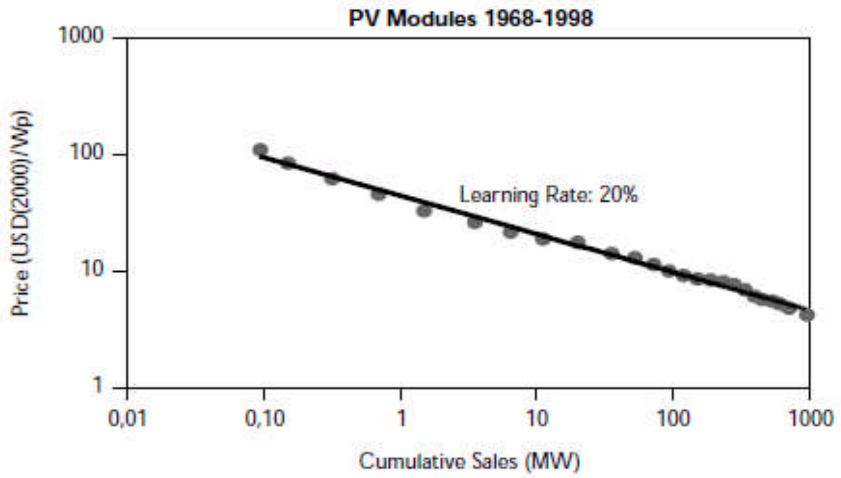
- Next year a new generation of hybrid hard disk drives (HHDDs) will be launched
- Combining a magnetic disk drive with a NAND flash cache, to speed up performance
- Some think that hard disk drives will still be the main storage medium for users wanting >20GB, for at least the next few years
- Suggests the value of looking further at these spillover relationships between new and incumbent technologies

Experience Curves, Learning Investments/Subsidies & Incumbent Technologies

IEA (2003) *Creating Markets for Energy Technologies*

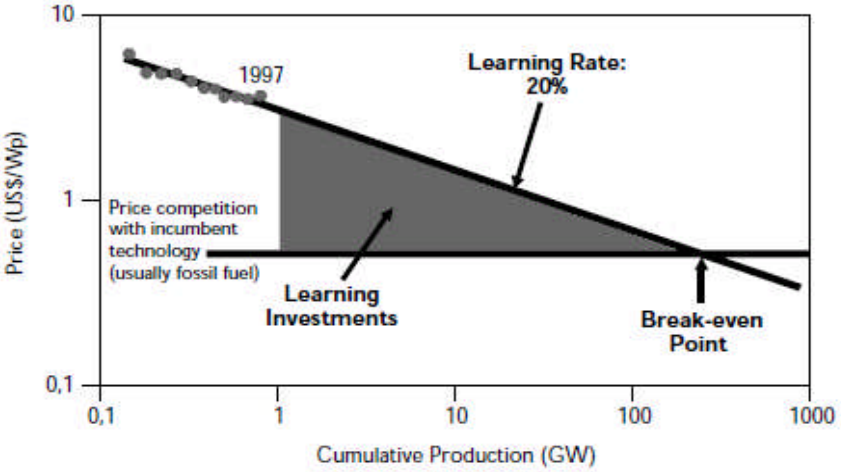
- For PV systems to compete with central power station technologies, module cost must fall to 0.5 US$/Wp
- The shaded triangle represents the *learning investments*
  - that will have to be covered from somewhere if the PV-electricity market is to expand
  - And if cost is to reach current incumbents' market price – the breakeven point

Figure 3.3. Thirty Years of Technology Learning



Source: Adapted from Harmon (2001).

Figure 3.4. Making Photovoltaics Break Even



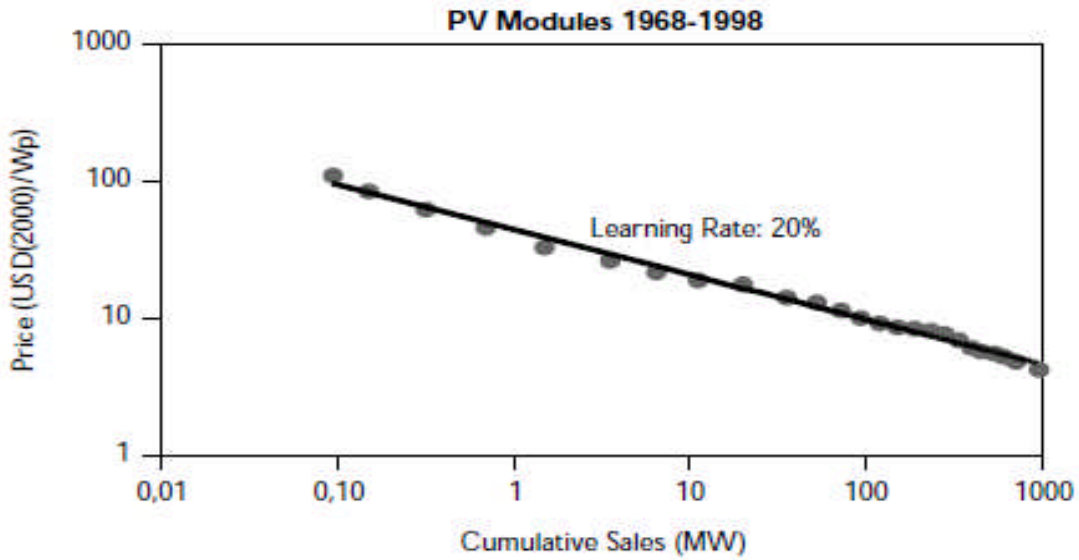
Source: OECD/IEA(2000).

IEA (2003) *Creating Markets for Energy Technologies: 56-7*

- "[But…] incumbent technologies may still be benefiting from market learning.
- That is, the price line for the incumbent technology should perhaps be sloping downward;
- However, [… this] does not change the general thrust of the argument.
- Some important incumbent technologies are old enough to make the assumption of a zero-learning effect reasonable.
- Where this is not the case there is still no problem […] because the logic of the experience curve implies that added sales reduce cost faster for the new technologies than for the old ones."

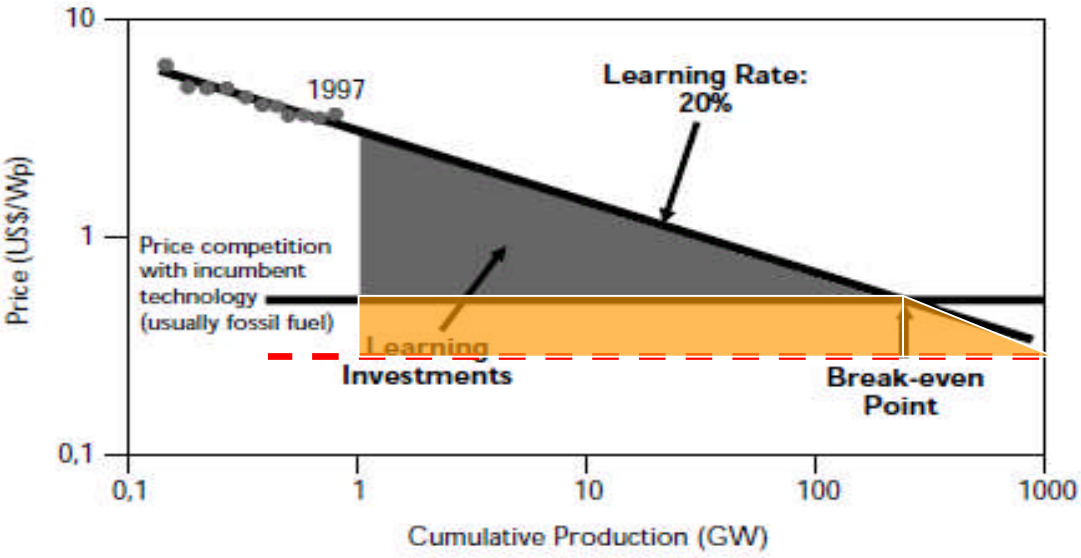
❑ But what if the incumbent's experience curve shifts downwards?

Figure 3.3. Thirty Years of Technology Learning



Source: Adapted from Harmon (2001).

Figure 3.4. Making Photovoltaics Break Even



Source: OECD/IEA(2000).

- But what if the incumbent's experience curve shifts downwards?
- Bigger learning investment

Shifts in Incumbent's Experience Curve?

- But what if the incumbent's experience curve shifts downwards, because of SEE/Last gasp (and/or uncertain shifts in fossil fuel prices)?
- There will then be a non-linear relationship between the change in the price differential and the size of the learning investment/subsidy (see geometry of Fig. 3.4)
- So we need to pay serious attention to what's happening/might happen to incumbent technologies and their costs

Potential Significance of the SSE Hypothesis for Lower Carbon Transitions & Policy

- Significantly increased (price/quality) competitiveness of incumbents, through SSEs & fossil fuel price shifts, could :
  - Slow newcomers' sales
  - Delay their travel down experience curves
  - As they chase incumbents' shifting experience curves
  - Slowing the transition by restraining penetration rates (McVeigh et al.)
  - And raising policy costs via higher subsidies needed for competitive penetration
  - While forecasts that don't allow for SSEs could overestimate penetration
- So, appreciating SSEs/Last Gasps matters, where there are mature technologies and we seek radical innovation
- And suggests giving proper attention to dynamic interactions between new and incumbent technologies

Another Blast from the Sailing Ship Effect?

The Guardian | Monday September 18 2006

Financial

Engineer sees wind set fair for return to age of sail

Hans Kundnani

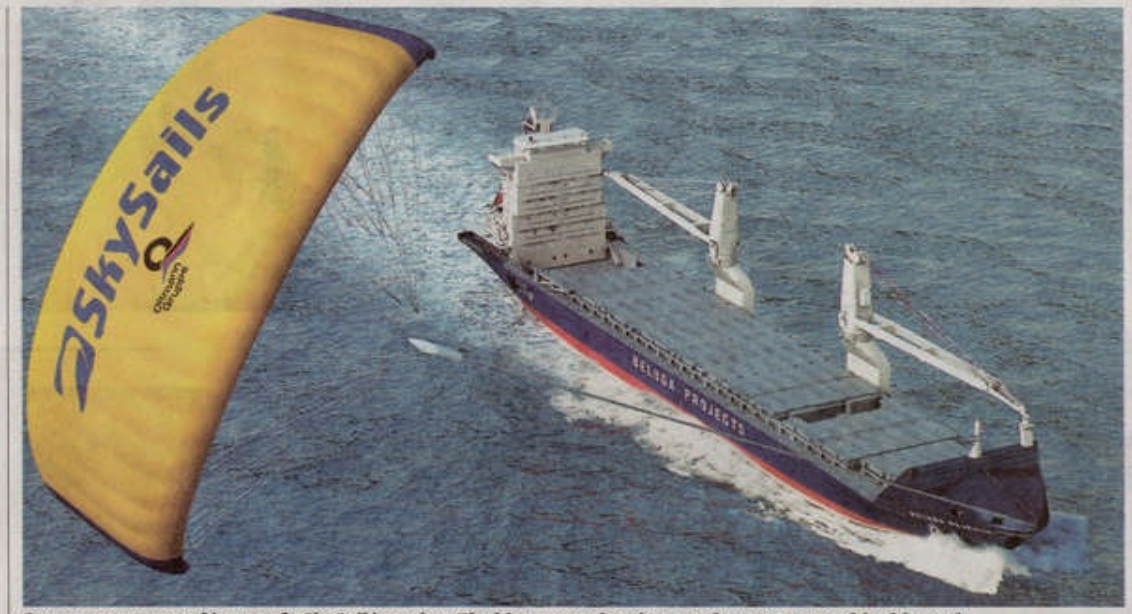
When Stefan Wrage first starting trying to get financial backers for a company that would power ocean-going ships by flying a kite in front, most people saw him, as he puts it, as a "freak".

Wrage, in his 20s at the time, insisted that his idea, which he called SkySails, would enable ships to use less fuel, not only saving them money but also benefiting the environment. No one was interested. "People said it wouldn't work," he says. "But no one was able to tell me why it wouldn't work."

Five years on, Wrage's firm now has shipowners' backing including €10m (£6.7m) from the Oltmann Group, a German ship financier. This week he is due to demonstrate an 80 square metre sail on a 55 metre buoy tender ship – a small cutter used to look after buoys and lighthouses. Next year he plans to use bigger sails on superyachts and on a 150 metre cargo ship owned by the Beluga Group, based in Bremen, Germany.

The turning point came in 2005 when oil prices started to climb above $60 a barrel. The economics of the shipping business changed and any idea, however bizarre it sounded, seemed worth exploring. Doors that had been previously closed to Wrage opened. "Suddenly, it was a lot easier to raise money," he says.

Although it seems bizarre to most people, to Wrage the idea of putting boats and kites together always seemed obvious. As a child growing up in Hamburg, Germany, his two passions were sailing on the Alster lake and flying his home-made kites on the beach. But he had always wondered why the immense power of the wind that carried his kite could not be used to propel vessels along the water. "It was just a boy's idea," he says.



Computer-generated image of a SkySail in action. The kite system is to be tested on a 55 metre ship this week

from doing vacation jobs, he decided to try to make his childhood idea – which he now believed could make money – a reality. He applied for his first patent and set up SkySails in 2001.

Ingenious

Ever since the introduction of steam powered ships in the 19th century, wind has made only one brief comeback – in the 1970s, another period of spiralling oil prices. But Japanese and Danish experiments with sails came to nothing.

Wrage's idea was, in comparison, ingenious. His SkySails fly at a height of between 100 and 300 metres above sea level, where winds are up to 50% more powerful. Instead of using a mast, they are fastened to the ship by a tow line attached to a winch in the bow of the ship, which reels out the sail for use.

The key challenge for Wrage was to perfect steering using kites. Initial experiments with dinghies and store-bought kites in the Baltic Sea were a disaster. In 2002 he hit rock bottom: he had

Finally he persuaded another engineer to invest £70,000, and he began testing models in a Hamburg ship basin. By 2005, when oil prices started to spiral, he had a working model of a 50 metre, 20 tonne boat to show potential investors. "It gave us a lot of credibility," he says.

This year, new international rules on marine pollution also took effect forcing ships to reduce sulphur emissions. Low-sulphur fuel costs up to 50% more than ships' regular bunker fuel – an addi-

SkySails this month. He hopes what wa initially dismissed as a fantasy will become a standard for ships of all sizes travelling up to 15 knots and could help cut fuel costs – which can make up ove half of a ship's operating costs – by 50%.

The SkySails, which will be delivered from 2008, are controlled by an autopilot which reels out the sail when weather conditions are favourable and reels it back in when they are not. They cost between €400,000 and €2.5m, depending on the size. Wrage says he aim to equip 1,500 ships in the next 10 year

But although many in the shipping world are now sold on the idea of finding alternative power sources to reduce fuel consumption, opinions are divided on whether Wrage's idea will take off.

"The industry is by nature very conservative and cautious," says Edwin Lampert, editor of the Marine Engineer

> 'People said it wouldn't work – but no one was able to tell me why it wouldn't work'

Review. "I'm sceptical that it will migrate en masse overnight." Even those who are cautiously enthusiastic say tha even if all the technical problems can b solved, SkySails may not work for all ships or on all shipping routes.

John Carlton, global head of marine technology at Lloyd's Register, says tha while he thinks they could be of great benefit for smaller ships, they are unlikely to be used to propel larger vessel

But Wrage believes that, in principle a vessel of any size could use SkySails. Eventually, he says, even oil tankers could be using 1,000-square-metre Sky Sails. "Not today, not tomorrow, but

Sources

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