Technological Rates of Change

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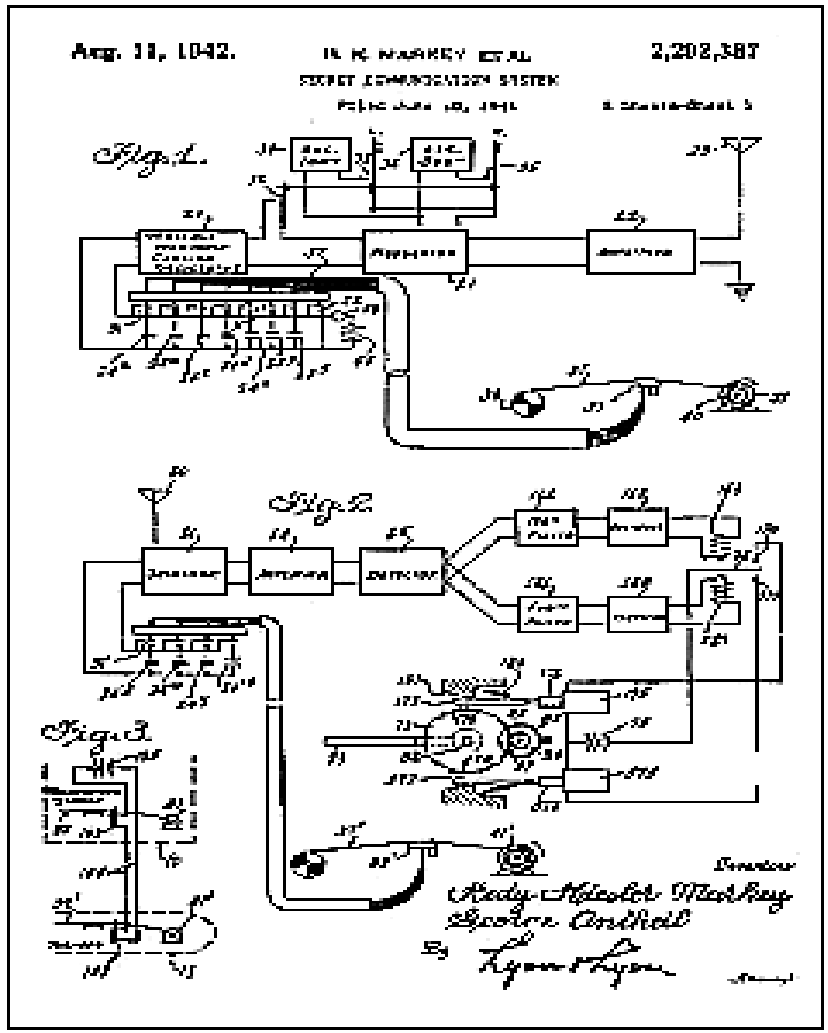
The Innovation Life Cycle

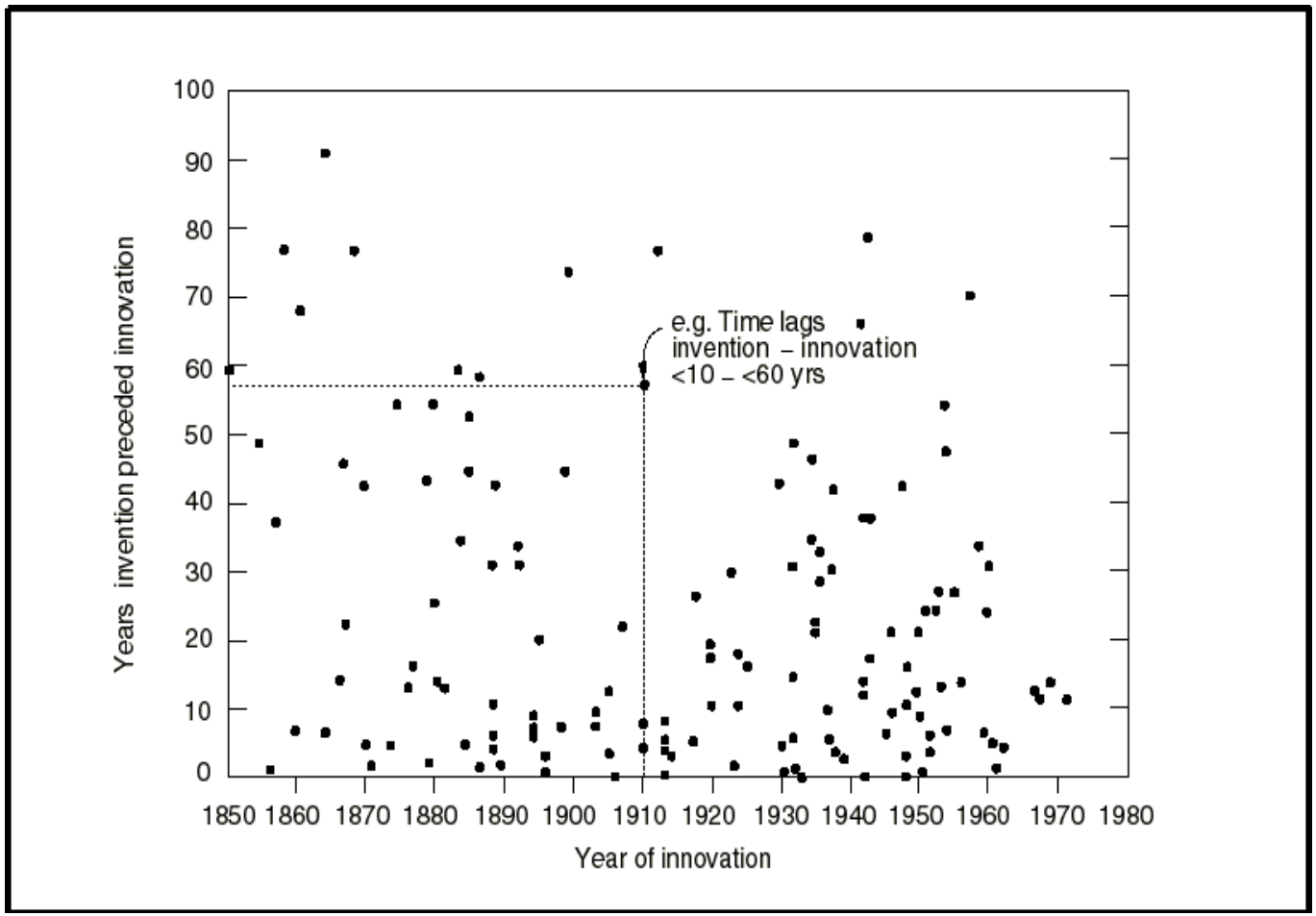
- **Invention** (new knowledge, research)
- **Innovation** (new application of knowledge, R&D)
- **Niche markets** (exploration of application possibilities and debugging via supplier-user interaction)
- **Diffusion** (standardization, cost reductions via learning curve and scale effects, globalization of markets)
- **Saturation** (dominance of the market)

Invention – Innovation Lag: The Unrecognized Inventor

Movie Actress Hedy Lamarr (Eva Kiesler) together with musician George Antheil patented “secret communication system” in 1942 which US Navy thought useless. Now as “spread spectrum technology” this is the basis of all cell phones. Invention-Innovation lag: 50 years!



Time Lag Between Invention and Innovation: No shortening of stochastic variation

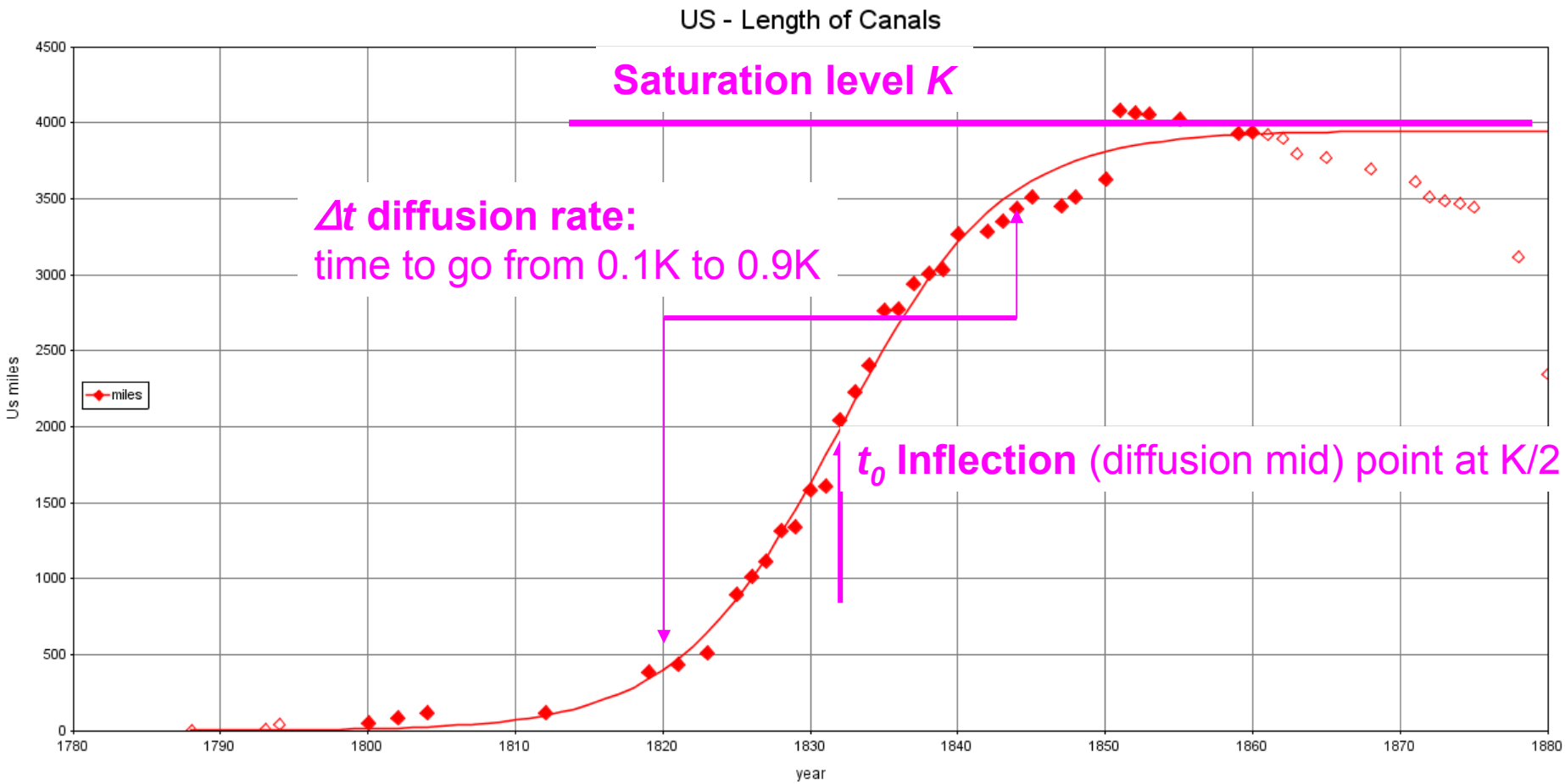


Source: Rosegger, 1996

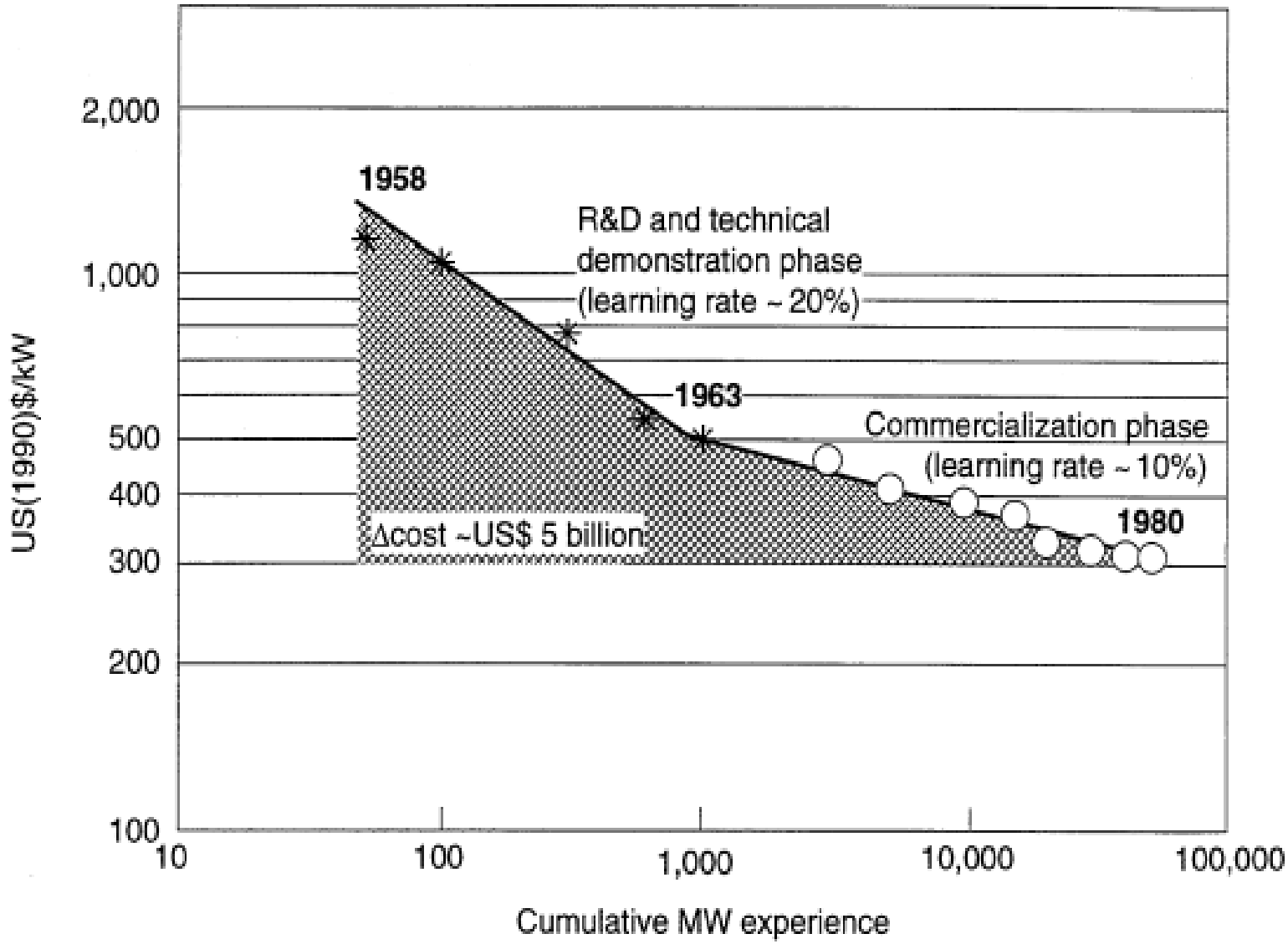
Why the Emphasis on Diffusion?

- Innovation is significant only when widely applied
- Generally the diffusion life cycle phase takes longest
- Availability of descriptive & causal formal models

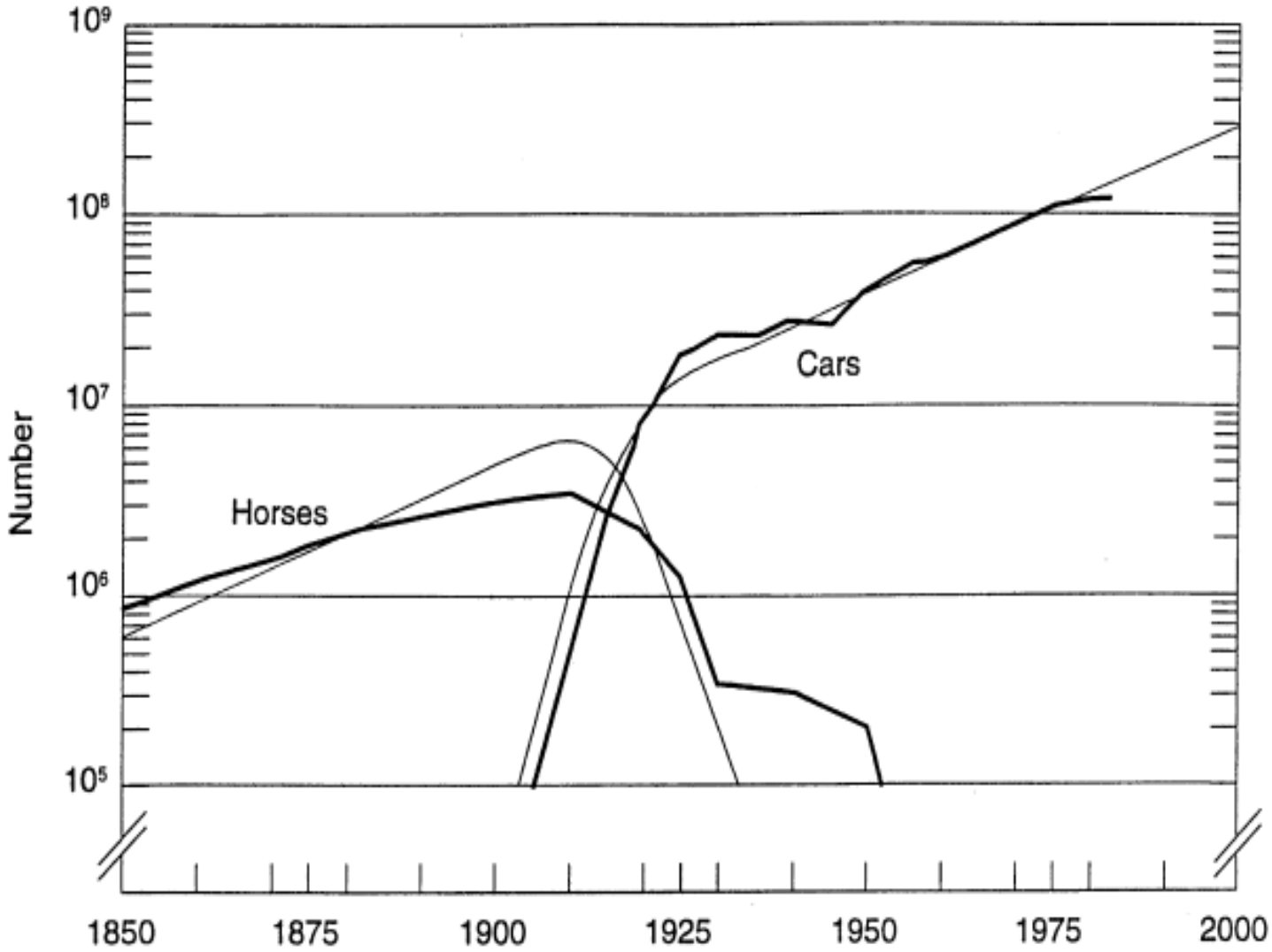
Logistic Growth Primer



K = 4000 miles, t_0 = 1832, Δt = 24 years

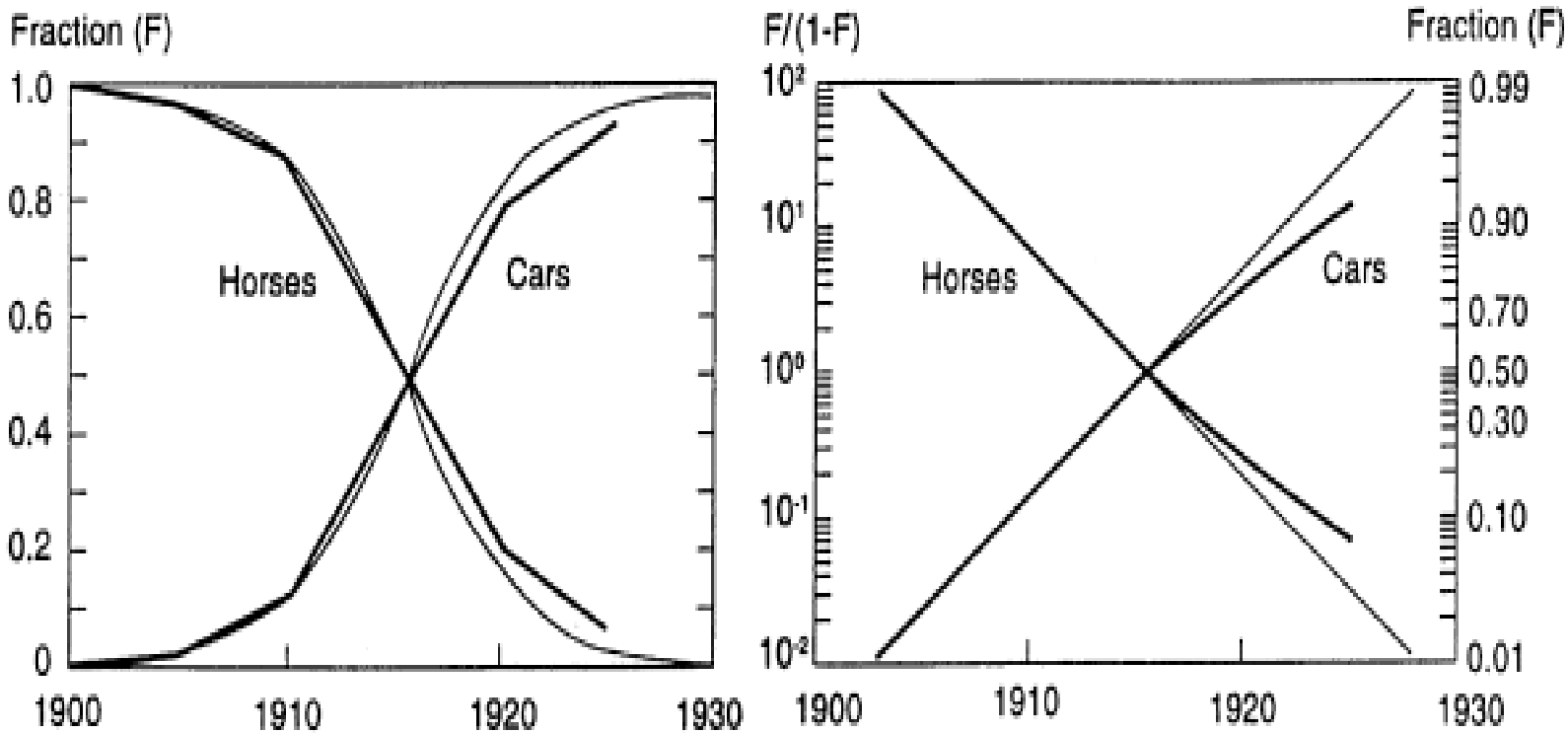


Source: A. Grübler et al., *Energy Policy, 27*, 247-280, 1999

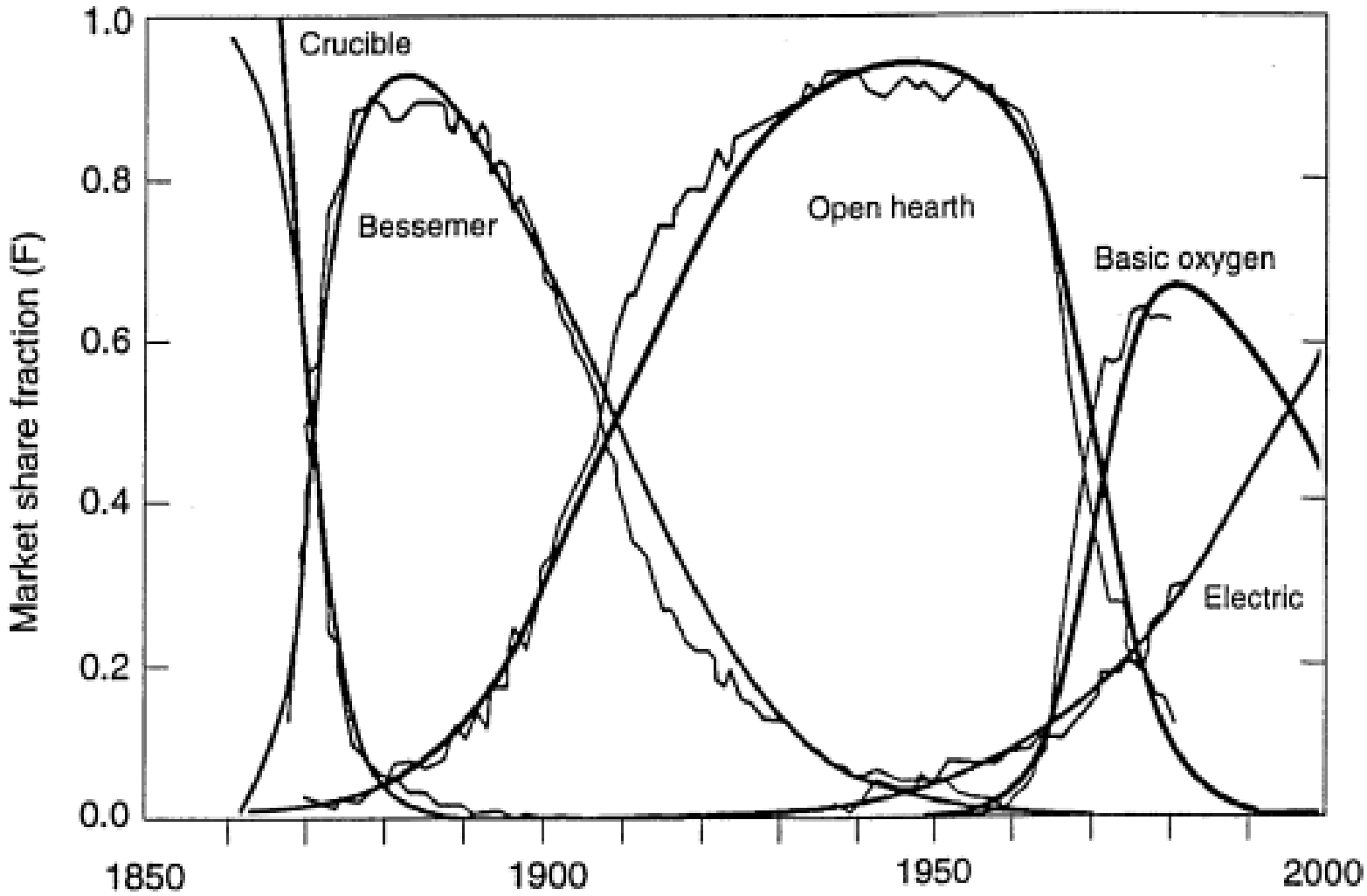


Source: A. Grübler et al., *Energy Policy, 27*, 247-280, 1999

USA – Horses vs. Cars for Road Transport (fractional share F in total fleet; linear plot and logit transformation)



$\Delta t = 13$ years



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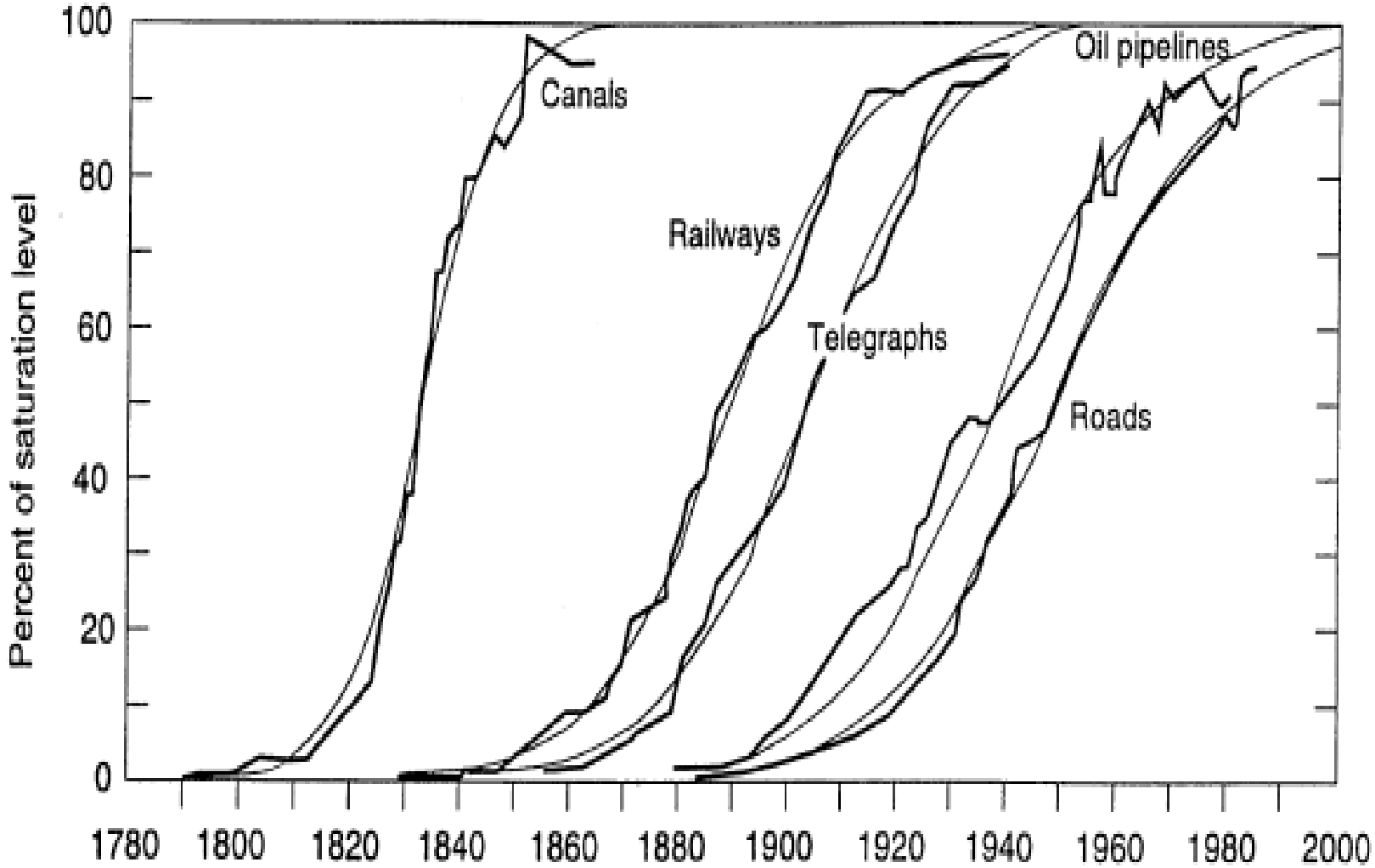
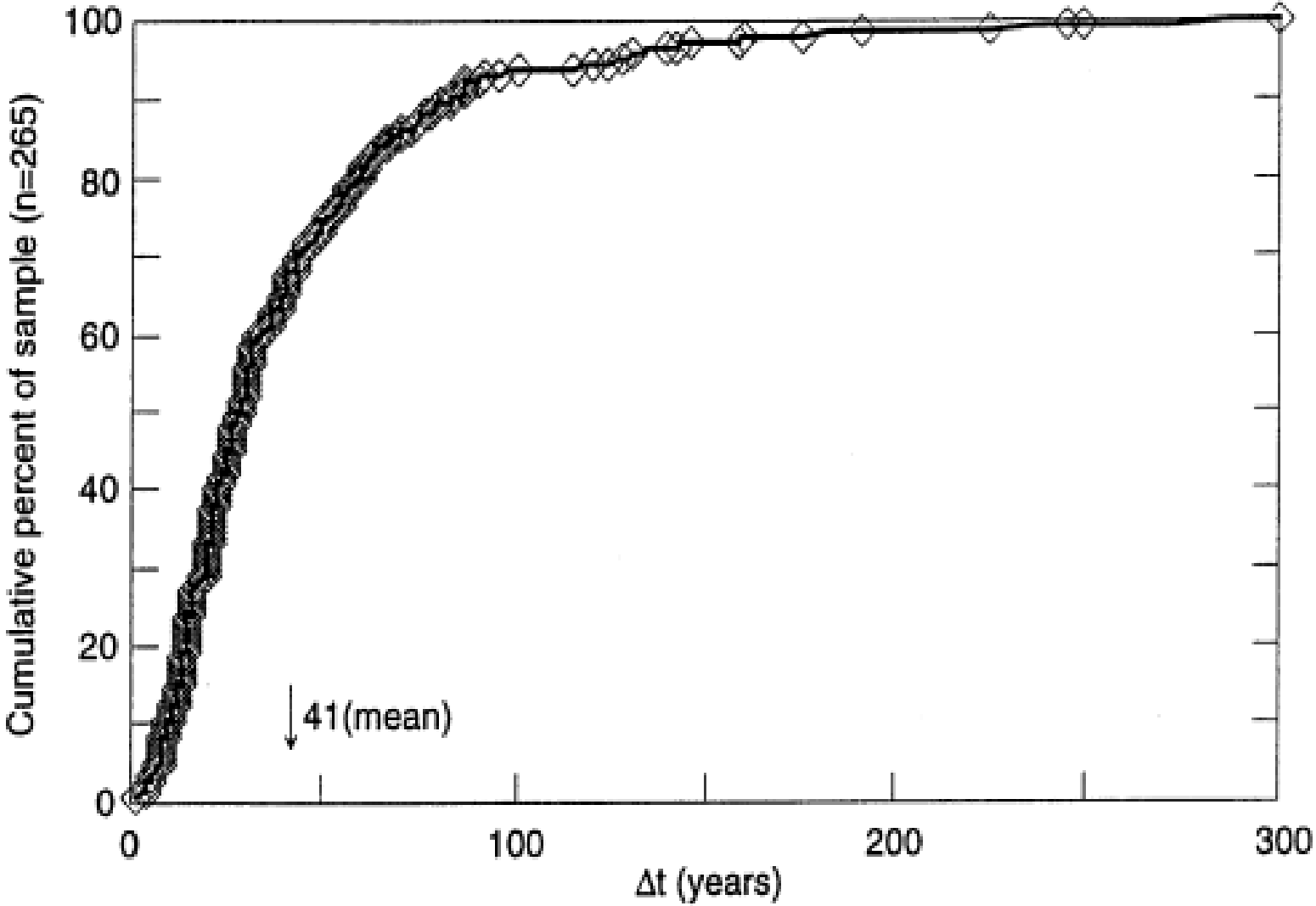
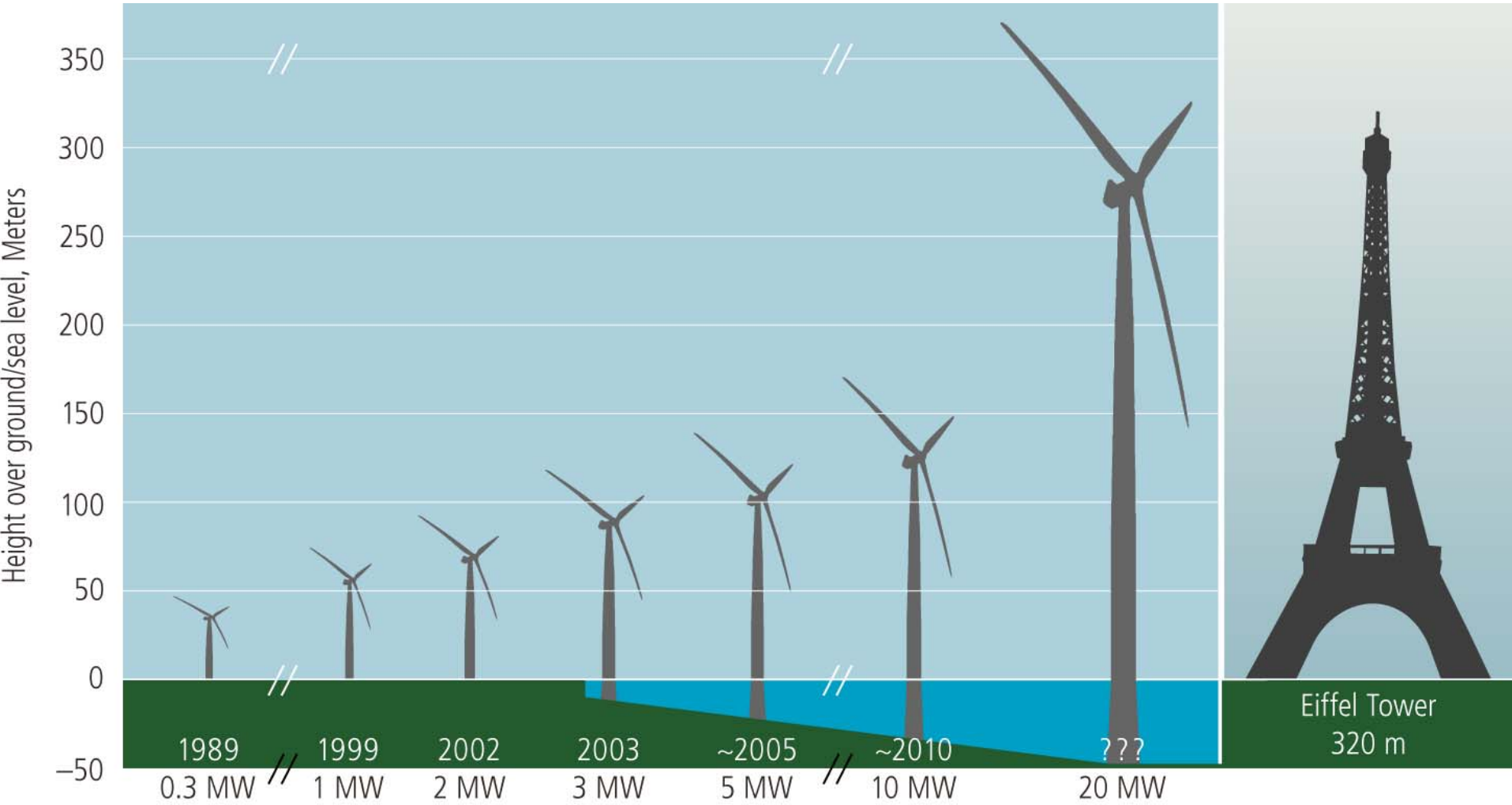


Source: A. Grübler et al., *Energy Policy, 27*, 247-280, 1999

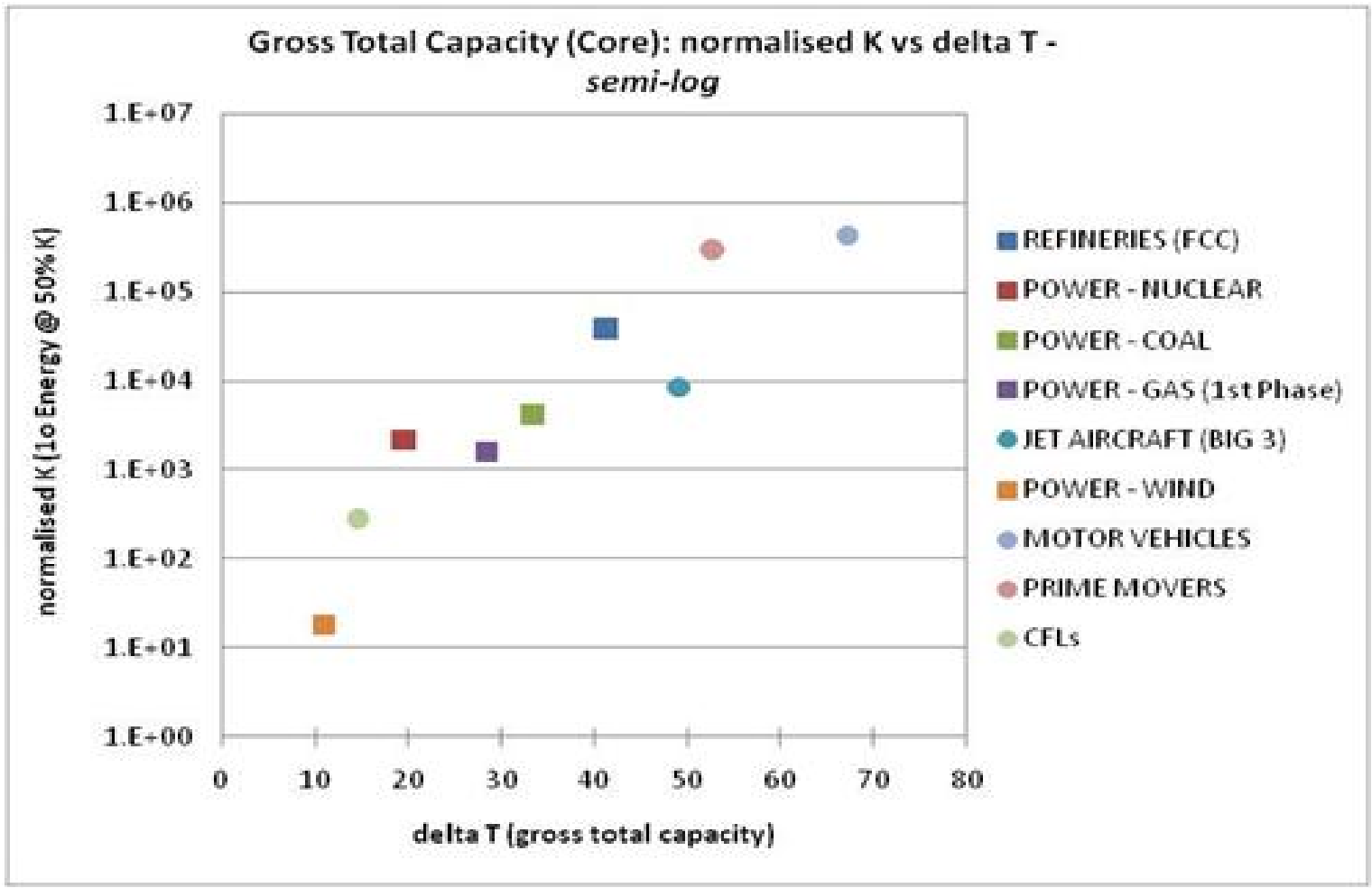


Source: A. Grübler et al., *Energy Policy, 27*, 247-280, 1999

Growth in Unit Scale of Wind-turbines



Historical relationship between EXTENT and RATE of industry scaling is consistent across technologies

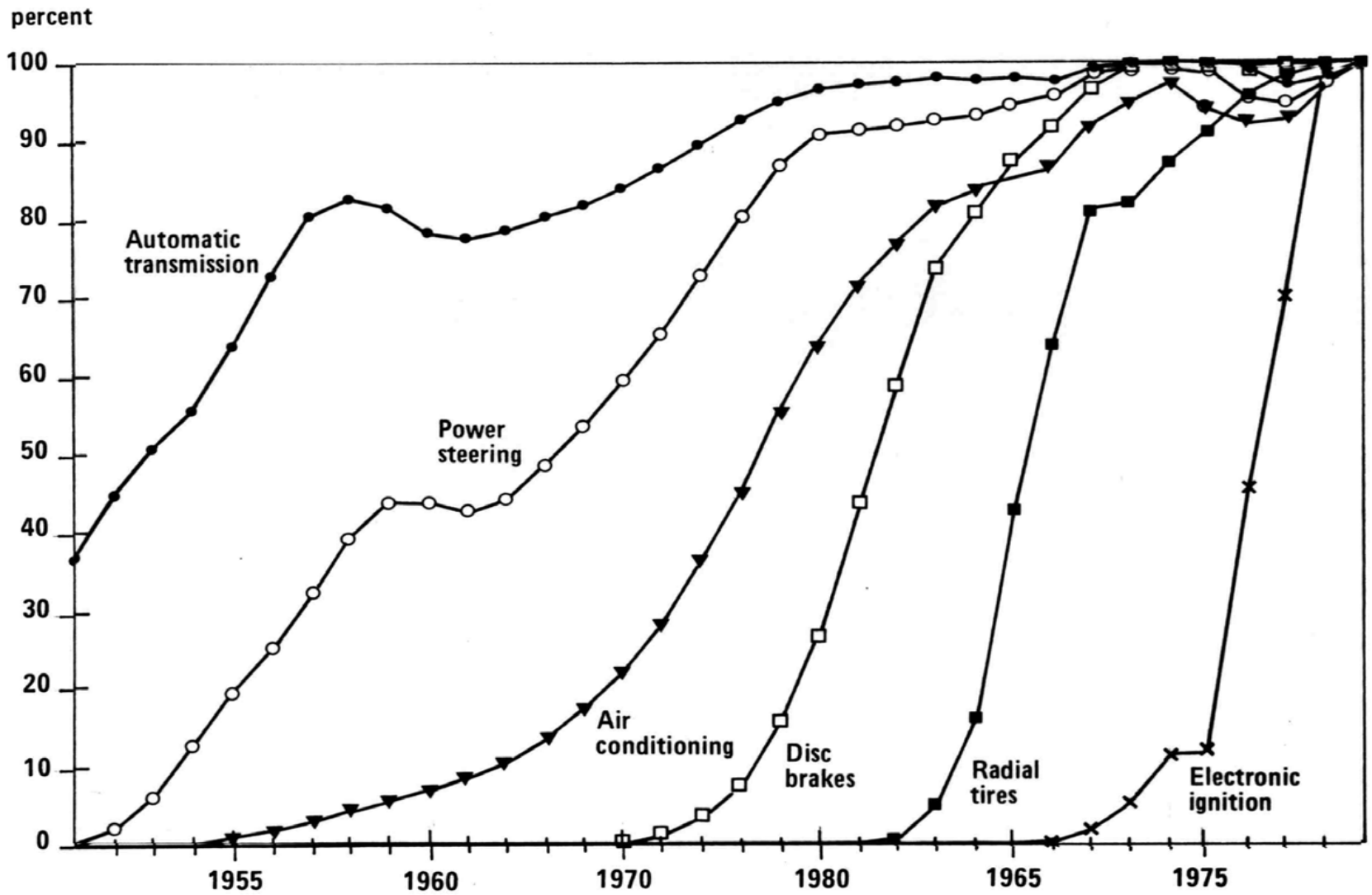


(NORMALISED) GREATER EXTENT

SLOWER RATE

Source: C. Wilson, 2009

Diffusion of Novelties in US Car Fleet (% of sales): Acceleration of incremental innovation in maturing technology



Diffusion: Macro variables

- Involves time and space (S-curve and spatial hierarchy centers)
- Market size vs speed and impact:

  Large size & impact = slower diffusion

  Small size and impact (fashion) = fast diffusion
- Diffusion (slower) vs. substitution (faster)

Determinants of Diffusion Speed (beyond macro)

- Type of adoption decision (individual, collective, authoritative)
- Type of communication channels (mass media vs. word-of-mouth)
- Nature of social system (interconnection, sources of learning: internal vs. external)

Explaining Differences in Diffusion Speed

(each additional + implies *ceteris paribus* slower/longer diffusion)

Δt	Example	Diff/ Sub.	Rel. advantage	Scale	Infra-structure needs	Techn. Interde-pendence
80/110	coal vs wood USA/World	S	++	++	++	+++
47/60	railways France/World	D	+++	++	++	+++
25	% US homes with radio	D	+++	++	+	++
28	mechanization coal mines Russia	S	++	+	+	++
16	Car vs. horse, France, UK	S	++	+	++	++
15	Color vs. B/W TV, USA	S	+	++	+	+

Source: Grübler/Nakicenovic/Victor, 1999, Energy Policy 27:247-280

Rates of Change

- History suggests typical turnover rates of systems of between 20-70 years depending on:
  -- Market size
  -- Technology characteristics (e.g. costs)
  -- Adoption environment (e.g. market growth, capital)
  -- Policy support
- Fastest: short lifetime, low capital (<10 yrs)
  e.g., fashion gadgets, appliances
- Slowest: long lifetime, capital intensive (>70-100 yrs)
  infrastructures, settlements
- Inverse relationships:
  (larger) size → (slower) speed
  (larger) importance/significance → (slower) speed

Is Change Accelerating?

- More myth than reality
- Frenetic incremental innovations in maturing markets (cars, Microsoft,…)
- Piggy-back on existing infrastructures (nuclear, Internet, cell-phones)
- With growing capital stock: More to change!
- Basic diffusion patterns in time and space unchanged
- Big hits require time!