fcn Institute for Future Energy Consumer Needs and Behavior

E.ON Energy Research Center

Energy Technology Choices in Turbulent Times: Innovation, Habit Persistence, and Uncertainty

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Presentation Outline

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1. Introduction
2. Diffusion of innovations – a time-intensive process
3. Habit persistence
4. Rational behavior and uncertainty
5. Outlook

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1. Introduction – changing policy and research foci

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- Energy crises of the **1970s**: energy consumer becomes a focus of interest
  - Widespread belief that energy consumption can be easily explained by physical data (e.g. appliance efficiencies, climatic conditions)
  - Energy analysts soon discovered **large "unexplained" variance**, which was attributed to differences in human behavior
- **1980s**: Sustainable development increasingly recognized as an overarching goal
  - Economic, ecological, and social dimension (⇨ interdisciplinary research)
  - Formidable political challenges (e.g. climate change, supply security)
- **1990s**: Widespread market liberalization – changing levels of risk and uncertainty for decision-makers

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1. Introduction – energy research and use at a crossroads

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- **2010** and beyond: **enormous long-term challenges remain**, due to limits to growth and unsustainable pathways (e.g. climate change, peak-oil and -gas / re-concentration in the Middle East, over-population, rising energy demand, discontinuous development)
- Great technological **variety**, few dominant technologies, (automated) increasingly **complex systems**
- Several **competing solutions**, technological **lock-ins**
- **Limited funds** for R&D and promotion of innovative technology diffusion
- Lack of **public acceptance** (e.g. large power plants, CO_2 pipelines)

⇨ **High risk & uncertainty** (e.g. about long-term economic viability)

⇨ Signs for **paradigm change** (emerging technologies – distributed generation, DC systems, e-mobility, ICT for energy efficiency)

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1. Introduction – consumer choices

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- Energy consumer **investment decisions**:
  - Why do individuals/organisations invest in certain technologies?
  - What are the perceived costs and benefits of adoption?
  - Influenced by market failure, budget constraints, expectations etc.
- Liberalized markets: **choice of energy supply / supplier**
- Inference of **individual energy demand behavior** from aggregate data
- We do not need **energy** *per se* but **energy services**
- **Lifestyle impact** on energy consumer needs and behavior
- **Attitudinal change** as a precursor of behavioral change
  - Education & information programs ('Waste of energy is uncool')
  - Energy fairs, demonstration projects (conveying info about innovations)

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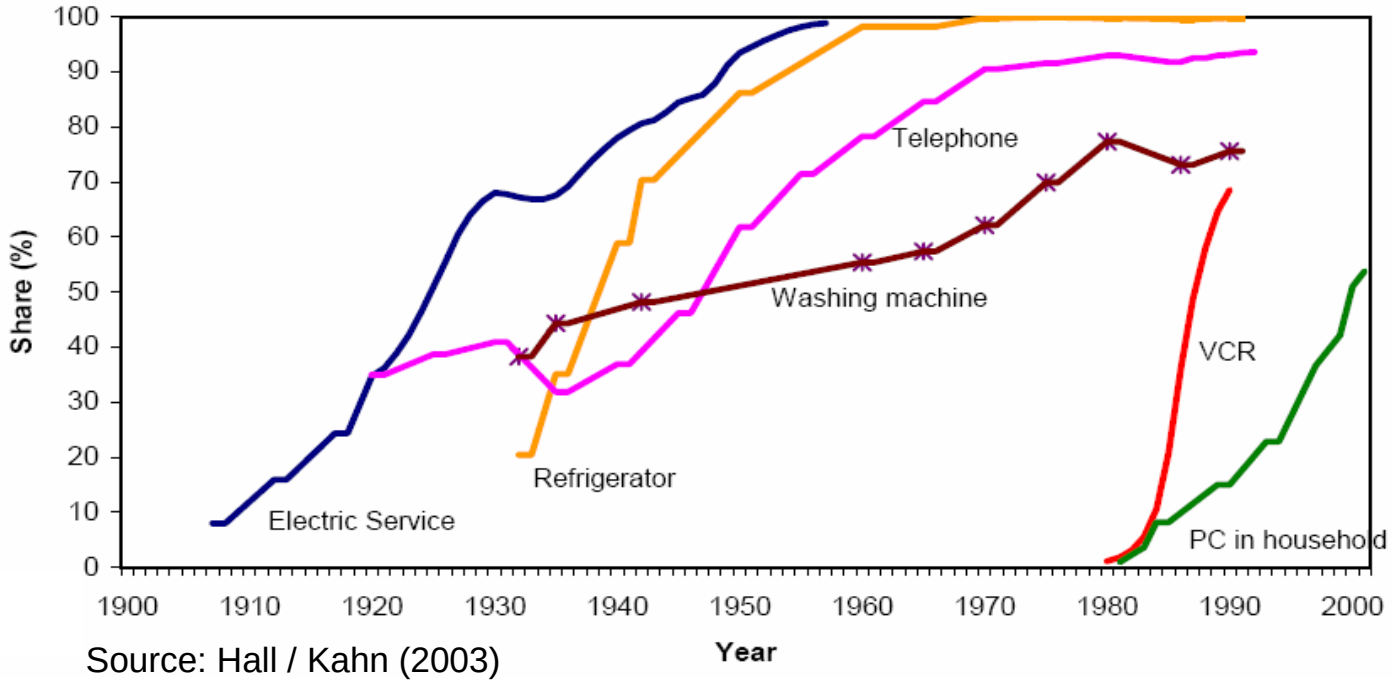
Stylized facts:

- Not every innovation is successful (market diffusion)
- Technology adopters are heterogeneous (and thus their benefits)
- There exists a welfare-optimal speed of diffusion (not “the earlier the better”)
- Diffusion is often a time-intensive process (sometimes takes decades)

Figure 1
Diffusion Rates in the U.S. for Selected Consumer Products



Source: Hall / Kahn (2003)

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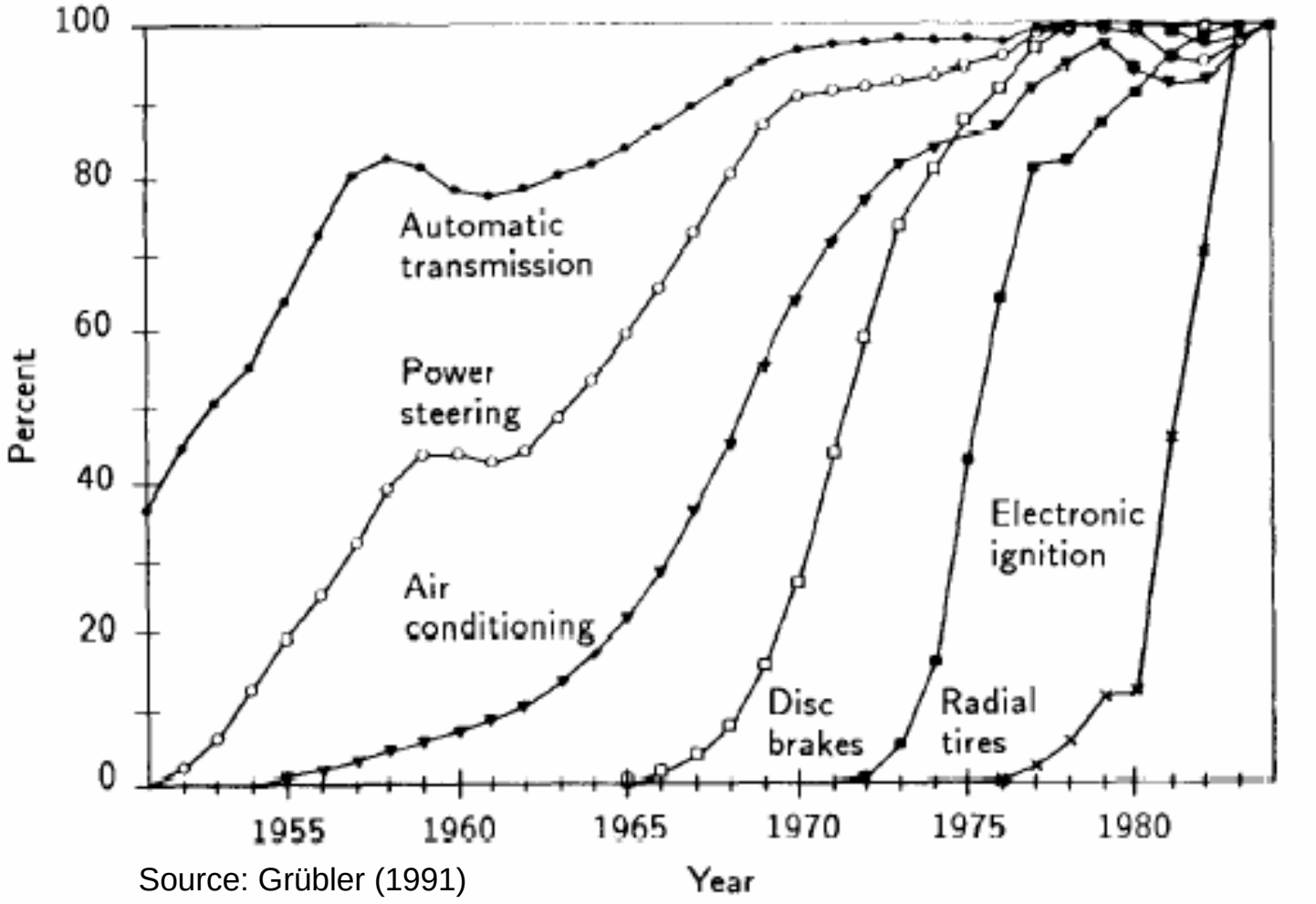
Diffusion of new technologies in the U.S. car industry (% of saturation level)



Source: Grübler (1991)

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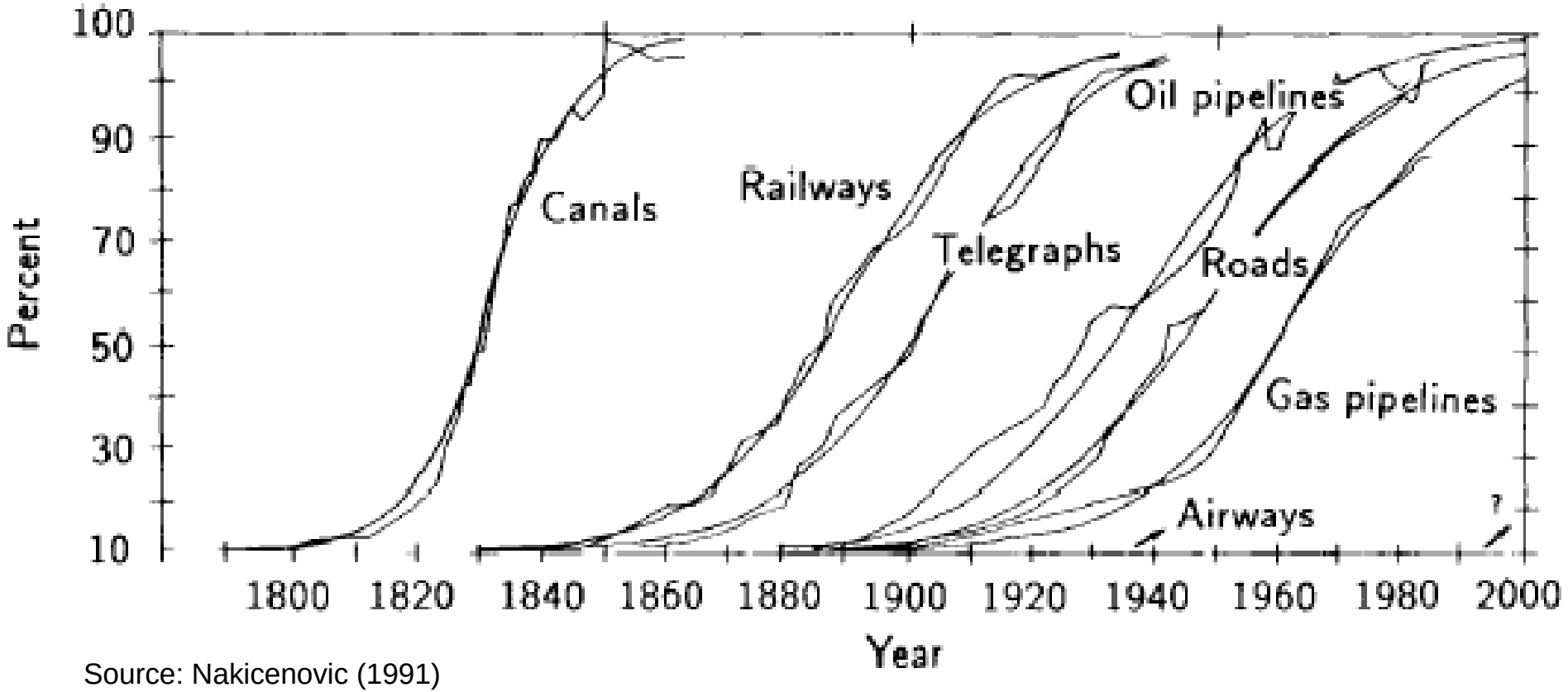
Diffusion of infrastructure in the U.S. (% of saturation level)



Source: Nakicenovic (1991)

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2. Diffusion of innovations – evolutionary process in a complex system

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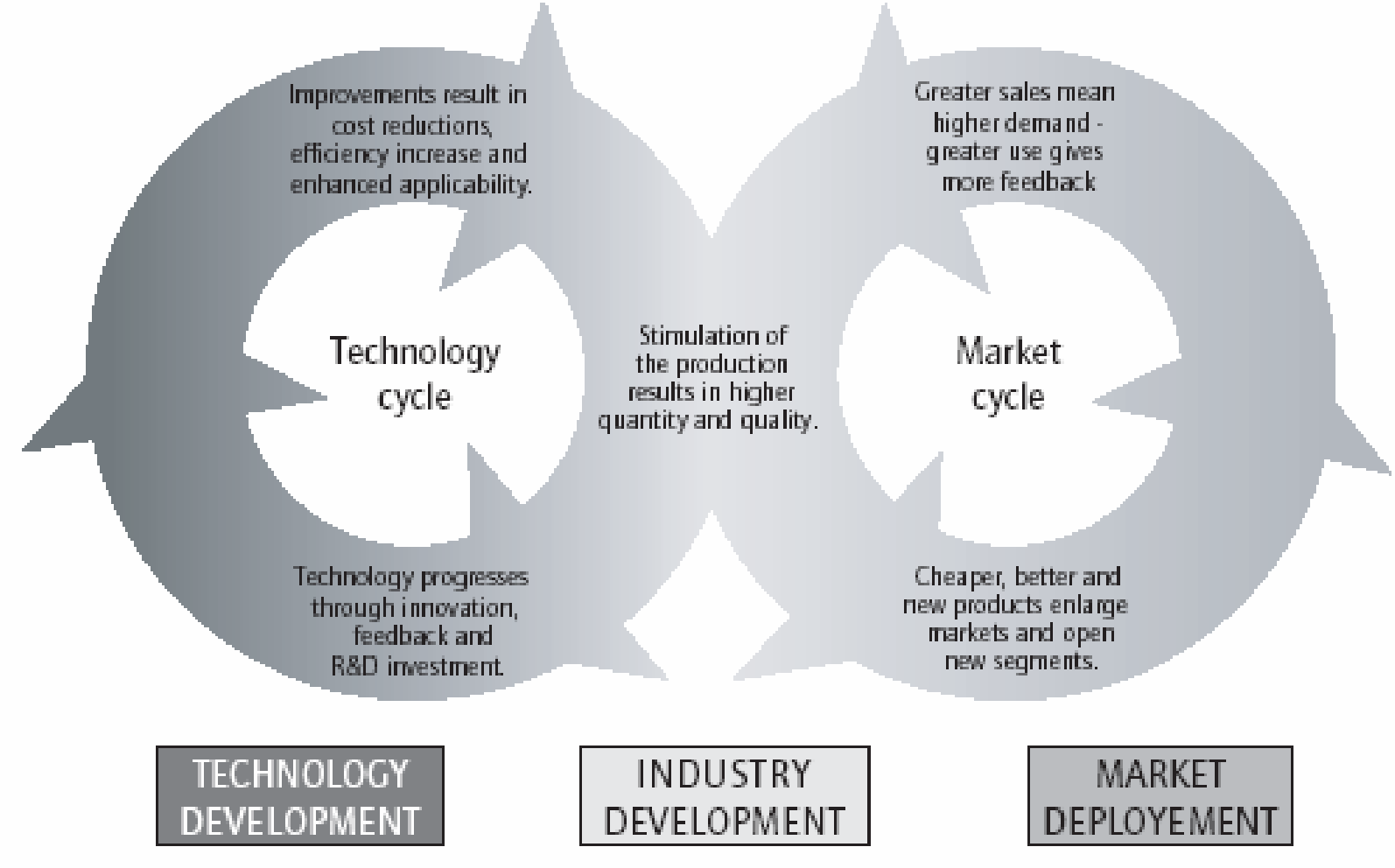
Virtuous interlocked cycles in a supportive policy environment



Source: IEA (2003)

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3. Habit persistence – different consumer behavior models

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- Economics: rational choice models of consumer behavior
  - Typically **utility or profit maximization**
  - Changes in behavior because of **changing market conditions**
  - Energy behavior can most effectively be changed by using **economic incentives** (e.g. low interest loans, tax credits)
- Social, psychological, lifestyle models of behavior
- Attitudinal models of behavioral change (Ajzen / Fishbein, 1977,1980; Ester, 1985) – change in attitudes enables behavioral change

<u>Problem with most models:</u> large unexplained variation (‘blind spots’)

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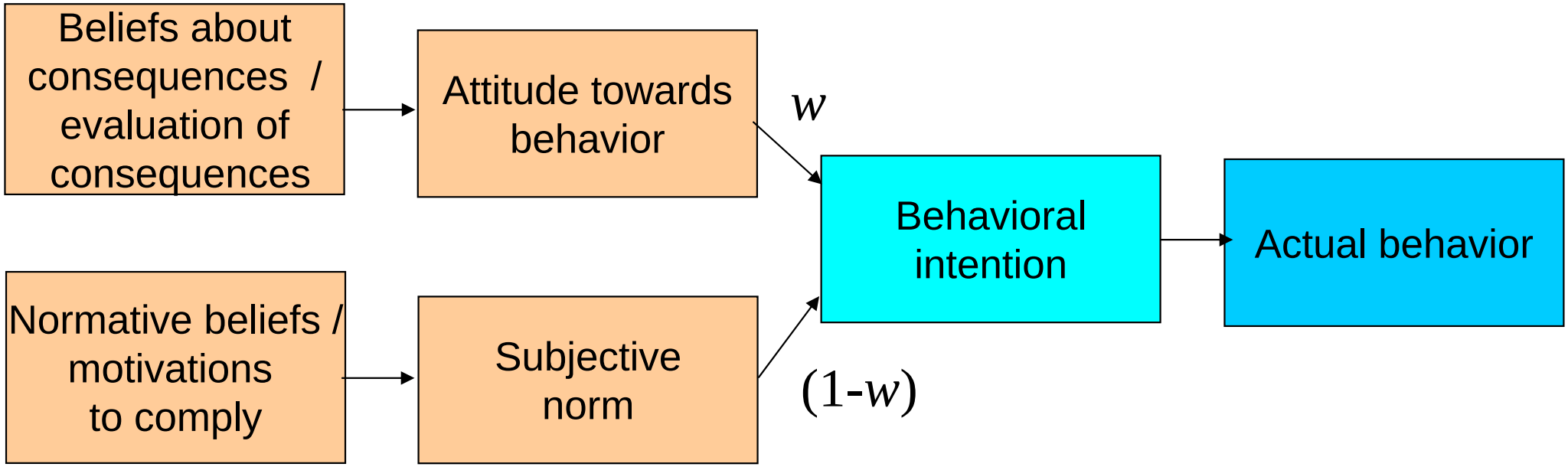
3. Habit persistence – psychological attitudes models of energy conservation



Source: Ester (1985), simplified

3. Habit persistence – the consumer (decision-maker) side

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- Economic reasoning: only **market failure** (e.g. due to asymmetric information, externalities, landlord-tenant dilemma) justifies **government intervention**, e.g. to increase **energy efficiency**
- **Reasons for "energy efficiency gap"** in the absence of market failure:
  1. **Uncertainty** about future energy prices and possible savings, new energy technologies, and the state of the world
  2. **Aversion against adopting new technology** (w/o conceived higher benefit)
  3. **Heterogeneity** of adopters / consumers (individually varying benefits), myth of the representative agent
  4. **Habit persistence** of energy consumers (e.g. giving up light bulbs)

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3. Habit persistence – one of many barriers for energy efficiency gains and energy conservation

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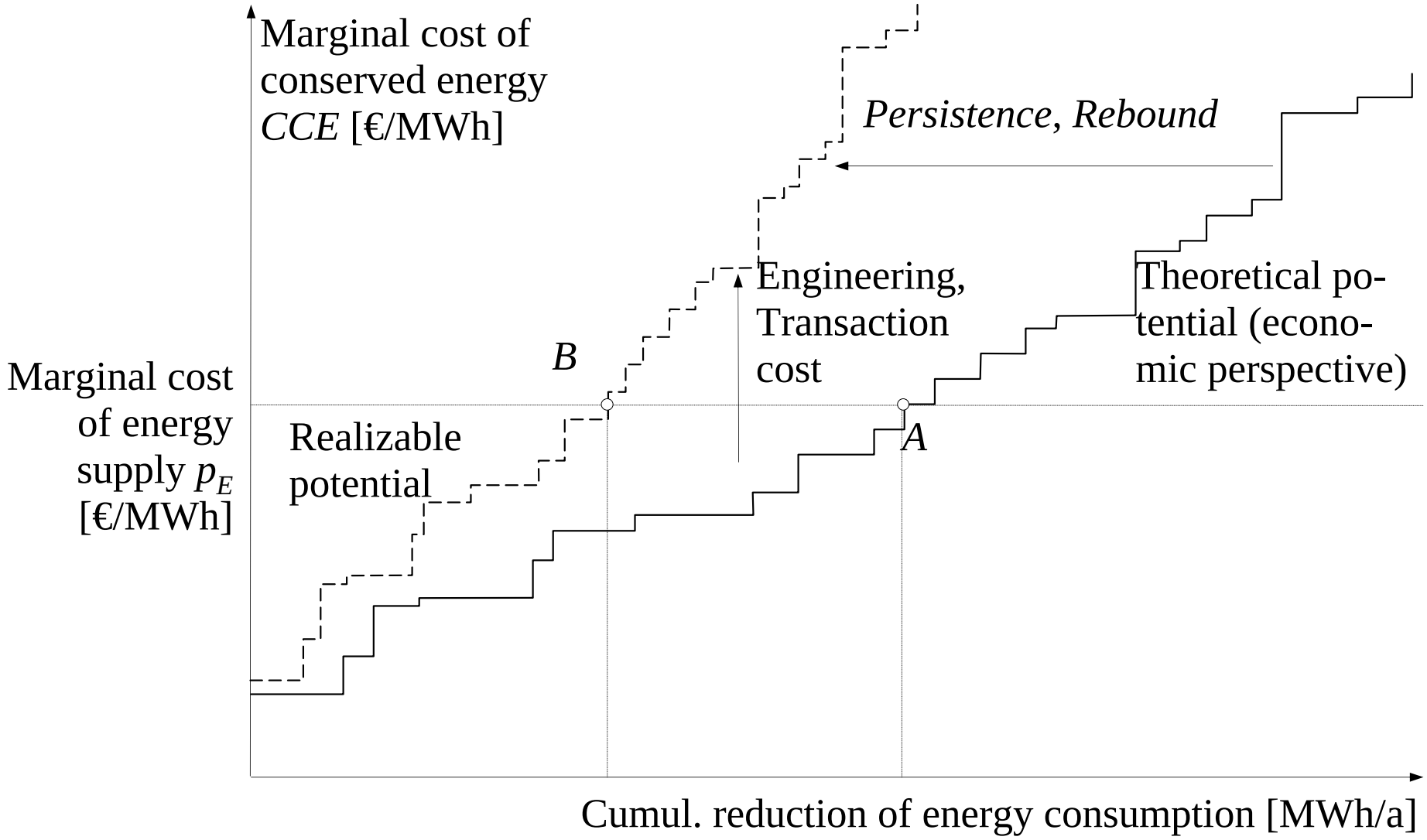

Source: Erdmann/Zweifel (2007): Energieökonomik – Theorie und Anwendungen, modified

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4. Rational behavior and uncertainty

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- Combination of **technology adoption and** (expected) **utilization** to satisfy needs (for energy services) ⇨ combined economic modeling
- Standard **rational economic choice model** (profit-maximizing firm, utility-maximizing consumer) often fails to explain real-world data
- **Bounded rationality** and satisficing behavior (Simon, 1955, 1986)
  - Limited search and optimization of choice
  - 'Good enough' decisions
- **Real Options (RO)** valuation (Dixit / Pindyck, 1994)
  - Irreversibility
  - Flexibility of investment timing
  - Uncertainty

  } "Value of waiting"

  ⇨ More stringent investment criteria due to opportunity cost consideration (NPV minus option value > 0)

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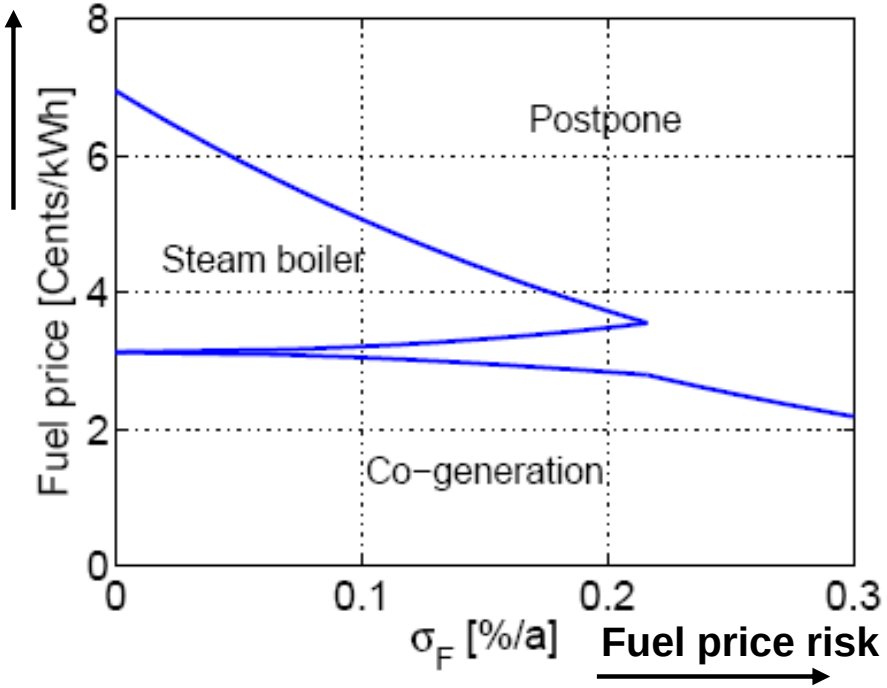
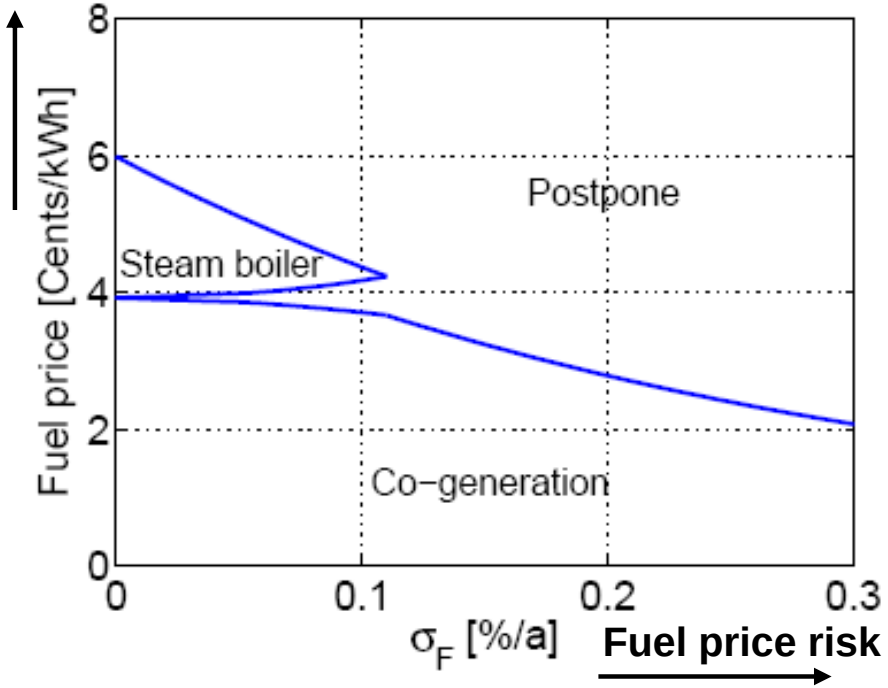
Simulation of the optimal investment decision under uncertainty

(case: CHP vs. steam boiler, with and without CO_2 levy), yielding three rational choice areas



(a) Without CO_2 tax



(b) With CO_2 tax

Source: Wickart / Madlener (2006)

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5. Conclusions 1/2

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1. Signs of **paradigm shifts**: ‘smart’ systems, e-mobility, distributed generation (e.g. private households as power producers)
2. **Value of waiting and of technological diversity** in situations of high uncertainty (at the expense of economies of scale)
3. Huge **research needs** remain, especially in the social sciences (consumer needs and behavior, decision-making with bounded rationality, evolving values and attitudes, social networks)
4. Lead / lag times and **slowness of diffusion** processes have to be kept in mind, esp. regarding capital-intensive technologies (transition processes take time!)
5. **Policy intervention** / spending of taxpayer’s money only in case of **market failure** (get the prices right)

5. Conclusions 2/2

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6. Numerous innovative or significantly **improved energy technologies**
   - Power generation (new materials, storage systems, CCS, virtual power plants etc.)
   - Transmission & Distribution / Automation (Smart Grids)
   - Final energy demand (low / passive energy houses, Smart Metering, intelligent control / Smart Homes etc.)
7. Tremendous **investment (and thus also financing) needs** globally, often lack of public acceptance (NIMBY-ism, BANANA-ism)
8. Recognition that **rebound effects** are a relevant stint to energy efficiency gains, and that the **'energy efficiency gap'** is sometimes justified / rational

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Any questions?

- Thank you for your kind attention!

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