

# **Path dependence and path creation in energy systems: competing theories and the influence of system interlinkages**

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- EnPath project
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# EnPath Project - Path Dependence and Path Creation in Energy Systems: A Multi-Level Perspective on Technological, Business and Policy Innovations 2009-2012



- Changing energy governance in Finland
- Policy coherence and framing in climate and energy policy –focus on bioenergy policy
- Role of intermediary organisations in energy systems change
- Changing strategies in incumbent energy companies and energy intensive industry
- Heating systems and energy efficiency in residential buildings
- Alternative energy solutions – Case I: transport biofuels vs. electric vehicles, Case II: solar(?)

# Recent EnPath papers & publications

- **Combining path dependence and path creation to energy system analysis**
  - Lovio, R., Mickwitz, P. & Heiskanen, E. (forthcoming). Path dependence, path creation and creative destruction in the evolution of energy systems. In: Wuestenhagen, R. & Wuebker, R. (eds.). *Handbook of Energy Entrepreneurship*. Edward Elgar.
  - **Kivimaa P., Lovio, R. & Mickwitz, P. (forthcoming). The influence of system interlinkages on path dependence and path creation in energy systems** (submitted to Research Policy).
- **Path dependence and policy innovation**
  - Heiskanen, E., Kivisaari, S., Lovio, R., & Mickwitz, P. 2009. Designed to travel? Transition management encounters environmental and innovation policy histories in Finland. *Policy Sciences* 42, 409-427.
  - Kivimaa P. and P. Mickwitz (forthcoming). Public policy as a part of transforming energy systems: Framing bioenergy in Finnish energy policy. Submitted to *Journal of Cleaner Production*.
- **Path creation for energy innovations**
  - Heiskanen, E., Lovio, R. & Jalas, M. (forthcoming): Path creation for sustainable consumption: promoting alternative heating systems in Finland (submitted to *Journal of Cleaner Production*)
  - Heiskanen, E. & Lovio, R. 2010. User-producer interaction in housing energy innovations. Energy innovations as a communication challenge. *Journal of Industrial Ecology* 14, 1, 91 – 102.
  - Lovio, R. & Kivimaa, P. *planned*. Comparison of path creation theories based on empirical cases for transport biofuels and electric vehicles (to be written later this year)

# Links to theoretical discussions

- Path dependence and path creation
  - Brian Arthur, Paul David, Paul Pierson
  - Raghu Garud & Peter Karnoe
  - Georg Schreyögg & Jörg Sydow et al. (Freie Universität Berlin)
- Barriers and facilitators of (technological) innovation
  - Staffan Jacobsson et al.
  - Michael Tushman et al.
- System transitions
  - Multi-level perspective, SNM: Geels, Schot, Raven et al.
  - Transitions governance: Adrian Smith et al.
- Policies and policy innovations

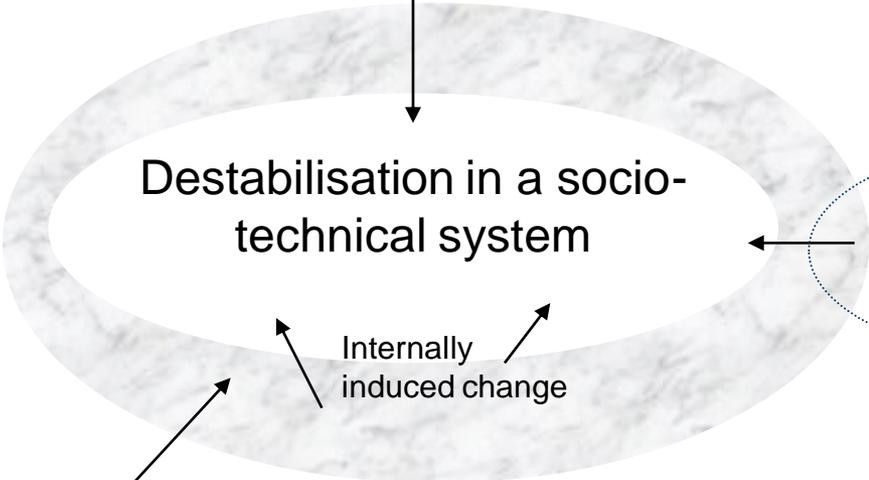


Tiina Hietikko-Hautala, 2008

# Definitions

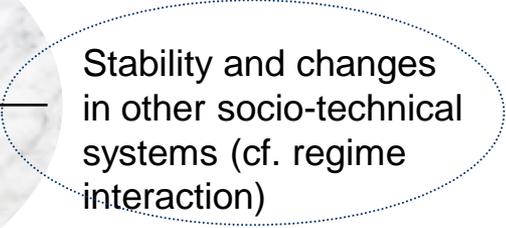
- Socio-technical systems (similar to socio-technical regimes)
  - incorporate relevant technical, economic and political sub-systems to serve a common aim, e.g. mobility
  - often have blurry boundaries that shift over time
- Path dependence (e.g. Arthur 1994, Pierson 2000, Unruh 2000)
  - used in diverse disciplines often as "history matters" (Mahoney 2000)
  - non-predictable outcomes leading through self-reinforcing processes (e.g. increasing returns) to technologies, legal structures etc. that persist against change even when potentially inefficient
- Path creation (Garud & Karnoe 2001, 2003, 2010; vs. Sydow et al. 2009)
  - Pioneers or entrepreneurs mindfully deviating from the dominant system needed to unlock existing paths
  - mindful deviation and real-time influence of actors
  - path creation vs. path emergence, path breaking etc...

Landscape changes, inc. external shocks, policy reforms (e.g. transition studies, policy analyses)



Destabilisation in a socio-technical system

Internally induced change



Stability and changes in other socio-technical systems (cf. regime interaction)

Innovation from technological niches (e.g. transition studies, strategic niche management)



# Research gap

Although the importance of factors external to energy systems has been acknowledged, the role and influence of other socio-technical systems on energy system change (system interlinkages) have remained conceptually underdeveloped and empirically somewhat neglected



# System interlinkages in literature

- Path dependence literature
  - Typically not system focused
  - Prior learning in another context (Arthur 1989) & inter-industry forces of coordination (Unruh 2000)
- Path creation literature
  - Systems not part of ontology (e.g. Garud et al. 2010)
  - Co-evolution of technological fields
- Energy systems literature
  - Hughes's (1983) work on systems, but not system interaction
  - Research on Nordic energy systems: supportive interplay between several "arenas" (Midttun and Koefoed 2005).
- Transitions literature
  - Role of "the environment", e.g., Raven 2007, Verbong and Geels 2007
  - Multi-regime interactions between electricity and waste regimes – innovations as link, Raven 2007, Raven & Verbong 2007, 2009

# Analytical framework: System interlinkages

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System functions

Strengthening energy system  
path dependence

Destabilising energy system path  
dependence

Enforcing path creation in  
energy systems

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## Production

- Capital
- Human resources
- Natural resources
- Intermediate products & services
- Technology

## Consumption

## Research and development (R&D)

## Organisations and ownership

## Policies<sup>a</sup>

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# System interlinkages based on functions

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System functions	Strengthening energy system path dependence	Destabilising energy system path dependence	Enforcing path creation in energy systems
<b>Production</b> <ul style="list-style-type: none"><li>-Capital</li><li>-Human resources</li><li>-Natural resources</li><li>-Intermediate products &amp; services</li><li>-Technology</li></ul>	Investments in technology and knowledge, or by-products, in other systems that can be used for energy systems		
<b>Consumption</b>	Predictable and stable (or increasing) energy consumption in another system		
<b>Research and development (R&amp;D)</b>	Stable R&D structures and networks; non-disruptive innovation through mutually reinforcing path dependent systems		
<b>Organisations and ownership</b>	Barriers to entry of new actors from other systems due to large costs, implicit knowledge requirements, etc.		
<b>Policies<sup>a</sup></b>	Expectations from other policy domains supporting existing energy system structure		

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# System interlinkages based on functions

System functions	Strengthening energy system path dependence	Destabilising energy system path dependence	Enforcing path creation in energy systems
<b>Production</b> -Capital -Human resources -Natural resources -Intermediate products & services -Technology	Investments in technology and knowledge, or by-products, in other systems that can be used for energy systems	Radical shift in the use of production factors of another system	
<b>Consumption</b>	Predictable and stable (or increasing) energy consumption in another system	Change in another system that radically alters the quantity or nature of energy consumption	
<b>Research and development (R&amp;D)</b>	Stable R&D structures and networks; non-disruptive innovation through mutually reinforcing path dependent systems	Change in another system releasing R&D resources supporting disruptive innovation	
<b>Organisations and ownership</b>	Barriers to entry of new actors from other systems due to large costs, implicit knowledge requirements, etc.	Change in another system, causing a shift in the structure of organisations and ownership in the energy system	
<b>Policies<sup>a</sup></b>	Expectations from other policy domains supporting existing energy system structure	Changed policy expectations and power relations due to changes in other systems	

# System interlinkages based on functions

System functions	Strengthening energy system path dependence	Destabilising energy system path dependence	Enforcing path creation in energy systems
<b>Production</b> <ul style="list-style-type: none"> <li>- Capital</li> <li>- Human resources</li> <li>- Natural resources</li> <li>- Intermediate products &amp; services</li> <li>- Technology</li> </ul>	Investments in technology and knowledge, or by-products, in other systems that can be used for energy systems	Radical shift in the use of production factors of another system	Factors of production crossing system boundaries
<b>Consumption</b>	Predictable and stable (or increasing) energy consumption in another system	Change in another system that radically alters the quantity or nature of energy consumption	Change in energy needs arising from another system influencing e.g. practices of users or availability of energy for alternative purposes
<b>Research and development (R&amp;D)</b>	Stable R&D structures and networks; non-disruptive innovation through mutually reinforcing path dependent systems	Change in another system releasing R&D resources supporting disruptive innovation	Actors or networks of actors crossing system boundaries and creating agency for disruptive innovation
<b>Organisations and ownership</b>	Barriers to entry of new actors from other systems due to large costs, implicit knowledge requirements, etc.	Change in another system, causing a shift in the structure of organisations and ownership in the energy system	Spin-offs and owner-users from other systems facilitating change processes in energy systems
<b>Policies<sup>a</sup></b>	Expectations from other policy domains supporting existing energy system structure	Changed policy expectations and power relations due to changes in other systems	Regulators and policymakers driving policies for innovation and transitions

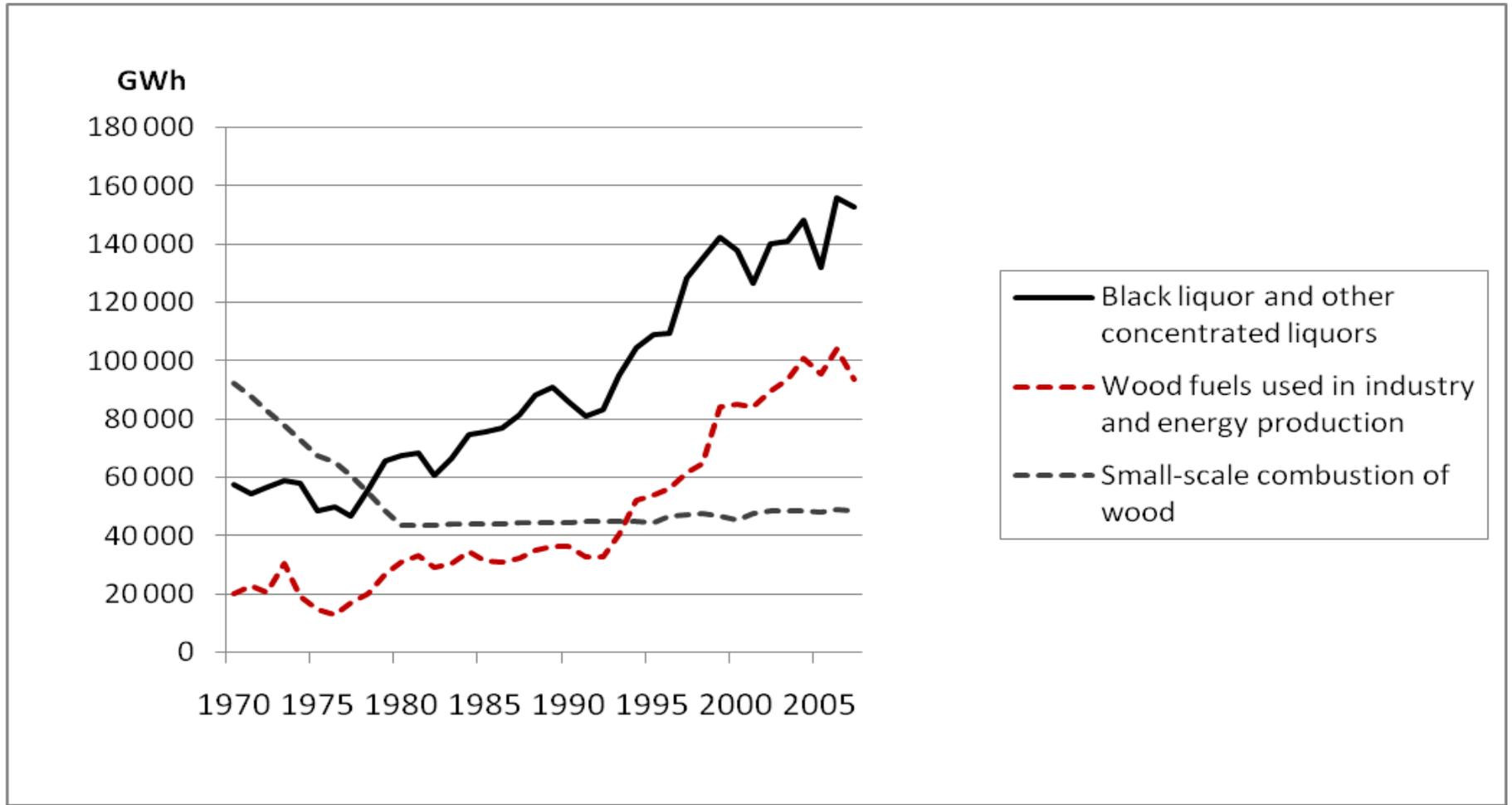
# Example: Finnish forest industry and its linkages to the energy system

- Characteristics of the Finnish energy system:
  - high share of industrial energy use, low prices & tax rates for industry,
  - diverse energy mix: wood fuels, nuclear, oil, coal, NG
- Characteristics of the Finnish forest industry system:
  - important exporter, industrial employer & energy user
  - Recently suffered from reduced demand and prices (destabilisation)

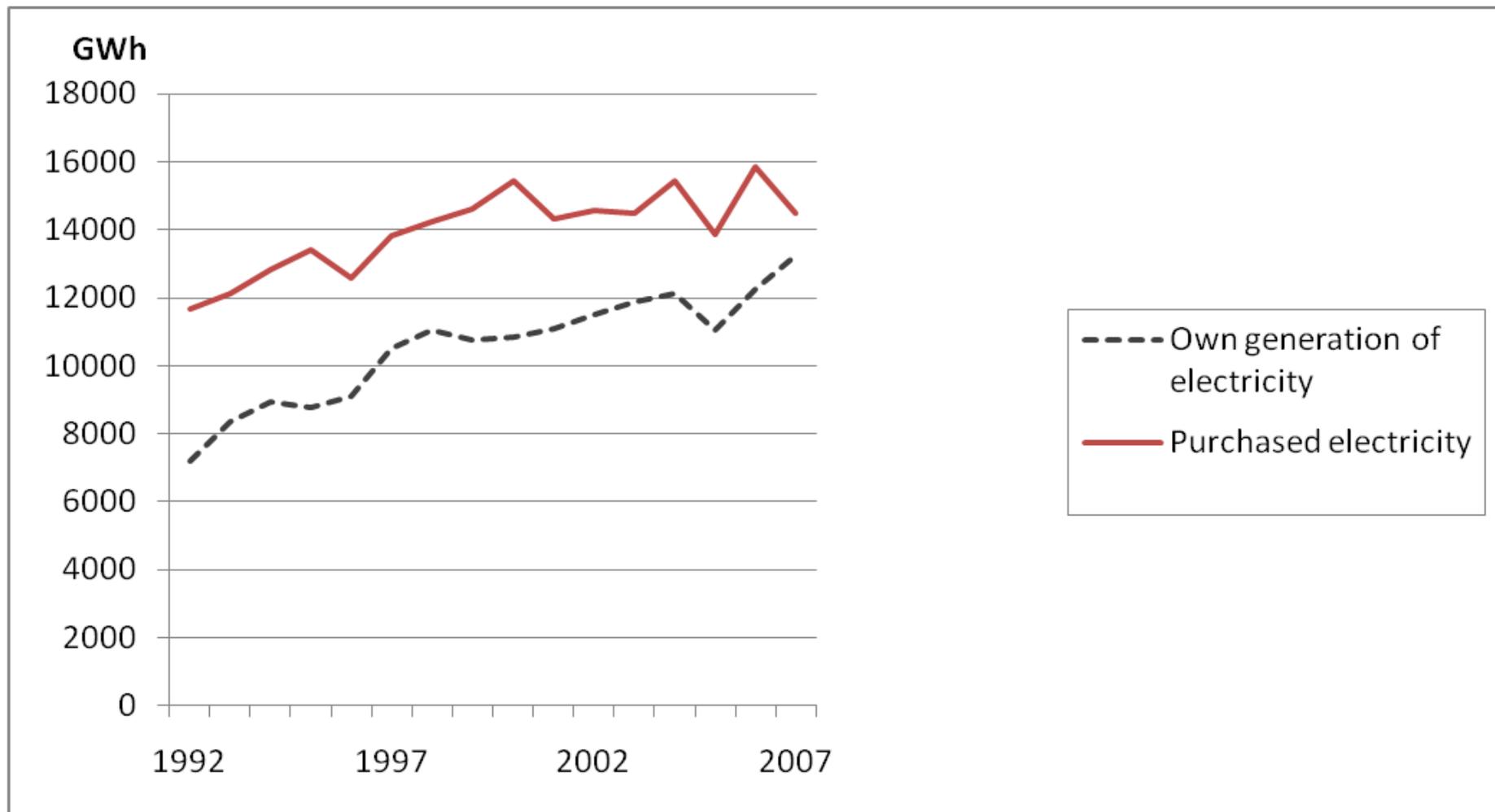
# Linkages between Finnish forest industry and energy systems

Interlinking functions	Strengthening path dependence	Destabilising path dependence
<b>Production</b> <ul style="list-style-type: none"> <li>- Capital</li> <li>- Human resources</li> <li>- Natural resources</li> <li>- Technology</li> <li>- Intermediate products &amp; services</li> </ul>	<ul style="list-style-type: none"> <li>-Energy intensive industrial structure supported by large-scale electricity production</li> <li>-Wood reserved mainly for pulp and paper rather than energy BUT large-scale bioenergy from forest industry's by products</li> <li>- Reducing investments</li> </ul> <p style="text-align: right;"><b>Example 1</b></p>	<ul style="list-style-type: none"> <li>-Closing down of pulp and paper mills – reduced electricity production from industrial by-products</li> <li>-Investments in new business areas (e.g. transport fuels)</li> <li>- Release of wood resources to other uses than paper production</li> </ul>
<b>Consumption</b>	<ul style="list-style-type: none"> <li>-Increasing demand for paper products</li> <li>- Pulp and paper mills as the largest industrial energy user</li> </ul>	<ul style="list-style-type: none"> <li>-Reduced demand for paper products</li> <li>-Reduced energy demand of the forest industry</li> <li>- Increased demand for new types of bioenergy products</li> </ul>
<b>Organisations &amp; ownership</b>	<ul style="list-style-type: none"> <li>- <a href="#">Forest companies as owners of electricity companies and production capacity</a></li> </ul> <p style="text-align: right;"><b>Example 2</b></p>	<ul style="list-style-type: none"> <li>- Forest companies as owners of electricity production and transport fuel production</li> </ul>
<b>R&amp;D</b>	<ul style="list-style-type: none"> <li>-Utilisation of forest industry's by-products for electricity</li> <li>-Transfer of industrial CHP to district heating</li> <li>- Dominance of strong, established networks</li> </ul>	<ul style="list-style-type: none"> <li>-Different types of products from woodfibre (including transport biofuels)</li> <li>-Expanded innovation possibilities</li> <li>- Re-direction of R&amp;D funding</li> </ul>
<b>Policy</b>	<ul style="list-style-type: none"> <li>-Low energy tax rates and exemptions for energy intensive industry</li> <li>- Support for nuclear energy &amp; forest industry – based bioenergy</li> </ul>	<ul style="list-style-type: none"> <li>-EU requirements</li> <li>- Reduced policy support for forest industry (?)</li> </ul>

# Example 1: Bioenergy sources in Finland 1970 - 2007



# Purchased and self-generated electricity used by the Finnish forest industry during



# System interlinkages & path creation – some notes (1)

- Production
  - Stability of another system influences the costs of alternative new paths in an energy system – *large-scale bioenergy production by forest industry*
  - Actors needed to find potential cost benefits from other systems and apply them to energy system – *energy innovations utilising black liquor from forest industry*
  - Actors may also fight dominant paths - *cooperation between small forest owners to find alternative wood uses; municipal cooperatives for small heating plants*
  - Knowledge from other systems has aided renewables development → yet innovation does not necessarily lead to structural change

# System interlinkages & path creation – some notes (2)

- Consumption

- Change in needs/practices related to another system may be crucial for path creation leading to structural change in energy systems – *reduced energy use & bioenergy production from forest industry*

- R&D

- Despite aimed for innovation, existing R&D structures may support dominant paths and create barriers for new path creation – *no support for black liquor gasification until recently*

# System interlinkages & path creation – some notes (3)

- Organisations & ownership
  - Spin-offs from other systems – *technology developers*
  - Destabilisation of another system whose incumbents join energy system path creation – *changing interests of forest industry incumbents*
- Policy
  - Barriers to path creation due to layering and incoherence of policies
  - Strong links between industrial and energy policies – while less significant links between innovation and energy policies

# Conclusions

- Inertia and change in energy systems need explanations reaching beyond internal factors
  - Combined analysis of system functions with Raven's types of system interaction could reveal more information on energy system stability and change
  - Set of actors and artefacts involved in energy-related path creation is larger than those contained in the dominant energy system
- Thus actors should be knowledgeable on opportunities crossing system boundaries