European Conference on
Impacts of Climate Change on Renewable Energy Sources
Reykjavik, Iceland, 7 June 2006

Climate Change and the Future Nordic Energy System

with focus on the electricity system

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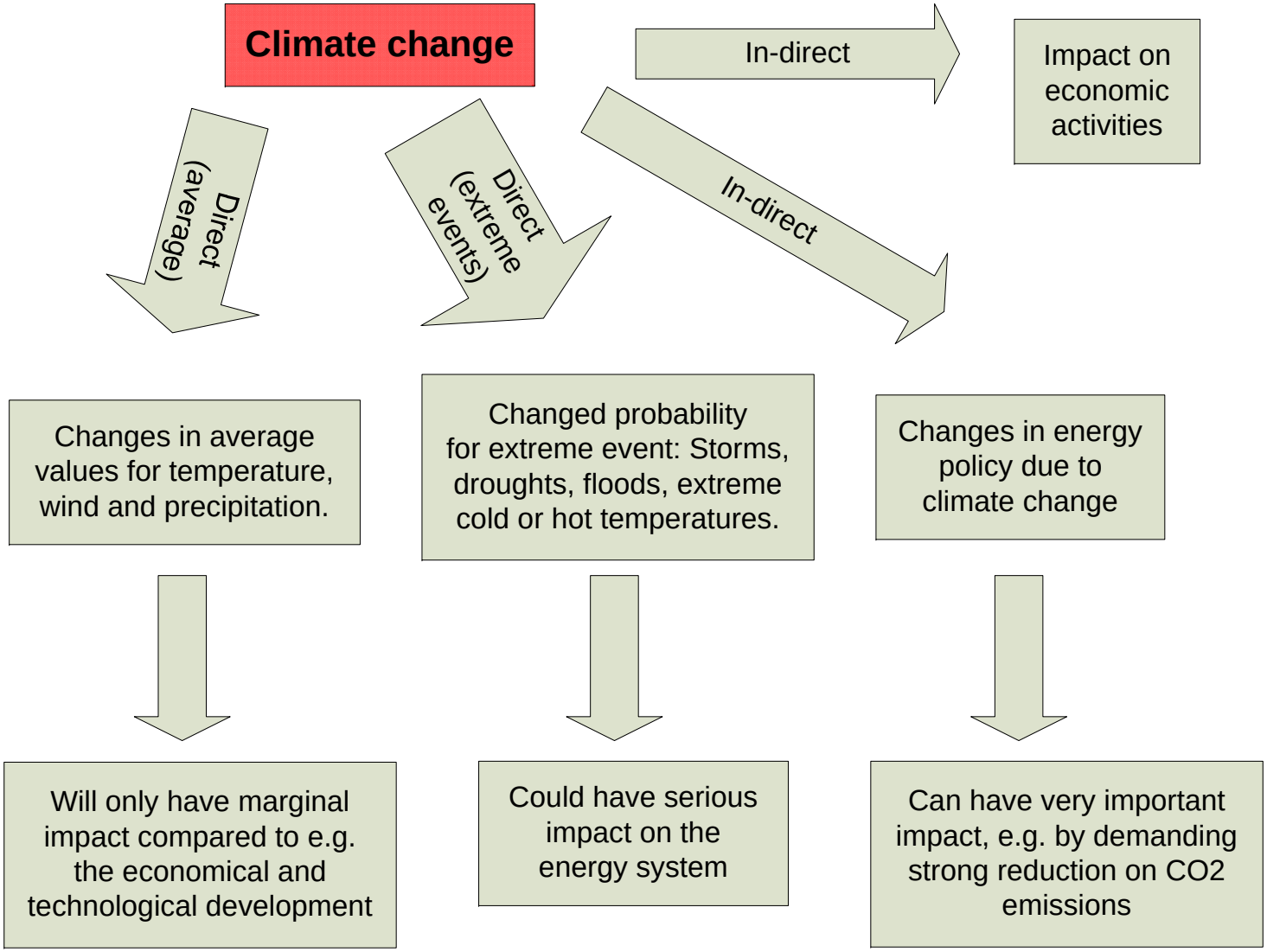
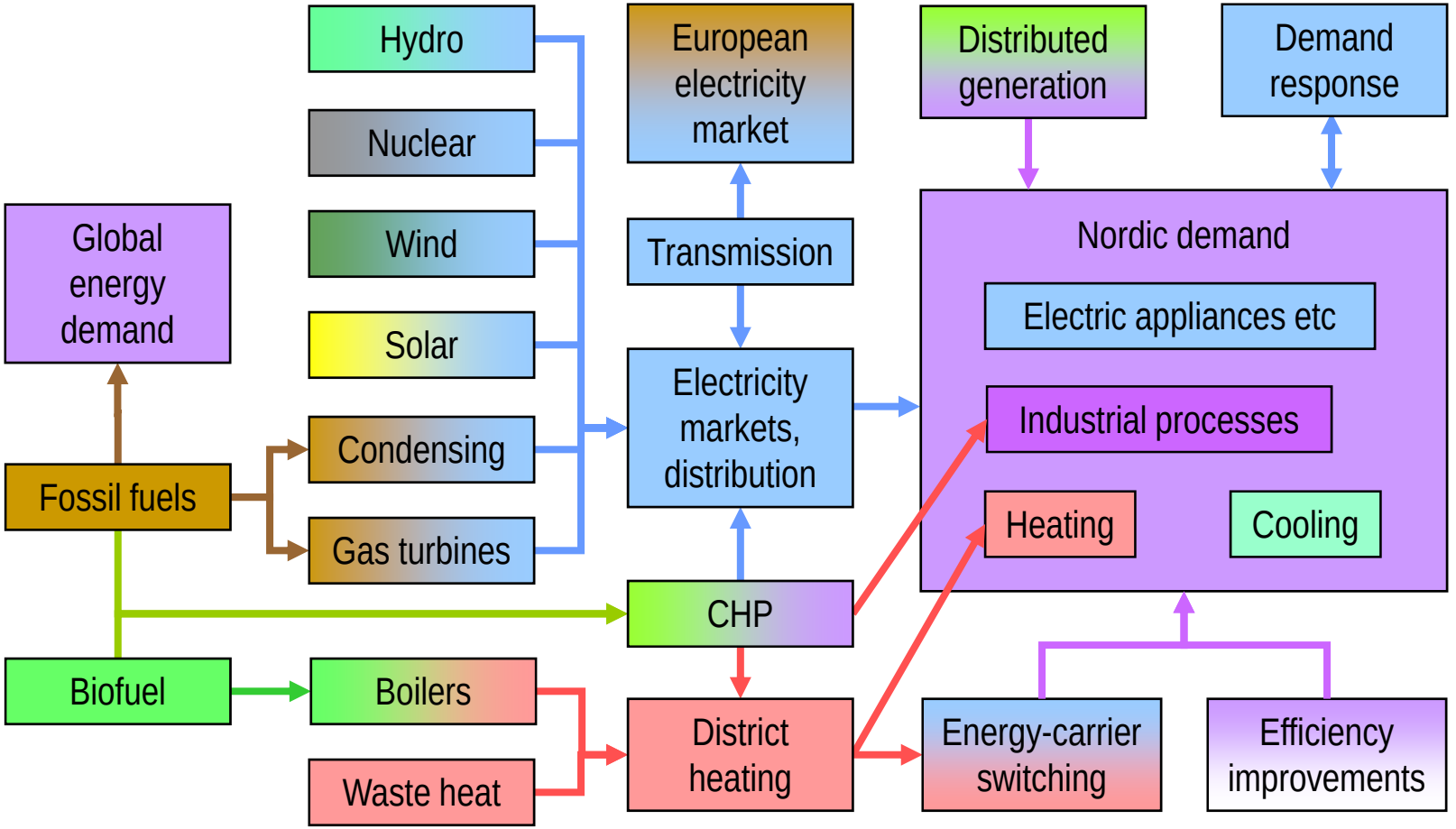
Direct and in-direct impact of climate change on the energy system



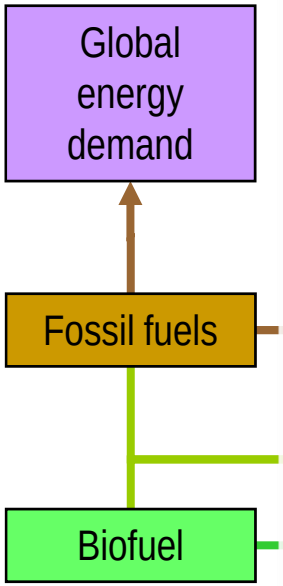
Energy system development

- Outline of possible long-term developments
  for the Nordic energy system
  due to economic, technical and political changes
- Stationary energy system
  focus on the electricity system
- 2050
- Three scenarios
- A medium-path scenario:
  a continuation of current trends
  modest economic growth
  balanced energy policy

Interplay among components in the energy system

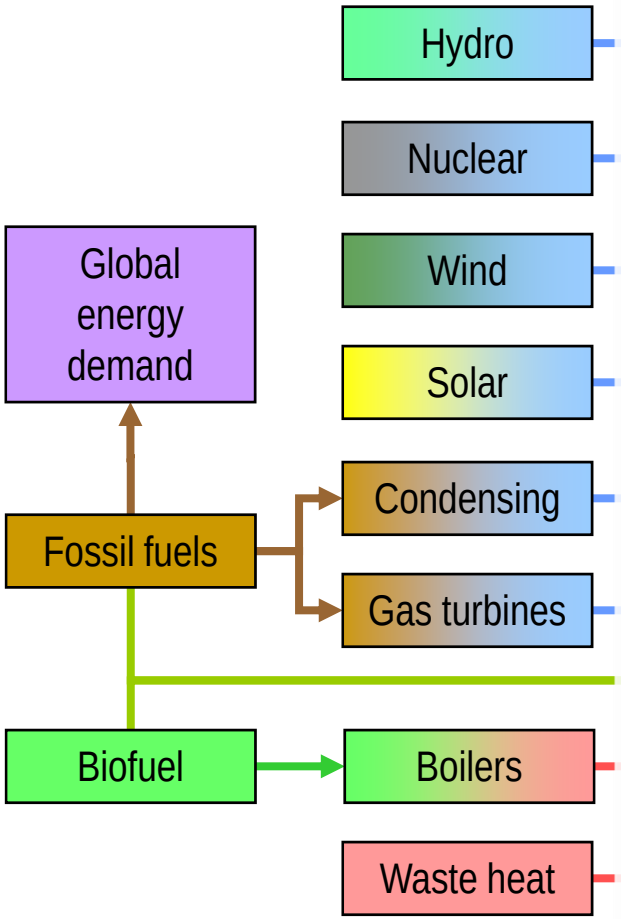


Global energy demand and supply



- Global energy demand increases due to industrialization and enhanced standard of living in many countries.
- Increased energy demand and limited cheap energy supplies make energy carriers more expensive.
- Fossil-fuel use decreases.
- Better conditions for biomass production helps enhancing biofuel supply.

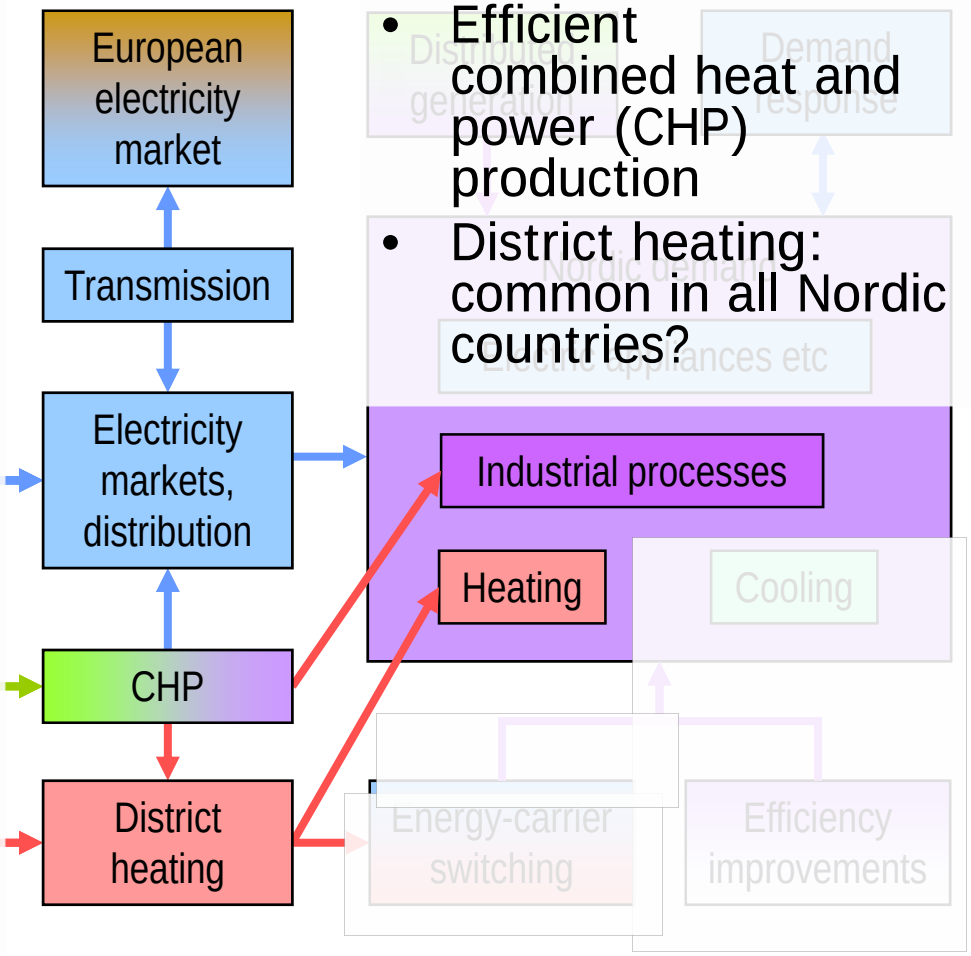
Energy conversion



- Condensing power decreases: low efficiency, increasing fossil-fuel costs, expensive electricity
- Renewable energy increases: biofuel, wind power, solar energy
- New technologies emerge: solar cells, fuel cells
- Carbon dioxide capture at power plants and storage in oceans or underground
- Hydrogen – an **energy carrier** : gasification of biomass / electrolysis e.g. vehicle fuel

Market, distribution CHP

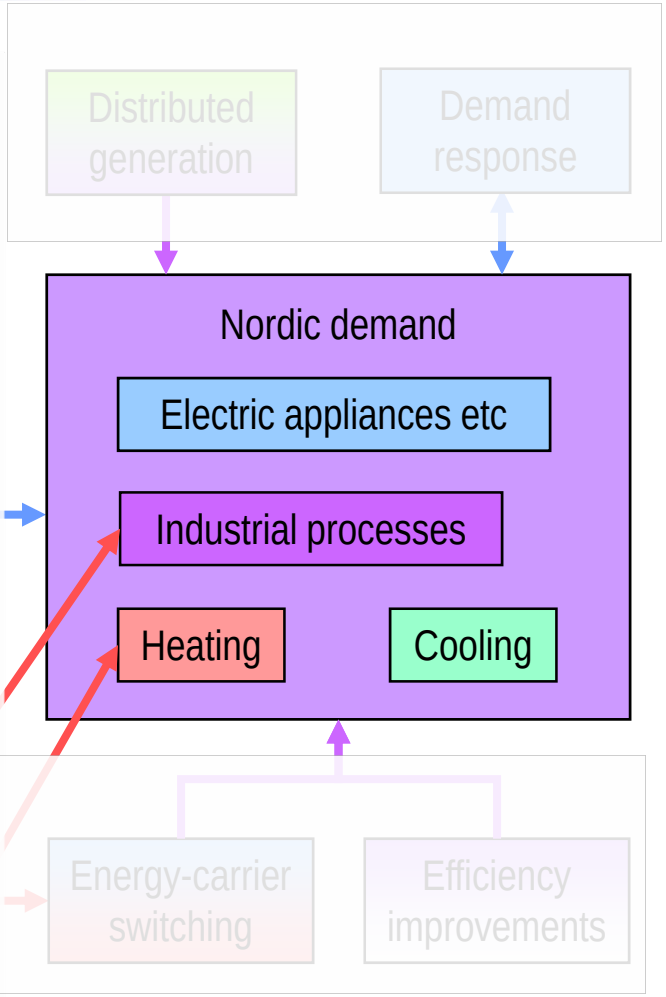
- Nordic power grids more linked to continental Europe.
- A common European electricity market
- Long distance power transmission between countries increases.
- Power electronics, Flexible AC transmission systems (FACTS), superconducting cables
- Electricity flow controlled systematically: allows a high share of wind power.



- Efficient combined heat and power (CHP) production
- District heating: common in all Nordic countries?

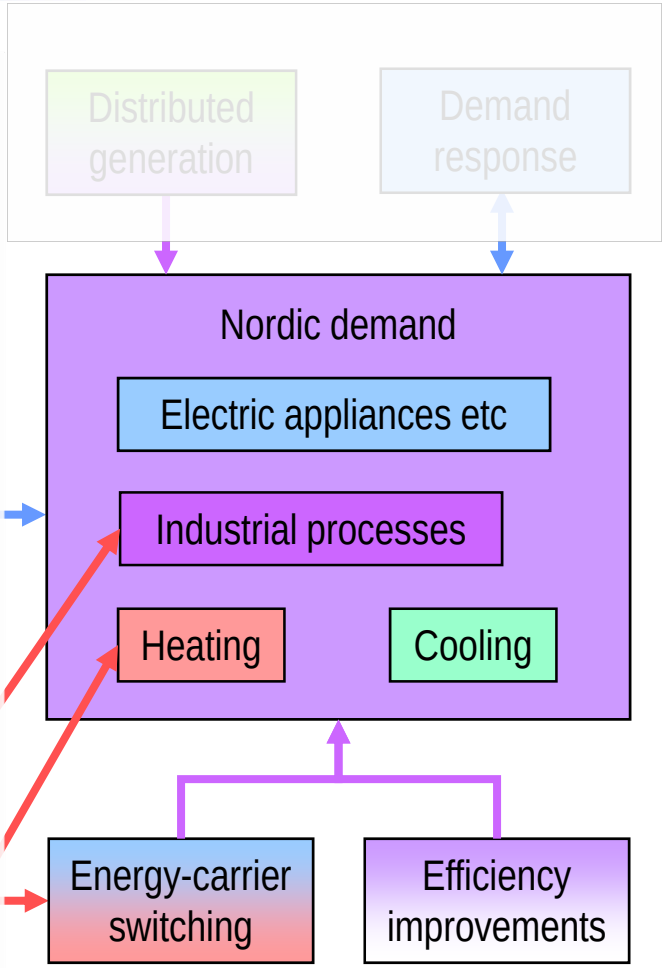
Energy demand

- Nordic electricity consumption per capita now much higher than EU average
- Increasing temperatures reduce space-heating demand and its seasonal variations.
- Cooling demand in summer increases, but less

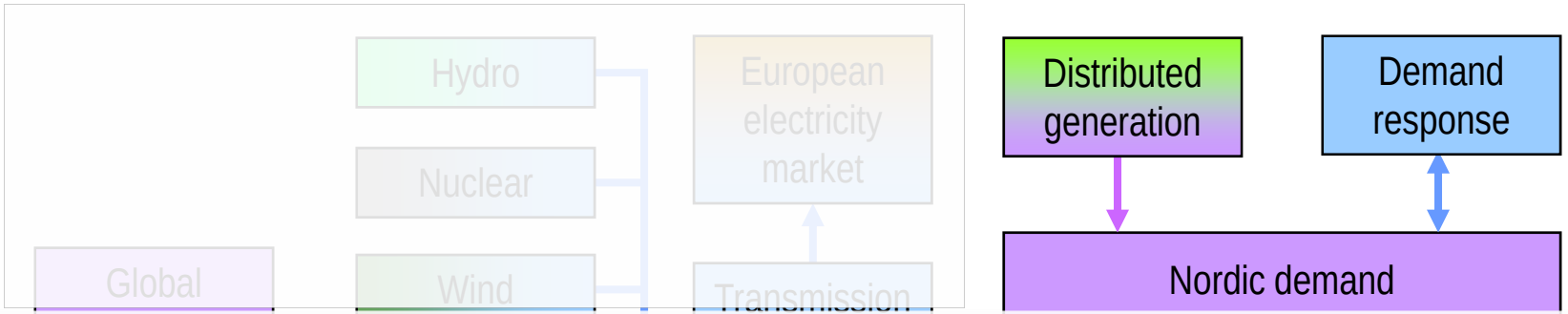


Energy conservation
Energy-carrier switching

- Energy is used more efficiently.
- Heat can be recovered for repeated use in industry and for heating.
- Electricity used for heat production can be replaced by fuels, district heating or solar energy.
- Heat-driven cooling
- Industrial electricity consumption decreases to continental level.



Distributed generation, demand response

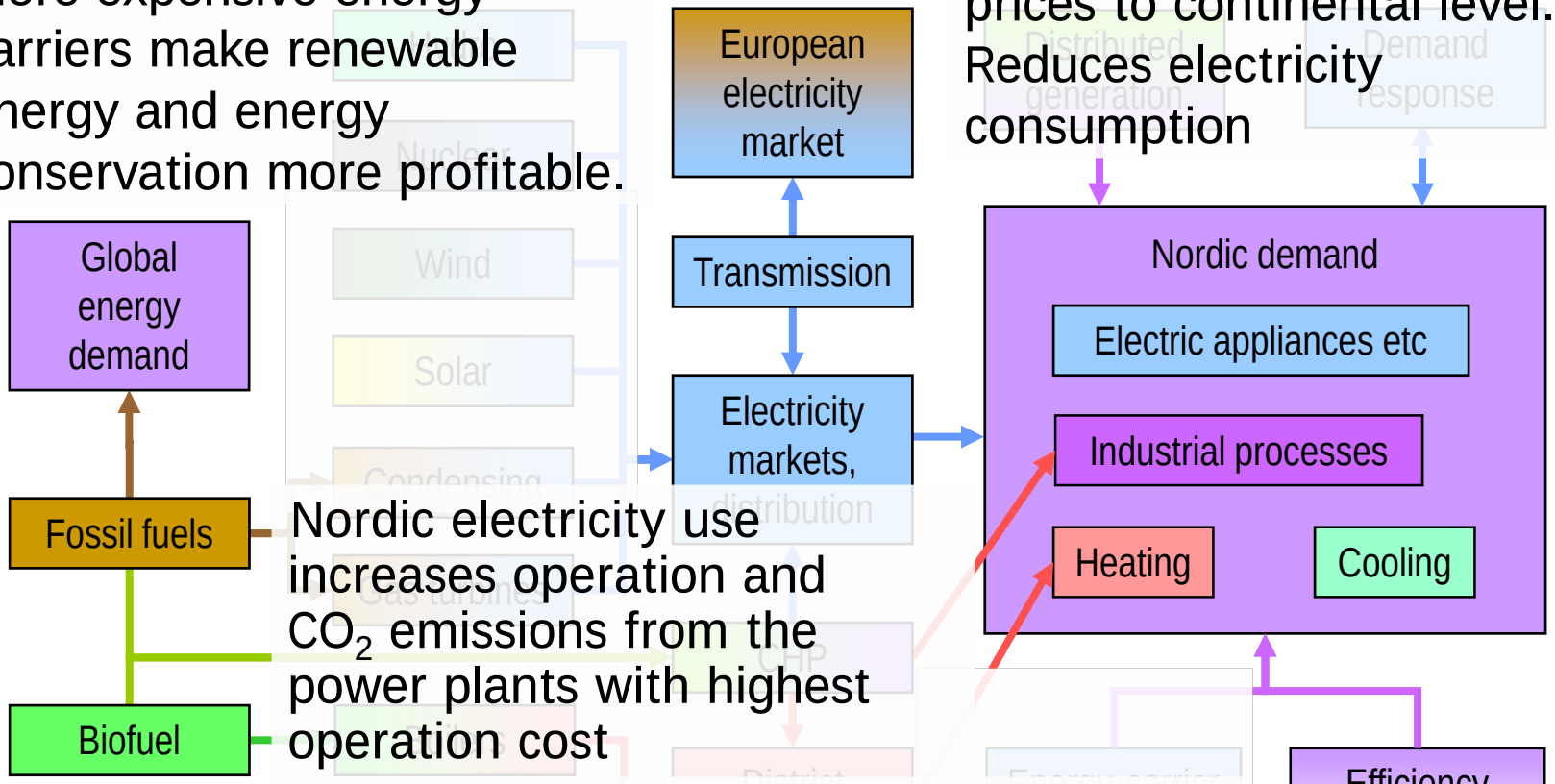


- Small-scale electricity (and heat) production, e.g. fuel cells
- Demand response
  Communication technology helps consumers change their demand.
  Delay demand to reduce peak generation
  Automatic demand control to avoid expensive periods
- Activate small-scale generation at high prices
- Dynamic nodal pricing
  Places have different prices due to local demand and supply.

System relationships

More expensive energy carriers make renewable energy and energy conservation more profitable.

More connection to continental power system raises Nordic electricity prices to continental level. Reduces electricity consumption



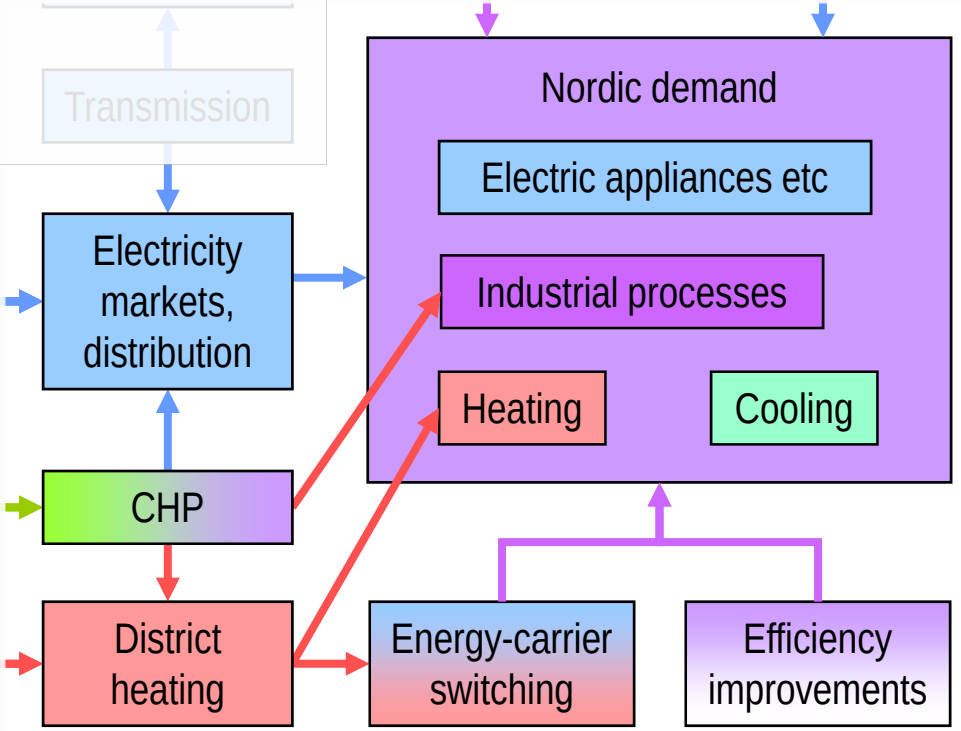
Nordic electricity use increases operation and CO_2 emissions from the power plants with highest operation cost

Now: coal-fired

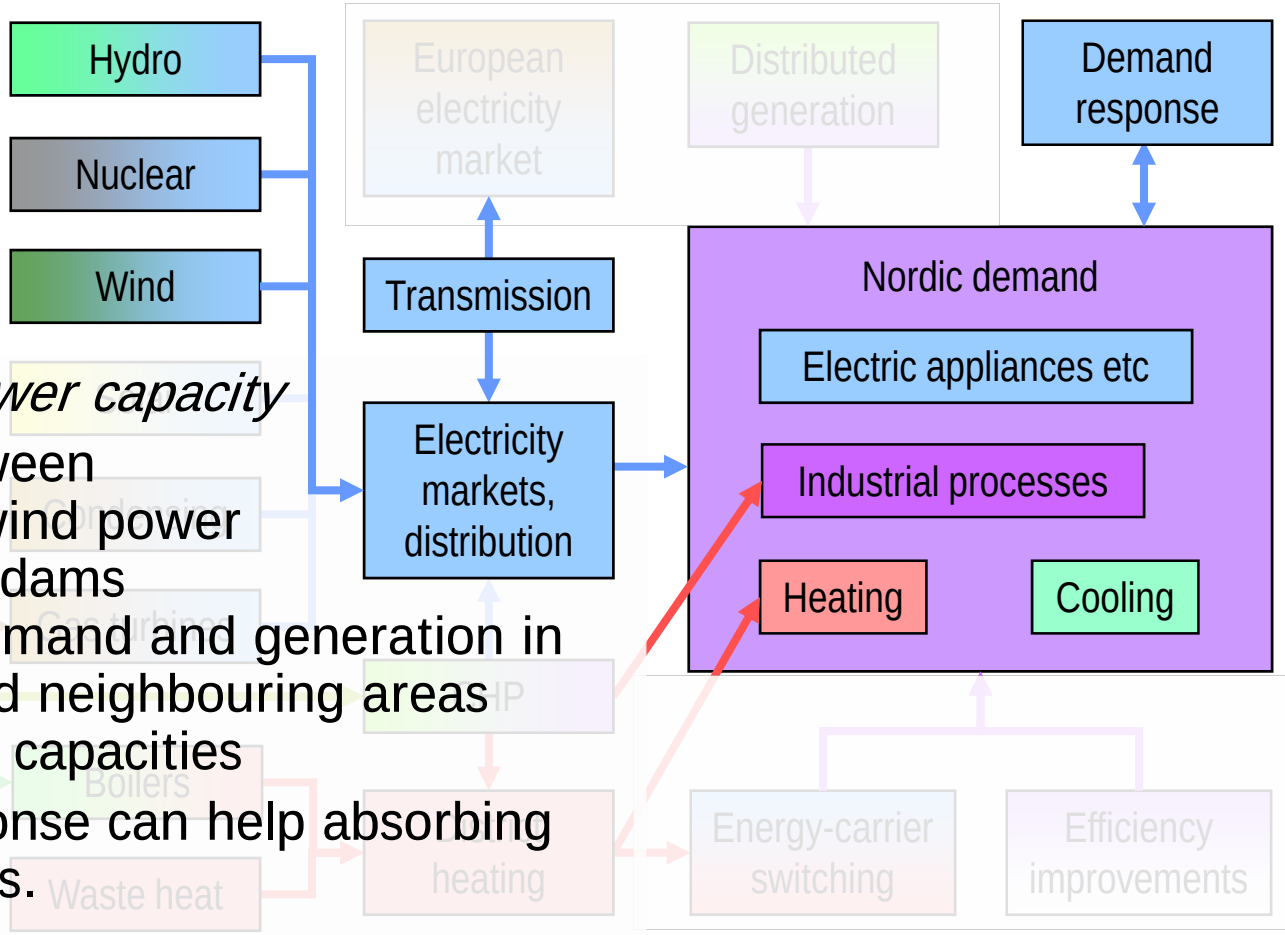
In the future: natural-gas-fired condensing plants

Impact of demand-side measures

- Efficiency improvements reduce primary energy supply but not the benefit.
- Switching from electricity for heating reduces seasonal variations of electricity consumption.
- Switching from electricity to district heating increases the heat sink for CHP production.



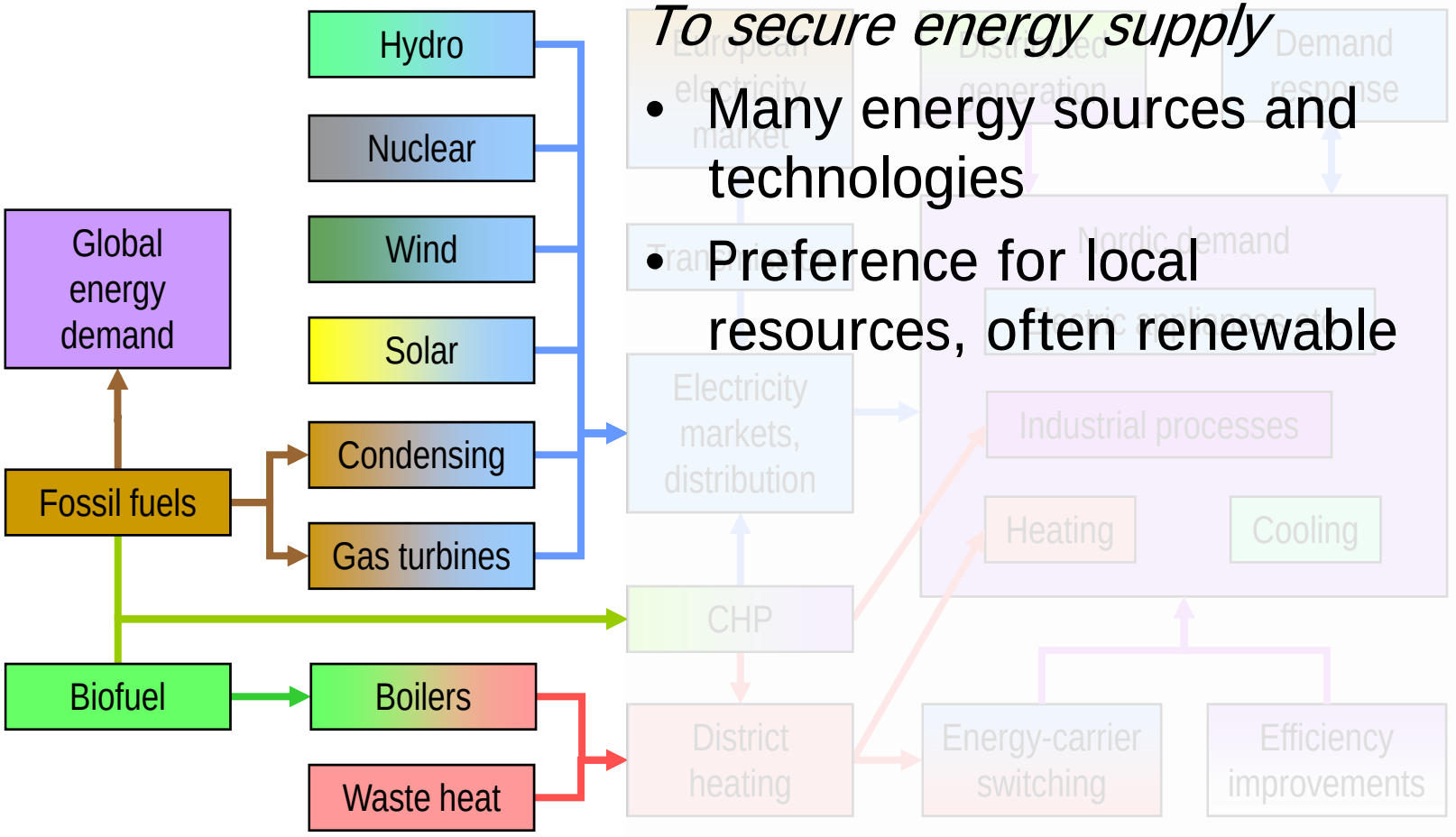
Balancing wind power



Possible wind power capacity

- Interplay between
  - fluctuating wind power
  - hydropower dams
  - electricity demand and generation in the same and neighbouring areas
  - transmission capacities
- Demand response can help absorbing wind variations.

Security of supply



To secure energy supply

- Many energy sources and technologies
- Preference for local resources, often renewable

Alternative scenarios

- *An extreme free market scenario*
- High economic growth
- Little environmental regulation
- High energy demand
- Large power plants:
  fossil fuel
  condensing power
  new large hydroelectric and nuclear plants

- *An environmental scenario*
- Low energy demand:
  high energy efficiency
  less heavy industry
- Firm policy instruments:
  renewable energy
  reduced CO_2 emissions.
- Distributed generation
- Low-energy buildings
  internal DC micro grids
- Domestic energy resources
  security of supply

- *Robustness*
  - share of hydropower
- free market: low
- environmental: high

Conclusion

- The direct impacts of climate change have less influence on the energy system than other transitions.
- Events occur that we cannot even imagine.