Scenario Workshop

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System Analysis
Outline

Part 1: Suggestion for base scenarios and technical alternatives

Part 2: Workshop on regulatory cases
Scenario process

**Step 1:** Condensing inputs from last scenario workshop and literature review into
- Main research questions (linked to modeling)
- Conceptual model (important parameters)

**Step 2:** Investigating TYNDP scenarios
- Choosing base scenarios

**Step 3:** Identifying technical alternatives:
- potential benefits from gas?
- main competitors?
- potential game changers?
not too many, but cover all competitors and game changers
Main research questions

1. What is the role of gas in the future Danish energy system when looking for the cost optimal way to achieve a zero emission system? (with import and without import of biomass) (now and during the transition)

2. What is the best (cost-optimal?) way of integrating renewable gases into the Danish energy mix?

3. Should the existing gas system (gas infrastructure) change in the future?

4. What is the cost of renewable and natural gas in relation to alternatives to achieve emission reduction targets in the energy, transport and industry sector?

5. Is there a robust choice for gas system and gas technologies which is not dependent on e.g. fuel price development?

6. Which regulation is required to reach the cost-optimal goal?
Conceptual model - Gas features

- Modelling gas flow with different pressure levels
- Modelling of gas storage, both short-term (line-pack) and long-term (seasonal) storage
- Representing gas losses and leakages
- Modelling collection of local biomass resources
- Modelling renewable gas production and upgrading and methanization of renewable gas to achieve natural gas quality
- Modelling P2G technologies and gas heat pumps
- Representing different gas qualities
- Modelling the potential demand from industry, transport and individual heating
Energy system model
Integrated energy system model
Future Work

[Diagram showing resource conversion and demand systems involving electricity, heating, and transportation.]
Modeling of the research questions

- In Balmorel
- Planned in Balmorel
- In TIMES
- Outside analysis
Research Questions Detailed I

1) Role of gas in the future Danish energy system - and during the transition
   • Share of gas in the
     – Electricity mix
     – Residential heating
     – Industry
     – Transport
   • Share of Renewable Gases
     – Biogas (Anaerobic digestion)
     – Bio-Methane (Anaerobic digestion - upgraded)
     – Syngas (Thermal gasification)
     – SNG (Thermal gasification – upgraded)
     – Hydrogen
   • Which technologies generate the Renewable gases?
     – Simple representation
     – Detailed representation on various technologies requires further data input from project partners and research colleagues
   • Future role of the different gases as a feedstock for production of Liquid fuels (methanol/DME/etc.)
     – Demand of liquid fuels
     – Production (OptiFlow)
   • Which share of district heating in Denmark will be covered by excess heat from
     – Thermal gasification
     – Bio-refineries
Research Questions Detailed II

2) What is the best (cost-optimal?) way of integrating renewable gases into the Danish energy mix?
   - Into the main grid or via dedicated grids?

3) Should the existing gas system (gas infrastructure) change in the future?
   - Pipeline capacity within Denmark
   - Pipeline transmission capacity to other countries
   - Storage facilities
   - Dedicated grids not connected to the main grid
   - Compressors
   - Competition to other infrastructures???

4) What is the cost of Renewable and natural gas in relation to alternatives to achieve emission reduction targets in the transport and industry sector and residential sector (non-ets goals)?
   - Industry: Compared to electrification
   - Industry: Compared to fuel shift (biomass/-fuels etc.)
   - Transport: Compared to electrification
   - Transport: Compared to fuel shift (biomass/-fuels etc.)
Research Questions Detailed III

5) Is there a robust choice for gas system and gas technologies which are not dependent on fuel price/technology development?
   - Question can be addressed by (global) sensitivity analysis
     - Sensitivity analysis on fuel prices
     - Additional global sensitivity analysis of other parameters?

6) Which regulation is required to reach the cost-optimal goal?
   Do we reach the cost-optimal system fulfilling the goals best with
   - Taxes?
   - Subsidies?
   - Trading schemes?
   - Targets?
   - Caps?
   - Bans?
Relation of Future Gas to TYNDP-scenarios

- Usage of basic data and idea for some parameters
- More parameters that are defined endogenously
- Follows general storylines but condensing it to two base scenarios
- Additional technical alternatives for answering Future Gas research questions
- Higher resolution on gas, especially renewable gas parameters required
- Higher geographical resolution for Denmark
- Up to 2050
Base scenarios - Storyline

DARK GREEN

- Worldwide high ambitions for climate emission reduction
- High biomass prices
- High CO2 price
- Low fossil fuel price
- High energy savings
- High demand side flexibility

- DK
  - no biomass import
  - 100% RE in 2050

- Medium technology costs

LIGHT GREEN

- Ambitions for climate emission reduction
- Medium biomass prices
- Medium CO2 price
- Medium fossil fuel price
- Medium energy savings
- Medium demand flexibility

- DK
  - some biomass import
  - Fossil ‘independent’ in 2050

- Medium technology costs
Relation to TYNDP-scenarios - parameter

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<th>Category</th>
<th>Criteria</th>
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Red: assumptions from Energinet/TYNDP
Blue: inputs from WP3
Green: modeled by WP4 based on technology/cost assumptions from Energinet/TYNDP
Gas in the energy system I

Potential benefits ↔ Competitors

*Flexibility*
- Providing short-term flexibility ↔ Batteries
- Providing seasonal flexibility ↔ Thermal storage

*Energy Carrier*
- Import/Export ↔ Electricity transmission, liquid fuels
- Energy density for transport ↔ Electricity transmission, liquid fuels
- Wide distribution / collection ↔ Electricity, batteries, liquid fuels

*Efficient biomass utilization*
- Way of getting most out of scarce biomass resource ↔ Electricity, biomass import, usage by agriculture / for materials, savings
- Basis for sustainable biofuel production utilizing excess heat ↔ Electricity, import of biofuels

*Driver of circular economy* ↔ Shifts in agriculture
Gas in the energy system II
Potential benefits ↔ Competitors

Transition phase
• Fast and cheap reduction of climate emissions by natural gas in the transition phase
• Cheap process heating

Security of supply
• Capacity
• Geopolitics
• Diversity of RE gas technologies

Sector coupling
• Reducing climate emissions in non-ETS sector
• Renewable gas for chemical / industrial sector

Combination of all the other solutions: bio, solar, wind, electric transport, liquid biofuels, EVs, etc.
Individual and DH heat pumps

Electricity transmission, liquids
Renewables within DK/Europe
Diversity of all other generation, storage, flexibility solutions

Shifts in e.g. agricultural sector
Partly electrification
Game Changer for role of gas in Denmark

- Electric highways and break-through for electric maritime and air transportation
- Other cheap seasonal storage
- Cheap CO2-capture from air and its use
- Massive energy savings
- Import of liquid biofuels that fulfill sustainability criteria
- Denmark as a LNG-hub
- Denmark as a gas transit country
Technical alternatives I

*Generation technologies*

- **REcentral**: Cheap electricity technologies for power supply – especially centralized ones
- **REdecentral**: Cheap electricity technologies for power supply – especially decentralized ones
- **REgasTech**: Technologies for Renewable Gas conversion get very cheap
- **CO2capture**: Technology to capture CO2 from air and central sources gets very cheap

*Competing infrastructures*

- **lessELtransm**: Low availability of electric transmission grid
- **strongDH**: No natural gas for heating and cheap DH-technologies
- **noGrid**: Gas infrastructure not further maintained
- **Dktransit**: DK as a gas transit country
Technical alternatives II

Resource dependency and costs
- ressourcePrice: High and low resource prices
- noBioImport: no import of liquid biofuels

Sufficiency
- LowDemand: strongly reduced energy consumption also in transport

Transport
- ELtransp: Massive electrical transport
- LNGhub: High demand for LNG (esp. for ships) from Denmark (strong MARPOL regulation Sulphur and Nox)
- DieselBan: Ban on diesel cars
- FuelCell: Cheap fuel cells for transport
Scenario Analyses

Cost-optimal solution for reaching the respective emission targets
Operation and Investment optimization

Base Scenarios
- Dark Green and Light Green: 2020-2050 in five year steps
- Calculated for DK, NO, SE, DE, additional runs with more countries for comparing results
- 14 base scenario runs in total + additional for more countries

Technical Alternatives
- Decision if calculated for Dark Green or Light Green
- 2030 and 2050 for 14 different technical alternatives (about 28 runs)
- Potentially utilization of method: global sensitivity analysis (a lot more runs)
Questions

• Do you agree that we can address the main research questions (excluding regulatory issues) with the suggested base and technical scenarios?

• Did we miss any significant potential benefit of gas in the energy system?

• Do you see other major competitors for the potential benefits?

• Do you see other significant game changer for the whole energy system and thus for the role of gas?

Review process

• Who could review which of the scenario parameters?
The End
Annex A
Data Flow I

Demand - Consumer behaviour
- Demand savings
- Decline or increase in demand

Transport (technology and cost)
- Gas vehicles
- Hydrogen vehicles
- Electric vehicles
- Electric highways

Potential
- Wind
  - Installed capacity
  - Profiles
- Solar
  - Installed capacity
  - Profiles
- Biomass + Waste
  - Yearly sum

Technologies - General technology development including cost development
- Sensitivity to gas quality (scenario setting or calculated outside of Balmorel)

Technologies
- Electricity/Heat
  - Thermal power plants
  - Wind and solar
  - CHP
  - Electric heat pumps
  - Hybrid heating
  - Solar heating
- Gas
  - Anaerobic biogas
  - Biogas upgrading
  - Pyrolysis/Syngas
  - Electrolysis
- Fuel
  - Fischer Tropsch
- Storage/Infrastructure
  - Line-pack
  - Gas storage

Characteristics:
- Efficiency
- Load characteristic
- Sensitivity to gas quality
- Emissions
- Methane leakage rates

Society
- Social/public acceptance concerning climate and environment
- Societal values, macro trends
- Societal opposition to shale gas and Russian gas

Supplying the demand
- Sticking to capacity limits
- Utilising Technologies according to their characteristics

Optimisation

Output Data
Annex A
Data Flow II

INFRASTRUCTURE (political setting)
- Political motivated electricity connections
- Political motivated gas connections

INFRASTRUCTURE
- Set capacities Electricity to other countries
- Set capacities Gas to other countries
- LNG Infrastructure
- Leakage rates

COSTS
- Technologies described above
- Infrastructure
- Investment
- O&M

RESOURCES
- Natural gas
- Oil
- Coal
- Bioethanol
- Methanol

REGULATION
- Environmental policy
- ETS targets
- Non ETS targets
- Common gas market
- Certification possibilities for green gas
- Harmonization of gas quality standards

REGULATION
- CO2 limit / resource usage limits
- CO2 tax / resource taxes
- Subsidies for green technologies
- Methane leakage limits

- In a cost-optimal way:
  - Dispatch
  - Investments

COSTS
- System cost
- Costs per technology?

ELECTRICITY PRICE

- Meeting regulatory limits