DTU

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Economic feasibility of fuel-shift appliances supplied by gas, electricity and district heating in Denmark

Examples of fuel-shift (hybrid) equipment

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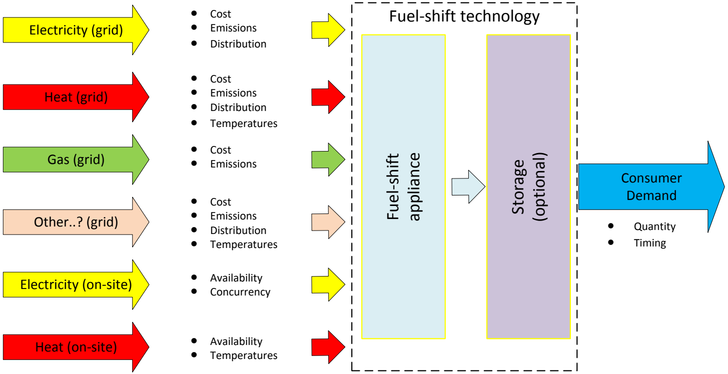
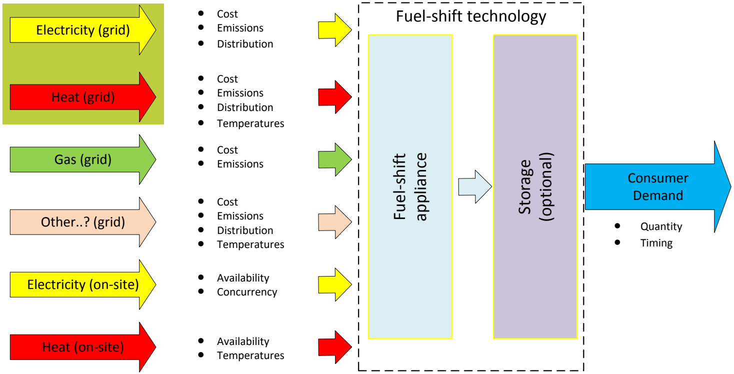
Possible supply schemes



Possible supply schemes



State of the art

Existing literature on the topic is very limited, although the concept is established and components exist.

Sector-coupling and thermal storage is a key part of smart energy systems [Lund et al. 2014].

Some link to Active Demand Response, where electric grids use the thermal inertia of heating networks [Patteeuw et al. 2015]. But focused on links to the electricity sector.

- \+ High shares of intermittent production may provide high price volatility
- \- Until 2040, the various sectors will be increasingly coupled (e.g. GW capacity heat pumps in DH)
- +/- ...

Aim and Research questions

Preliminary assessment to be conducted, with the aim to clarify the options and technologies which are relevant for fuel-shift in a Danish context

- *How can fuel-shift technologies, which are able to create flexibility between different energy carriers at consumer side, achieve feasible business cases considering both private and socio-economic criteria?*
- *How significant are the economic and environmental impact of fuel-shifting between energy carriers for common household appliances?*

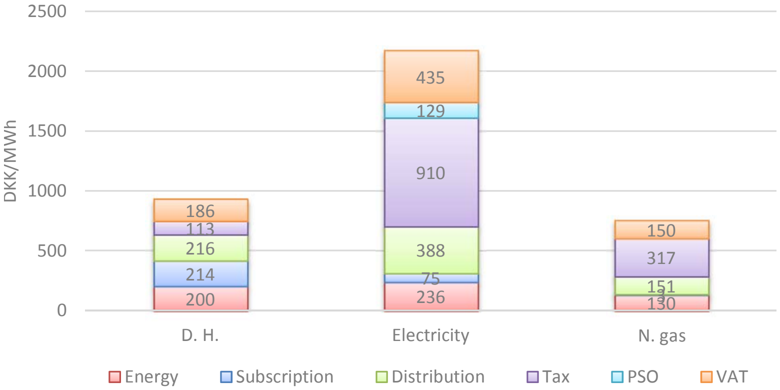
Socio and/or private economic feasibility?

Investment year Operation	2020 2020-2029	2030 2030-2039	Best
Socio-economic	A	C	max(A,C)
Private-economic	B	D	max(B,D)

- Feasible installations are characterised by improvements of variable cost during the technical lifetime (period of 10 years), to exceed additional cost of installation and maintenance.
- ”Additional fixed cost (AFC)” represents marginal investment and maintenance of equipment.

Methods

Elements of private economic consumer cost (2017)



Evaluated cases for fuel shift

Case	Description
1	Evening peak hours (from 18:00 to 20:00 - 1 kWh/h)
2	Night (from 00:00 to 06:00 - 0.33 kWh/h)
3	Morning peak hours (from 07:00 to 09:00 - 1 kWh/h)
4	Consecutive hours with biggest benefit (1 kWh/h)
HP1	As Case # 1 with HP
HP2	As Case # 2 with HP
HP3	As Case # 3 with HP
HP4	As Case # 4 with HP

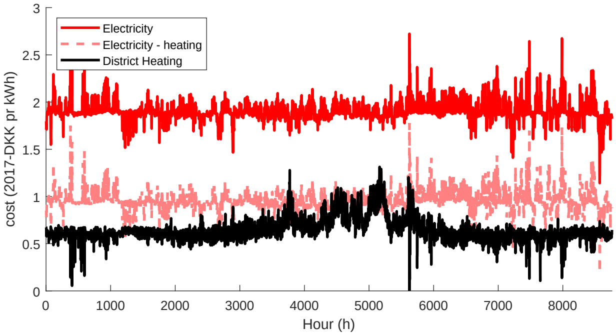
In case of heat pumps:

Electricity $COP = 3$ Heat $COP = 1.5$ N.gas $COP = 2.5$

Results

Example of fuel shift between electricity and district heating

Fuel shift assuming hourly consumer cost for electricity and district heating



Example of fuel shift between electricity and district heating (2020)

Case	Description	Fuel-shift DH → Electricity 2017-DKK	Fuel-shift Electricity → DH 2017-DKK
1	Evening peak hours (from 18:00 to 20:00 - 1 kWh/h)	0	371
2	Night (from 00:00 to 06:00 - 0.33 kWh/h)	4	256
3	Morning peak hours (from 07:00 to 09:00 - 1 kWh/h)	1	344
4	Consecutive hours with biggest benefit (1 kWh/h)	7	447
HP1	As Case # 1 with HP	191	525
HP2	As Case # 2 with HP	242	415
HP3	As Case # 3 with HP	189	495
HP4	As Case # 4 with HP	282	584

Outline of feasible fuel-shift options

	ref.	fuel-s.	Case # 1	2	3	4	1^{HP}	2^{HP}	3^{HP}	4^{HP}
Socio-economic	Elec.	DH	B	B	B	B	B	B	B	B
	N. gas	DH	A	B	B	B	B	B	B	B
	DH	Elec.	A	A	A	B	B	B	B	B
	N. gas	Elec.	A	A	A	A	A	A	A	A
	DH	N. gas	A	A	A	B	B	B	B	B
	Elec.	N. gas	B	B	B	B	B	B	B	B
Private-econ.	Elec.	DH	C	C	C	C	C	C	C	C
	N. gas	DH	B	A	B	B	B	B	B	B
	DH	Elec.	A	A	A	A	A	A	A	A
	N. gas	Elec.	A	A	A	A	A	A	A	A
	DH	N. gas	A	A	A	A	B	B	B	B
	Elec.	N. gas	C	C	C	C	C	C	C	D

A AFC $<$ 1000 DKK

B 1000 DKK $\leq$ AFC $<$ 5000 DKK

C 5000 DKK $\leq$ AFC $<$ 10000 DKK

D 10000 DKK $\leq$ AFC

Outline of feasible fuel-shift options

	ref.	fuel-s.	Case # 1	2	3	4	1^{HP}	2^{HP}	3^{HP}	4^{HP}
Socio-economic	Elec.	DH	B	B	B	B	B	B	B	B
	N. gas	DH	A	B	B	B	[illegible]	[illegible]	[illegible]	B
	DH	Elec.	A	A	A	B	[illegible]	[illegible]	[illegible]	B
	N. gas	Elec.	A	A	A	A	[illegible]	[illegible]	[illegible]	A
	DH	N. gas	A	A	A	B	[illegible]	[illegible]	[illegible]	B
	Elec.	N. gas	B	B	B	B	[illegible]	[illegible]	[illegible]	B
Private-econ.	Elec.	DH	C	C	C	C	[illegible]	[illegible]	[illegible]	C
	N. gas	DH	B	A	B	B	[illegible]	[illegible]	[illegible]	B
	DH	Elec.	A	A	A	A	[illegible]	[illegible]	[illegible]	A
	N. gas	Elec.	A	A	A	A	[illegible]	[illegible]	[illegible]	A
	DH	N. gas	A	A	A	A	B	[illegible]	[illegible]	B
	Elec.	N. gas	C	C	C	C	[illegible]	[illegible]	[illegible]	D

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Outline of feasible fuel-shift options

	ref.	fuel-s.	Case # 1	2	3	4	1^{HP}	2^{HP}	3^{HP}	4^{HP}
Socio-economic	Elec.	DH	B	B	B	B	[illegible]	[illegible]	[illegible]	B
	N. gas	DH	A	B	B	B	[illegible]	[illegible]	[illegible]	B
	DH	Elec.	A	A	A	B	[illegible]	[illegible]	[illegible]	B
	N. gas	Elec.	A	A	A	A	[illegible]	[illegible]	[illegible]	A
	DH	N. gas	A	A	A	B	[illegible]	[illegible]	[illegible]	B
	Elec.	N. gas	B	B	B	B	[illegible]	[illegible]	[illegible]	B
Private-econ.	Elec.	DH	C	C	C	C	[illegible]	[illegible]	[illegible]	C
	N. gas	DH	B	A	B	B	[illegible]	[illegible]	[illegible]	B
	DH	Elec.	A	A	A	A	[illegible]	[illegible]	[illegible]	A
	N. gas	Elec.	A	A	A	A	[illegible]	[illegible]	[illegible]	A
	DH	N. gas	A	A	A	A	[illegible]	[illegible]	[illegible]	B
	Elec.	N. gas	C	C	C	C	[illegible]	[illegible]	[illegible]	D

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Summary

- Only one combination of fuel-shift pairs and operational cases revealed a benefit large enough to allow AFC of 10000 2017-DKK for the private consumer. No Socio-economic case exceeds 5000 2017-DKK.
- A range of solutions (FS electricity -> DH or N. gas) allow AFC of between 5000 2017-DKK to 10000 2017-DKK. Fuel shift to electricity can only allow AFC of less than 1000 2017-DKK.
- Development in cost does not significantly off-set the feasibility of the fuel-shift technologies.
- Generally, the business case for fuel shift equipment is dependent on the tax of different utilities.
- Fuel-shift equipment will allow trade-off between cost and emissions. In the paper up to 8 % reduction in emissions are shown, or up to 12 % reduction of cost. Some of these reductions could be achieved by better operation of traditional equipment.

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