Energy Planning for Integrated Energy Systems

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Outline

- Integrated energy planning
- MILP model used
  - » Limitations of the model
- Case study: Singapore
- Results
  - » The role of different storage types
  - » Flexibility provision of industry and buildings
  - » The role of district cooling: optimal capacities
  - » Air pollution and renewable energy sources
- Conclusions

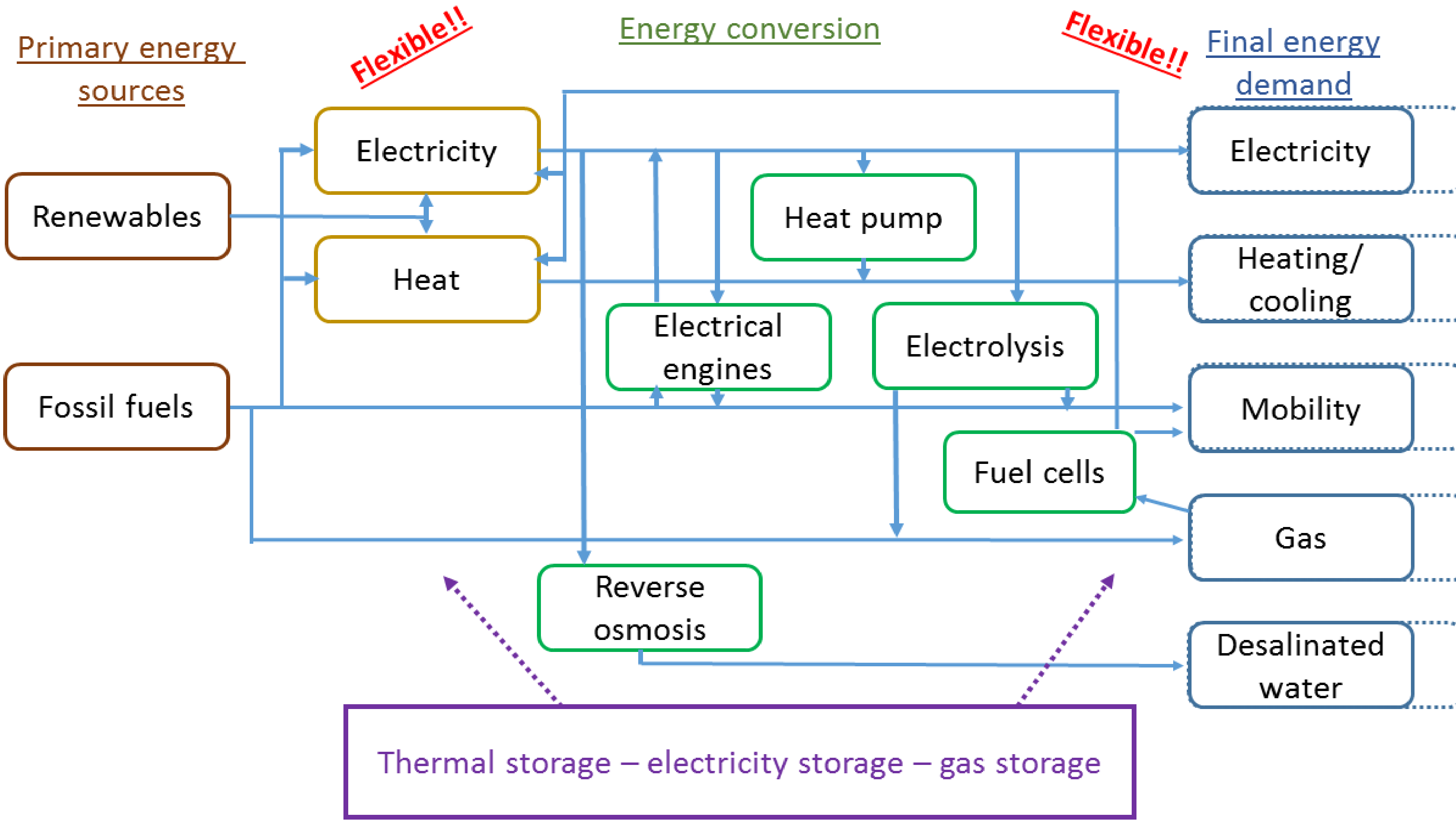
Climate change vs. Air pollution

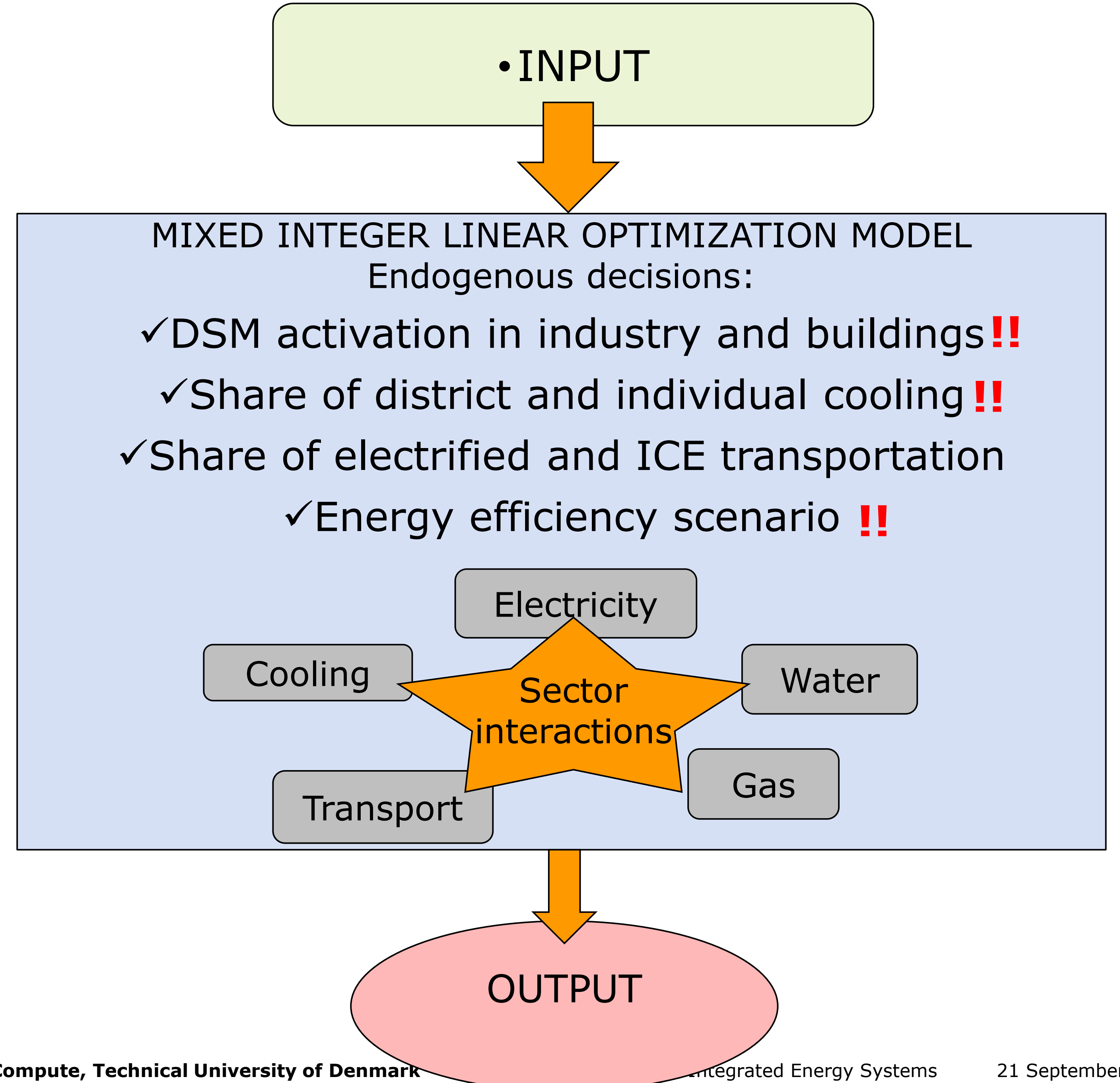
SO_x, NO_x, PM

CO_2, CH_4, N_2O

CO_2e

Integrated energy system modelling



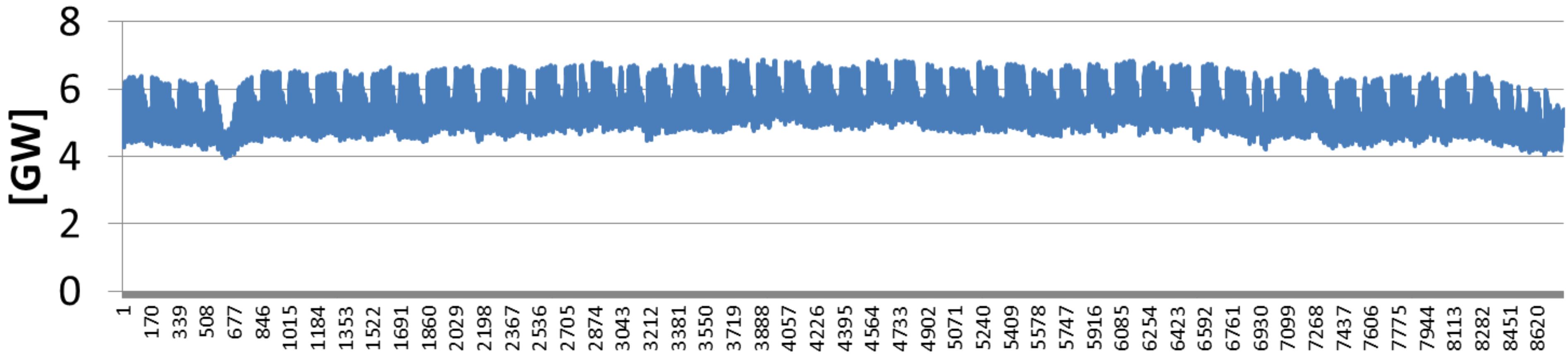

•INPUT
MIXED INTEGER LINEAR OPTIMIZATION MODEL
Endogenous decisions:
✓DSM activation in industry and buildings!!
✓Share of district and individual cooling!!
✓Share of electrified and ICE transportation
✓Energy efficiency scenario !!
Electricity
Cooling
Water
Sector interactions
Gas
Transport
OUTPUT

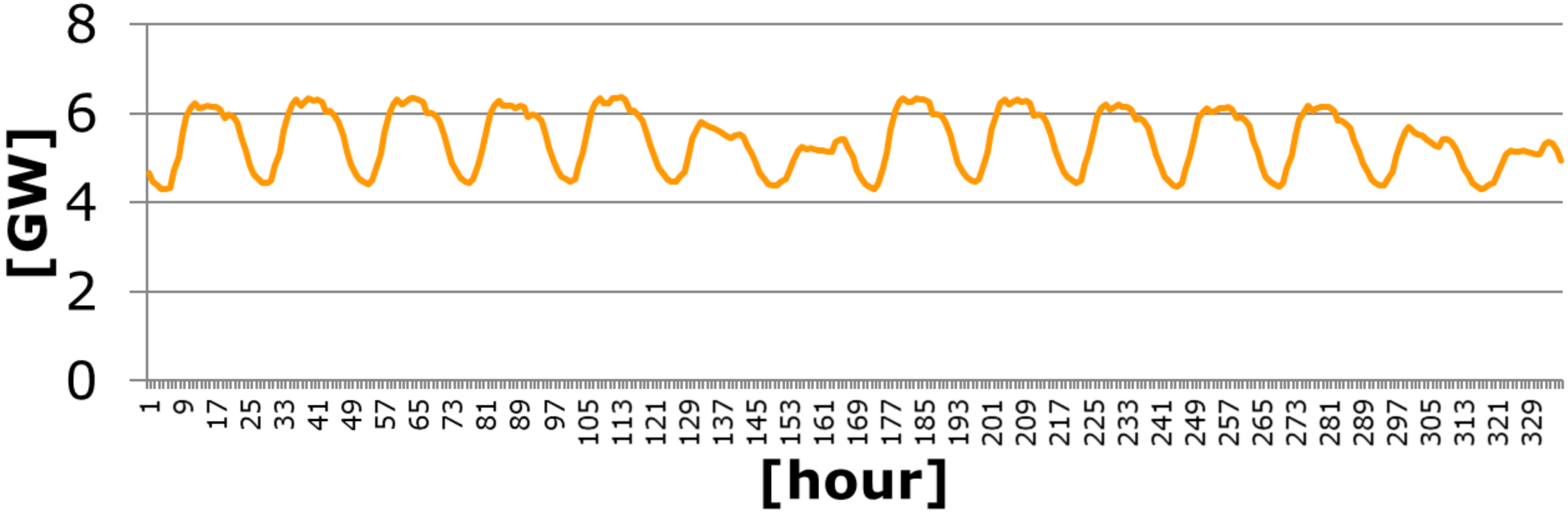
Limitations

- Spatial representation: transmission and distribution (congestion)
- Temporal resolution: frequency, voltage
- Industry representation
- Socio-economic costs only

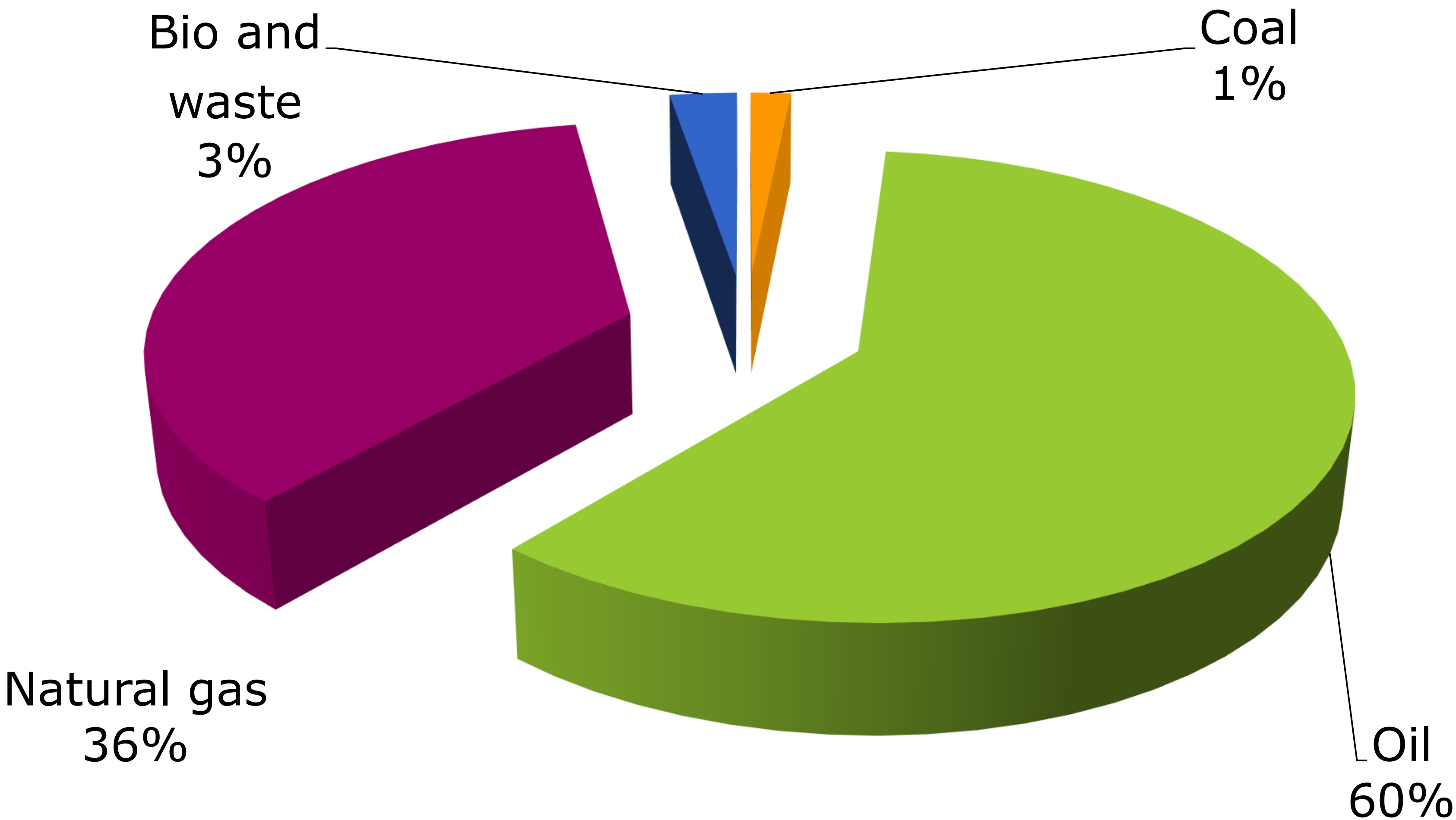
Case study: Singapore

- Population, area, GDP, industry





Primary energy supply of Singapore

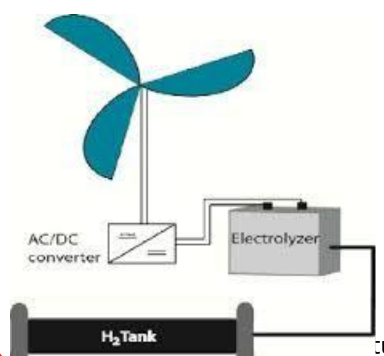


Source: IEA (2015)

Scenario development

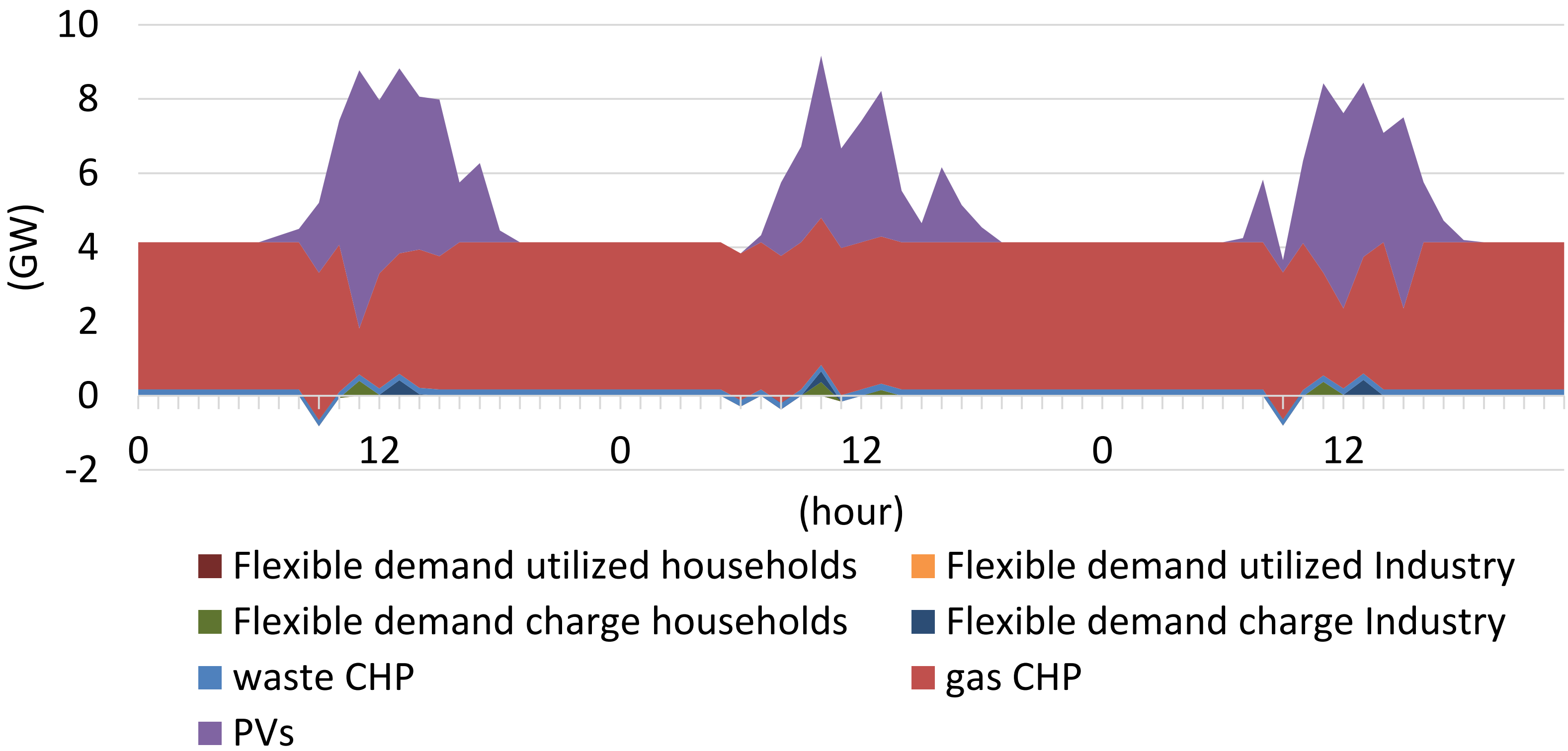
Technologies/ constraints	Scenario 1 BAU	Scenario 2 DC	Scenario 3 DC-PV	Scenario 4 DC-PV-el.transp.	Scenario 5 CO_2-constr.
Transport Electrification	✓ !	✓ !	✓ !	✓	✓
Photovoltaics	✓ !	✓ !	✓	✓	✓
District Cooling		✓	✓	✓	✓
SOFC, SOEC, synthetic fuels				✓	
CO_{2e} emissions					✓

Flexibility options in the energy system (4)



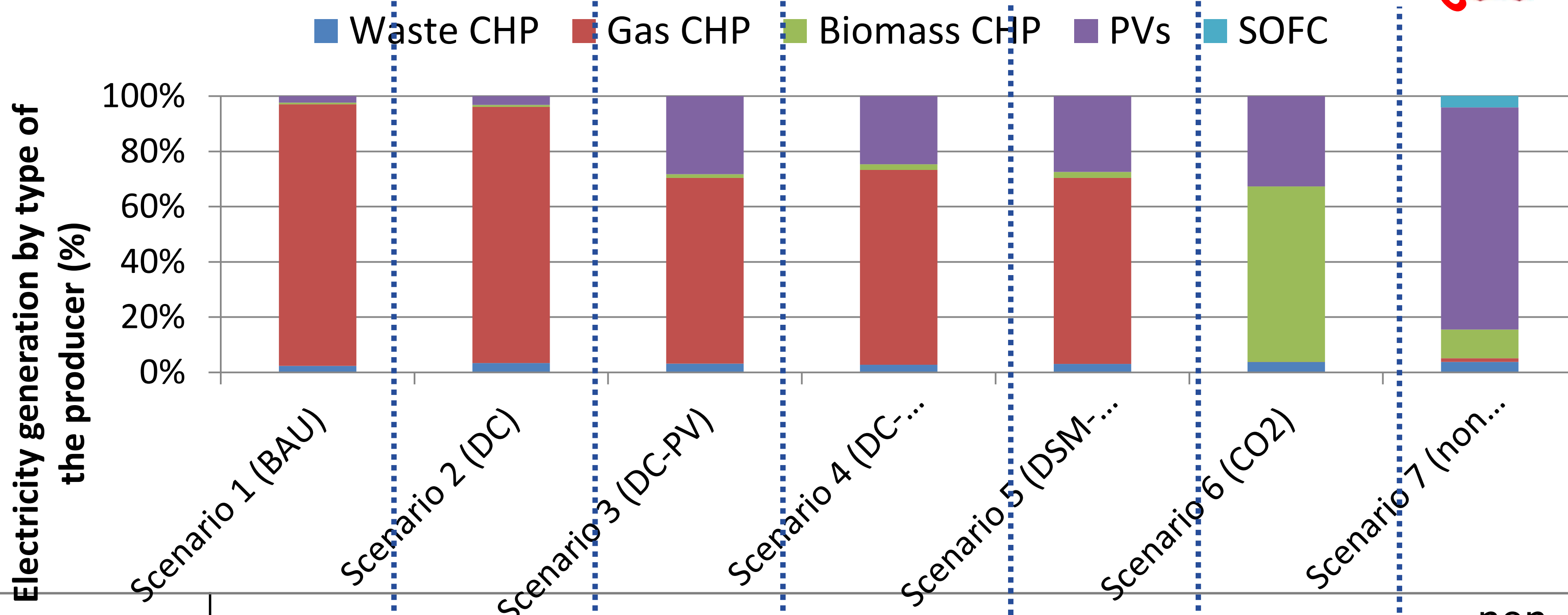
Demand response – industry and buildings

- Load shifting increased peak demand (!) – but optimal



- Load shifting in industry: 9%, 6% and 11% (Scenarios 5-7)
- Load shifting in buildings: 5%, 3% and 6%
- Total: 0.26-0.71% of final electricity demand

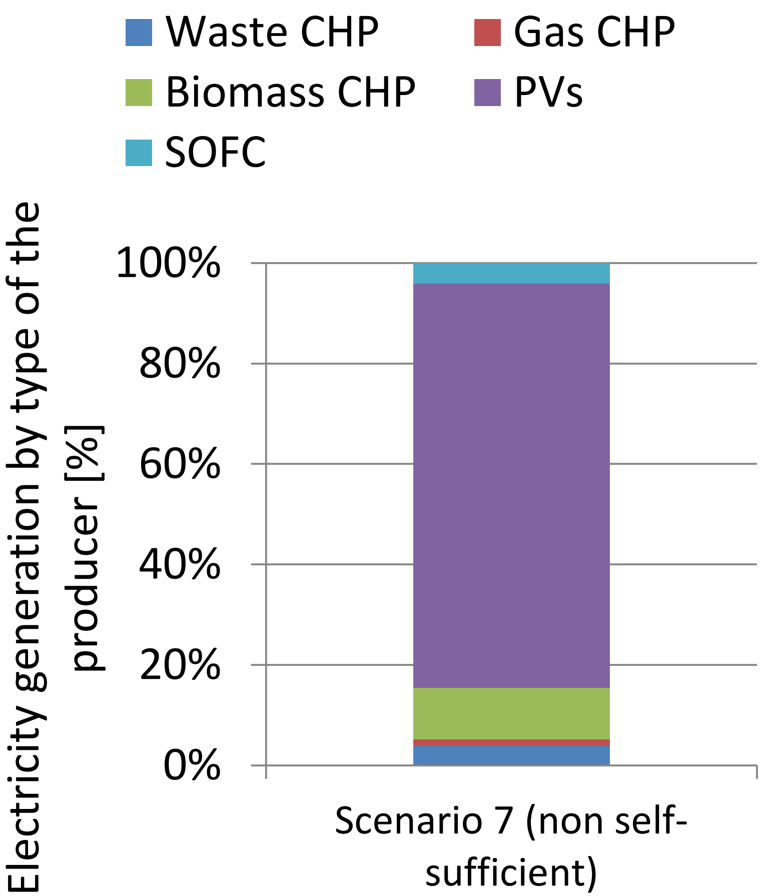
Storage capacities

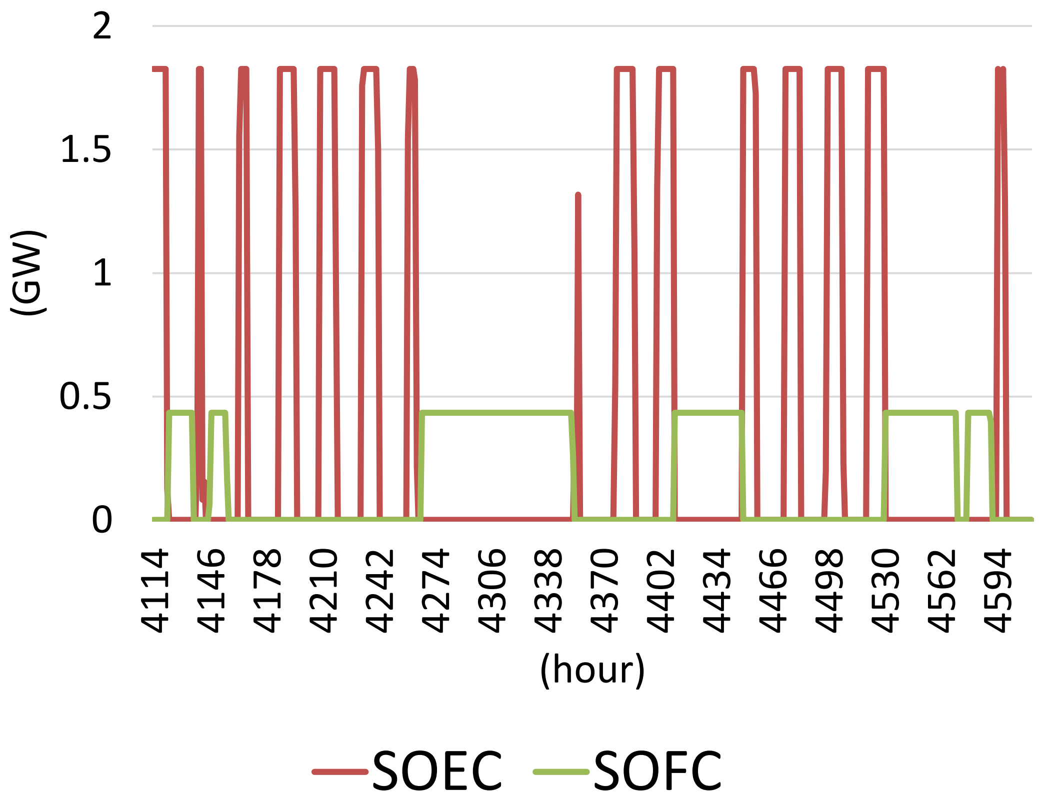


(GWh)	BAU	DC	DC-PV	DC-PV-el.transp.	DSM-EnEff	CO_2 cons.	non self-suff.
PTES	0	153	297	163	151	96	492
Grid batteries	5.9	0	0	0	0	0	20.6
Hydrogen	0	0	0	0	0	0	223
Methane	7.2	0	24.8	21.8	20.9	0	0
EV batteries	1.0	1.5	4.9	15.1	15.0	14.9	23.3

Case of Singapore: SOEC and SOFC

- Only Scenario 7 (80% share of PV in ele. generation)
- SOEC: 1,826 MW; SOFC: 434 MW (4% of final ele. demand)





V2G vs. smart charging

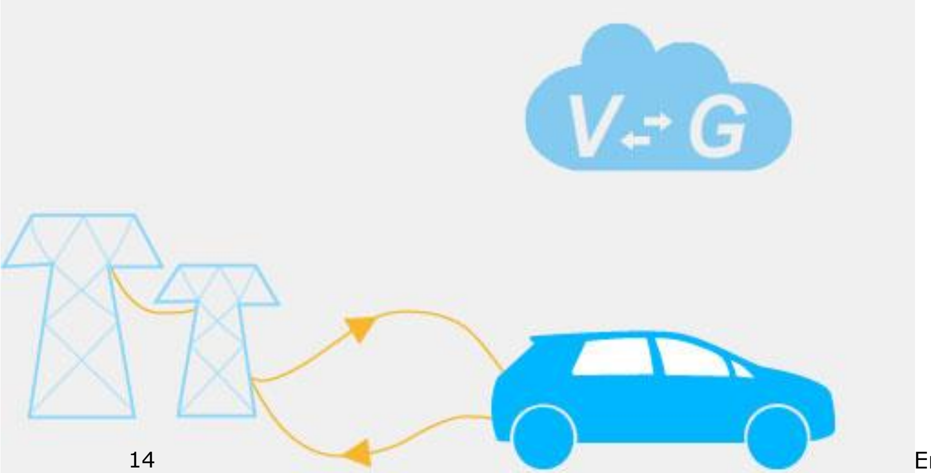
- Singapore 2030, Scenario 7: 80% PV penetration

- V2G: 16% of the total vehicle discharge
- V2G: 4% of the final electricity demand

- Curtailed energy: 4.2%

  - Other scenarios: 25%-33% PV(curtailed ele.: 0%-0.3%)

  - (V2G): 1.1% - 3.3% of the total vehicle discharge
  - Other scenarios (V2G): 0.3% - 0.7% of the total vehicle discharge

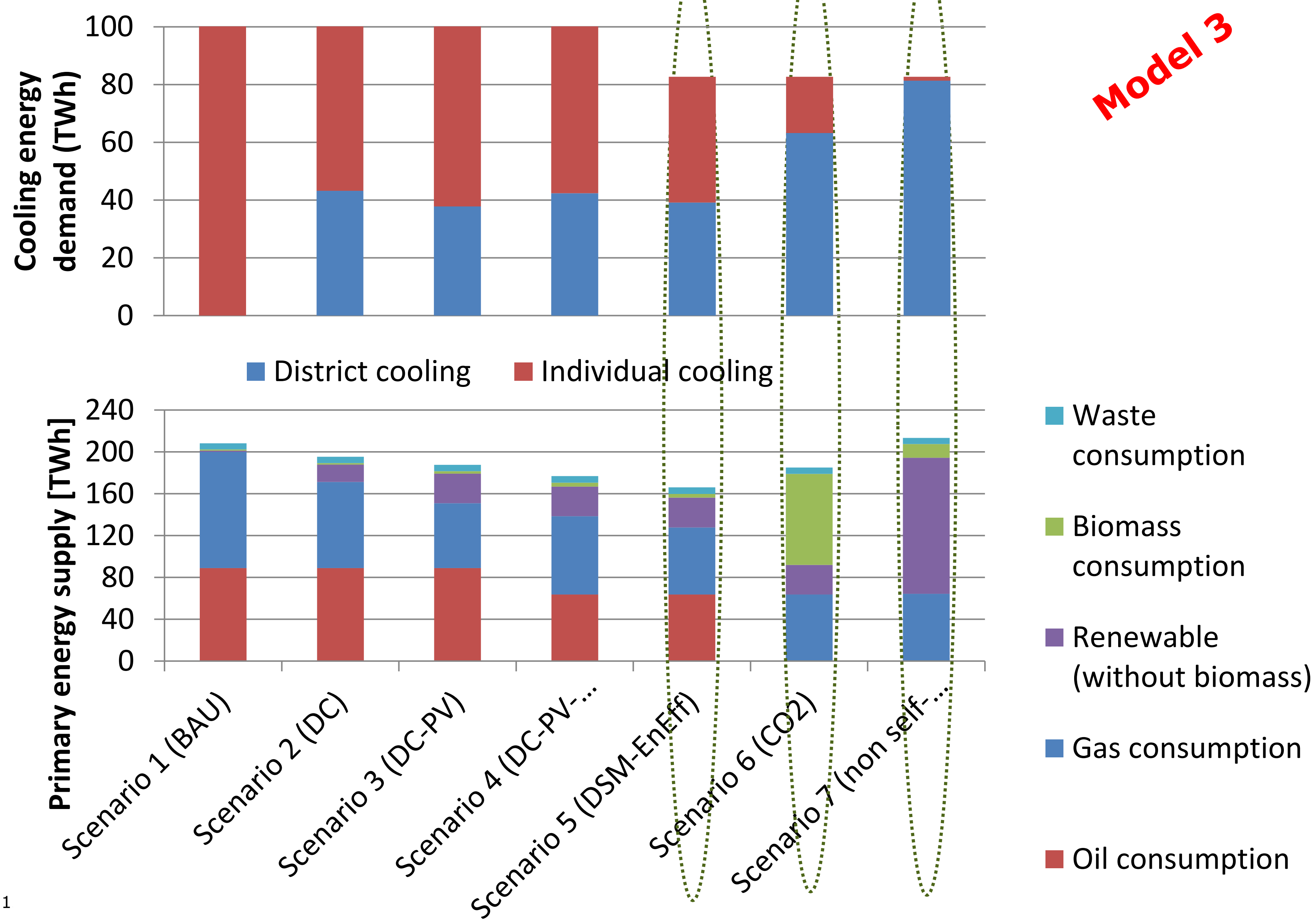


Source:wiseguyreports.com

Conclusions:

- PV *vs.* wind
- High penetration vs low penetration
- Smart charging is enough

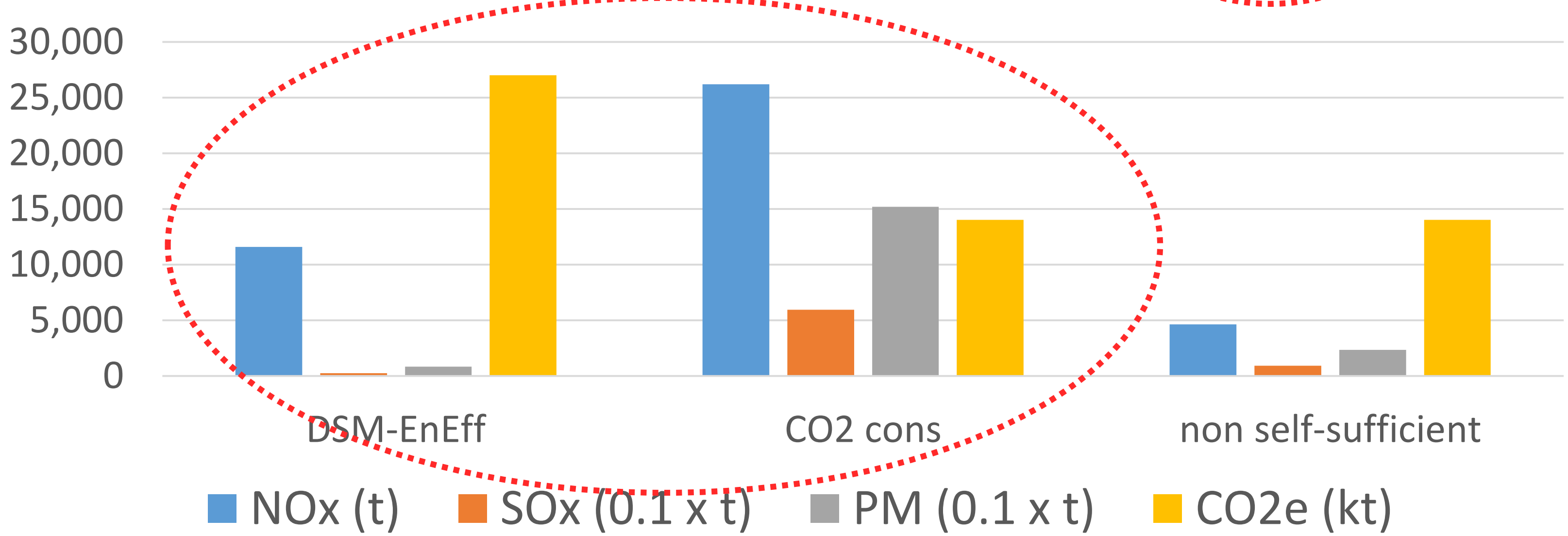
District cooling vs individual cooling vs variable renewable energy



Biomass and air pollution – the case of Singapore

Model 3

Socio-economic costs	Scenario 1 BAU	Scenario 2 DC	Scenario 3 DC-PV	Scenario 4 DC-PV-el.transp.	Scenario 5 DSM-EnEff	Scenario 6 CO_2	Scenario 7 non self-sufficient
air pollution (mil €) Local	682	674	669	31	27	63	10
CO_2e emissions (mil €) Global	910	787	700	614	568	292	294



Conclusions

1) The role of different storage types

2) Flexibility provision of industry and buildings

3) The role of district cooling: optimal capacities

4) Air pollution and renewable energy sources

Thank you!