Energy efficiency and space heating technologies

a systemic/technical/economic perspective

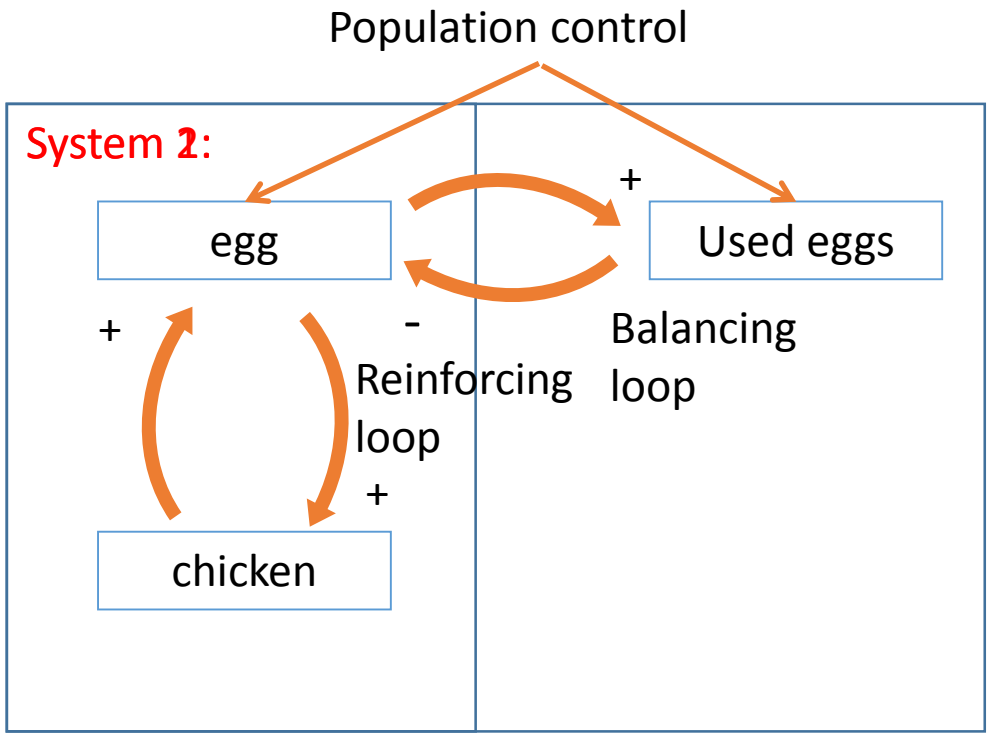
29.4

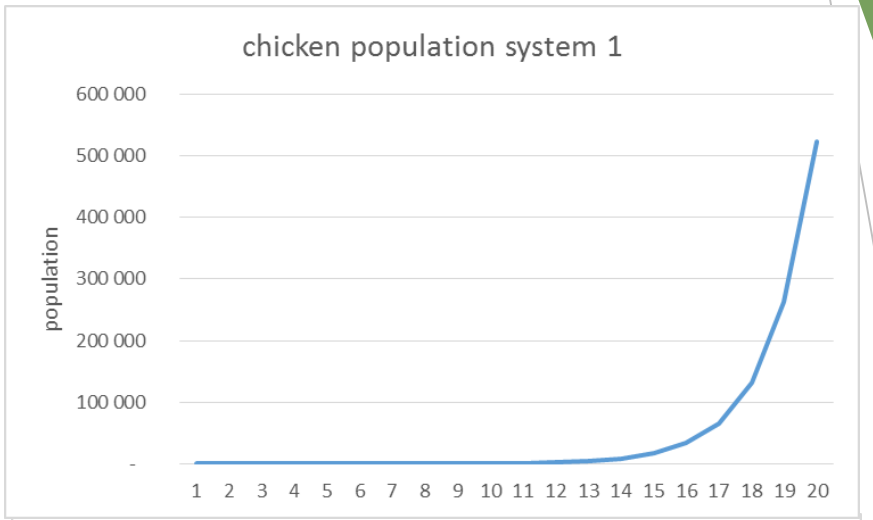
Stefan Kermer

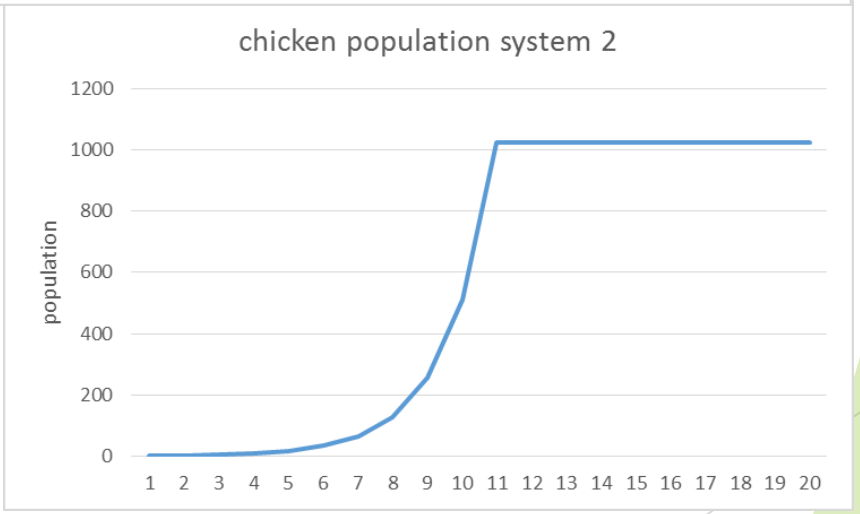
Agenda

- Introduction: a systemic perspective
- Energy conversion chains – from primary energy to energy services
  - Gas technology
  - heat pump
  - district heating
- Economic perspective: Price development (gas, electricity)

System boundaries and system behavior







Wagenaar (1978) and Wagenaar and Sagaria (1975) studied people's ability to understand exponential growth processes. They found people tend to extrapolate linearly instead of exponentially, assuming a quantity increases by the same absolute amount per time period, while exponential growth Doubles the quantity in a fixed period of time (Sterman, 2012).

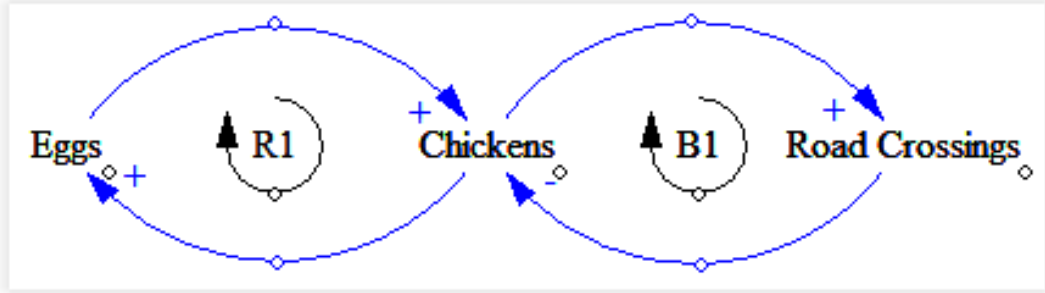
System analysis: Positive and negative feedback / System boundaries

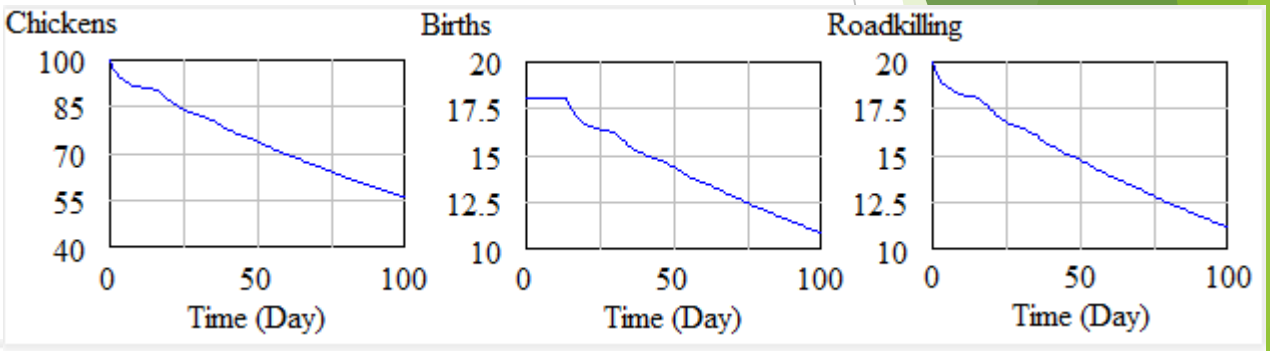
Same logic applies for energy systems

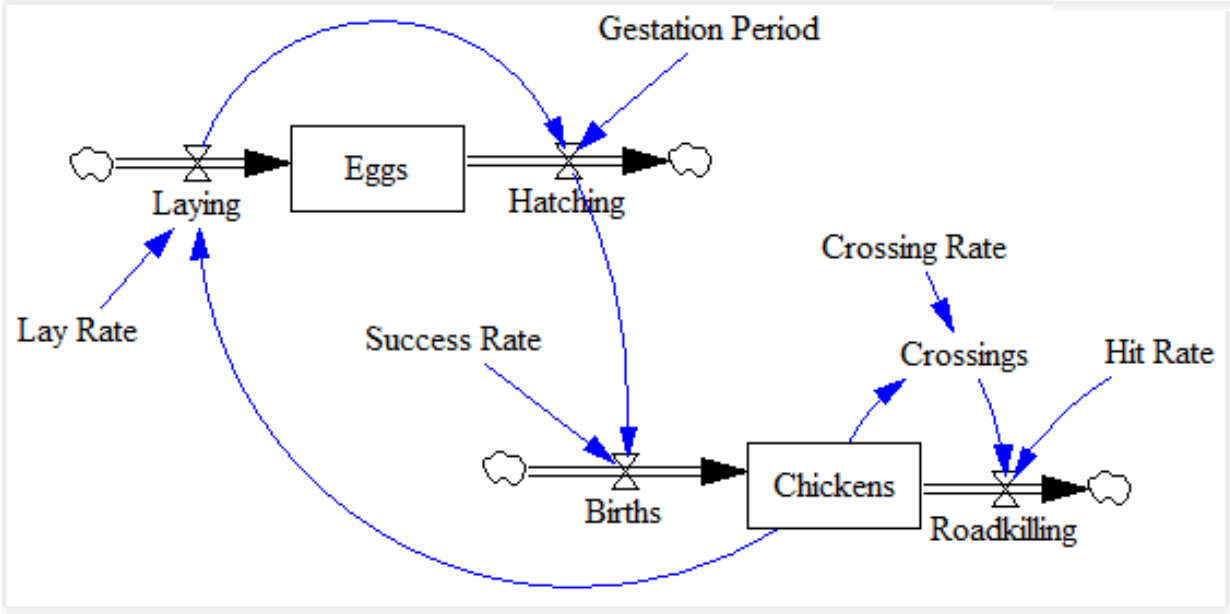
→Exogenous versus endogenous assumptions

→restrictions of the system (reserves/resources, prices, regulatory frames)

Another Explanation: Road Killings

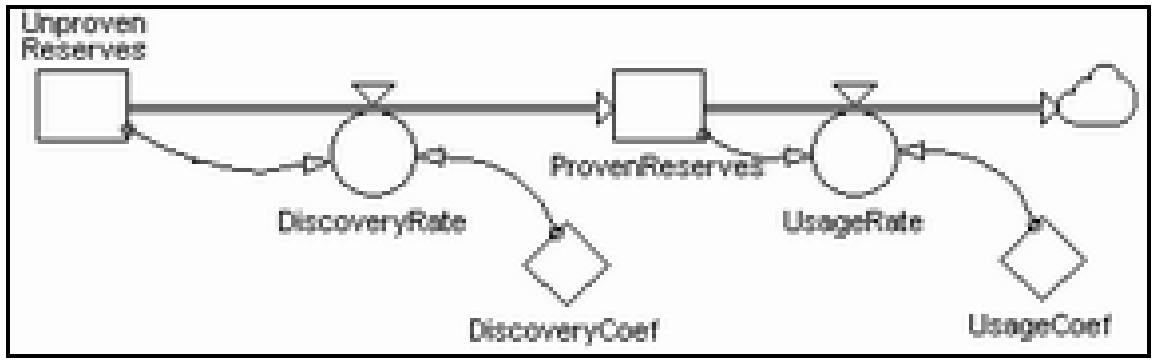


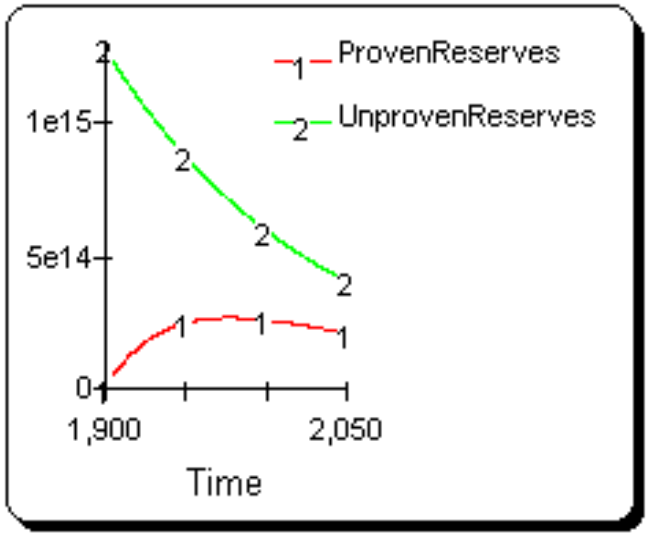


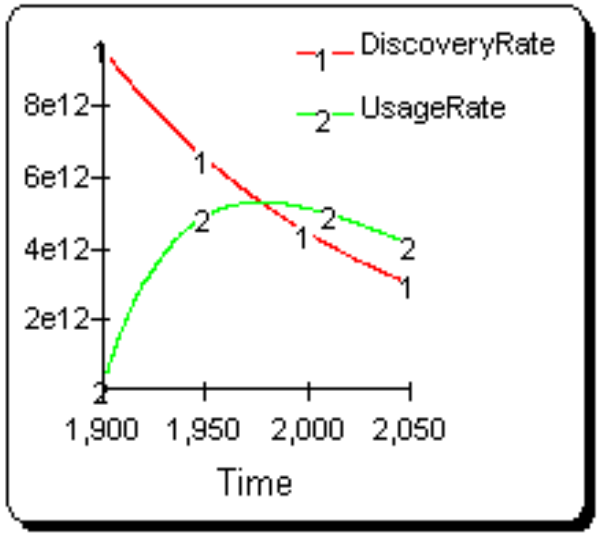


http://www.jamesphoughton.com/p/about.html

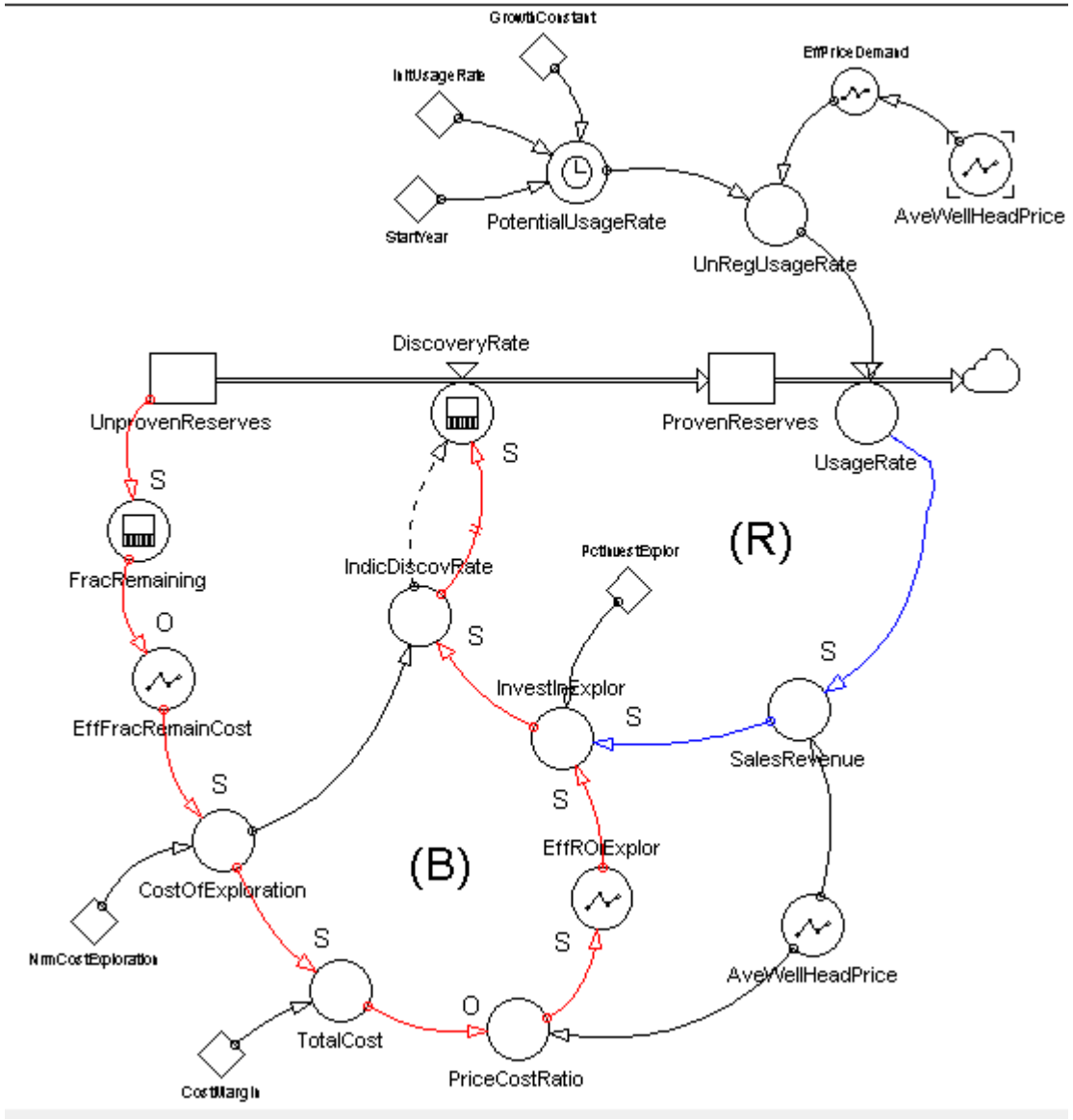
Natural Gas Development - Hubbert´s Theory by Radzicki & Taylor, 1997

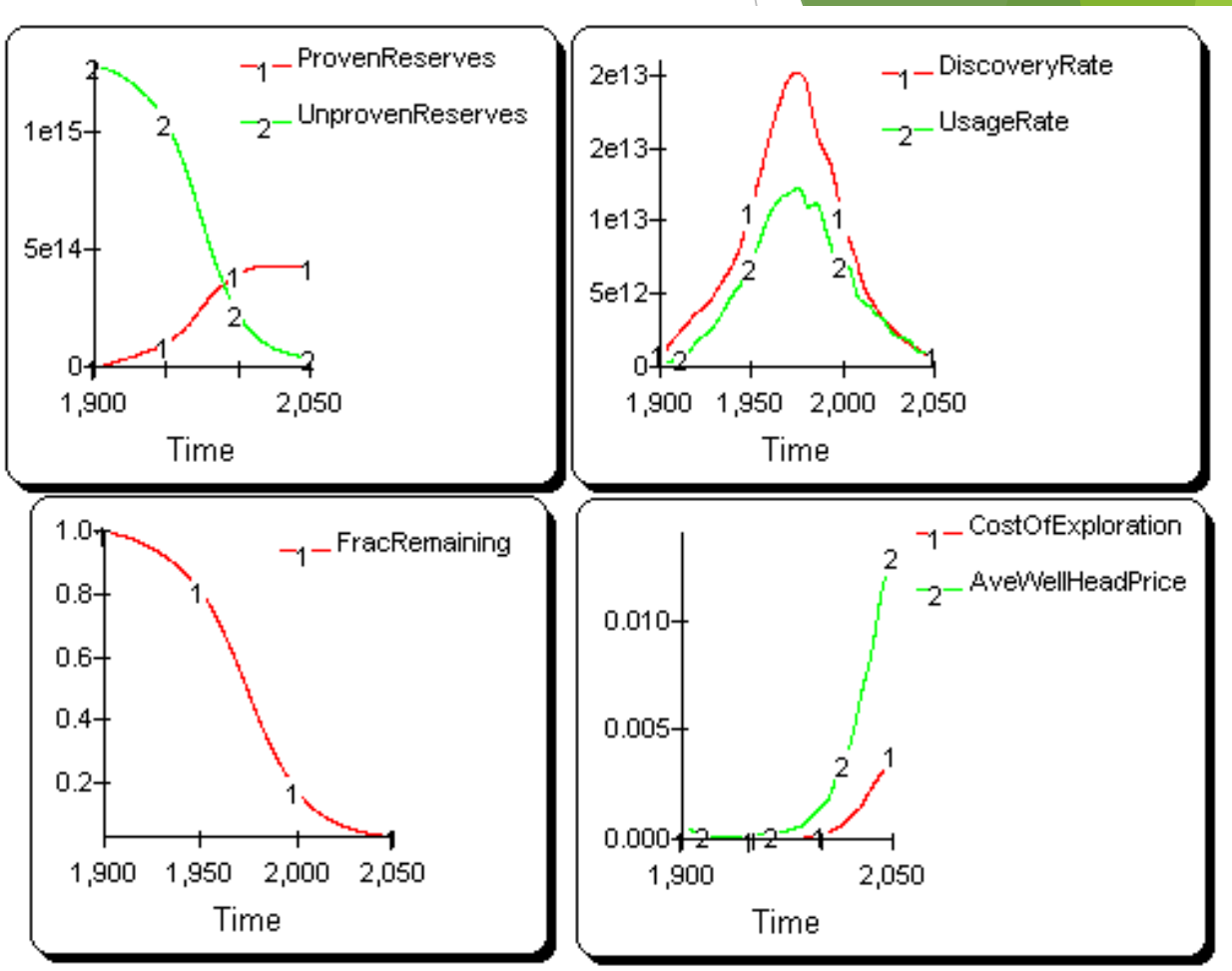




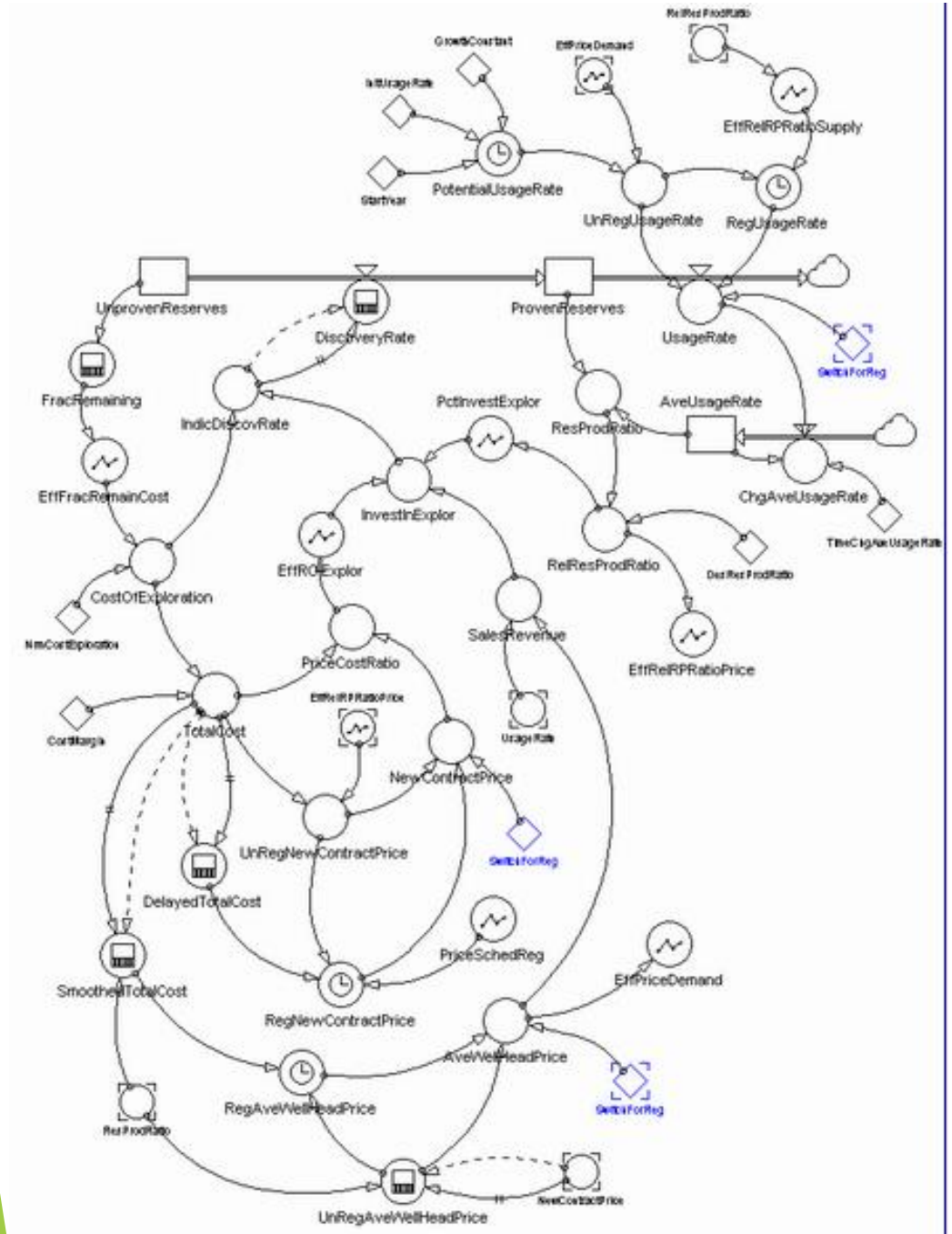


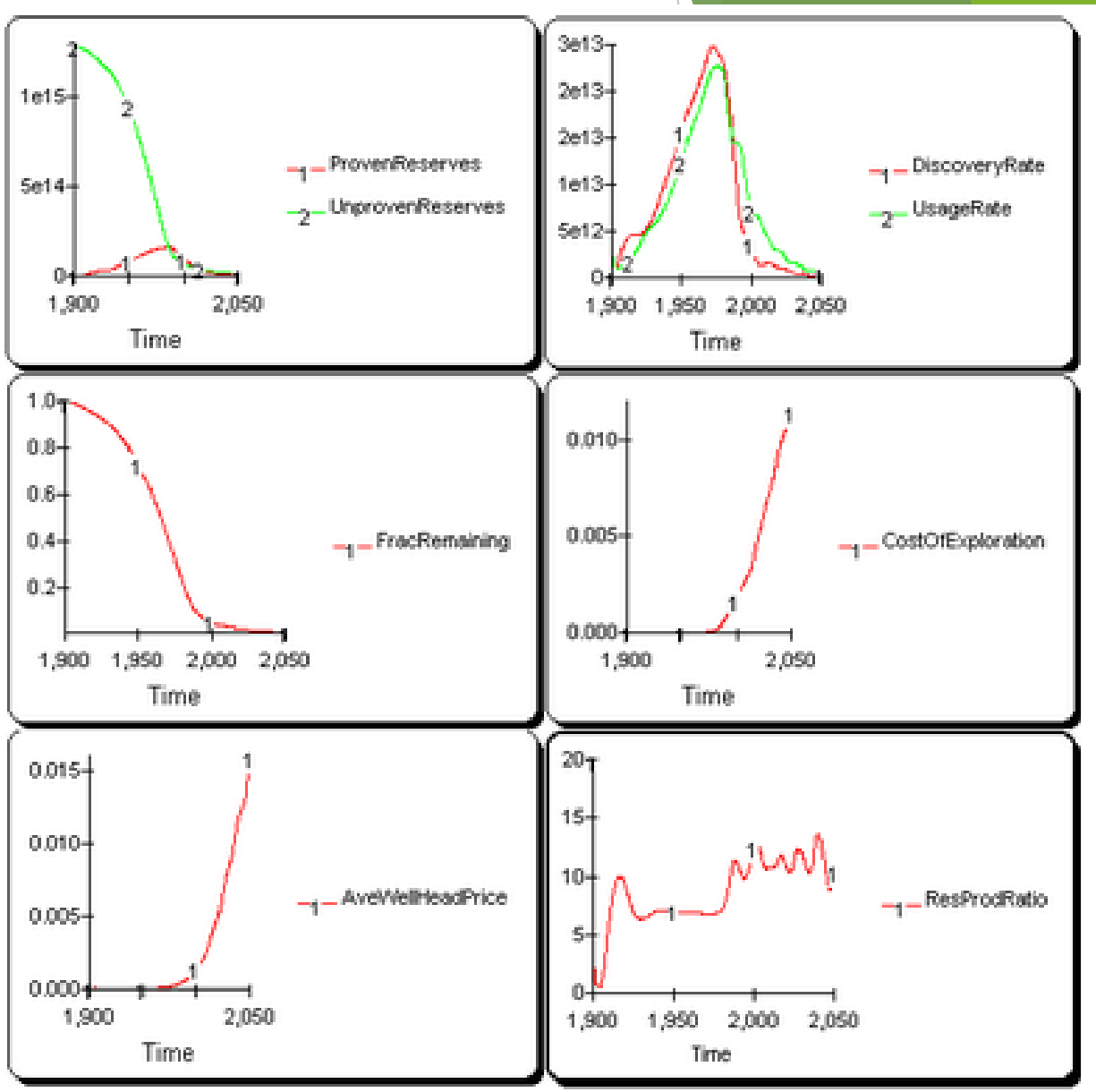
- First Cut of the model
- Development of natural gas discovery and usage





Third Cut of the model
Radzicki & Taylor, 1997

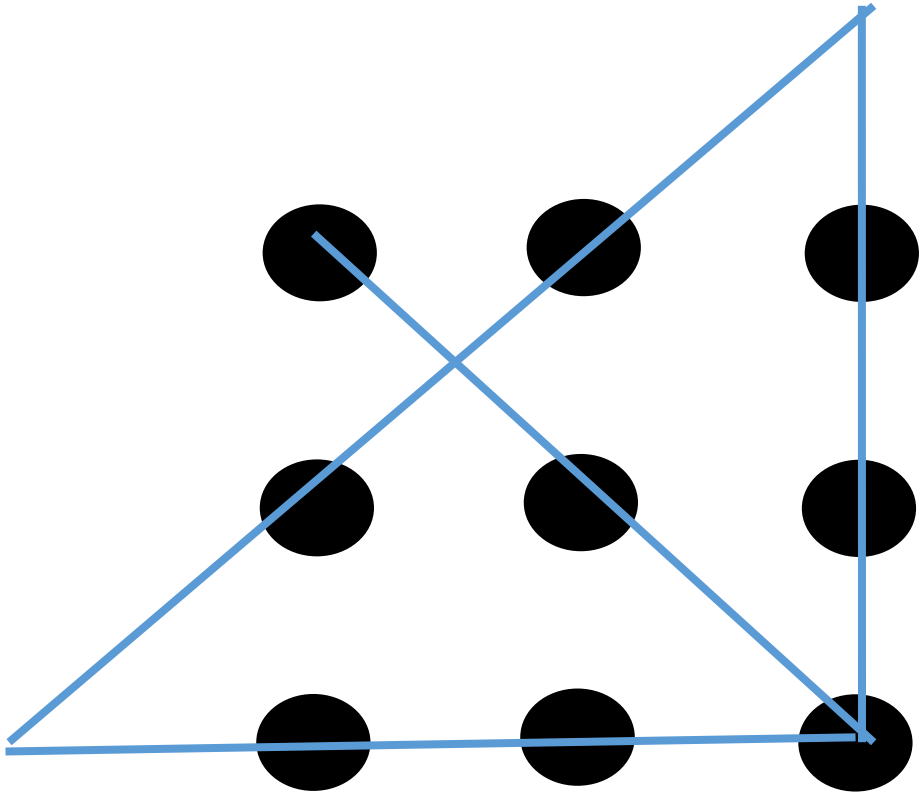




Sixt Cut of the model
Radzicki & Taylor, 1997

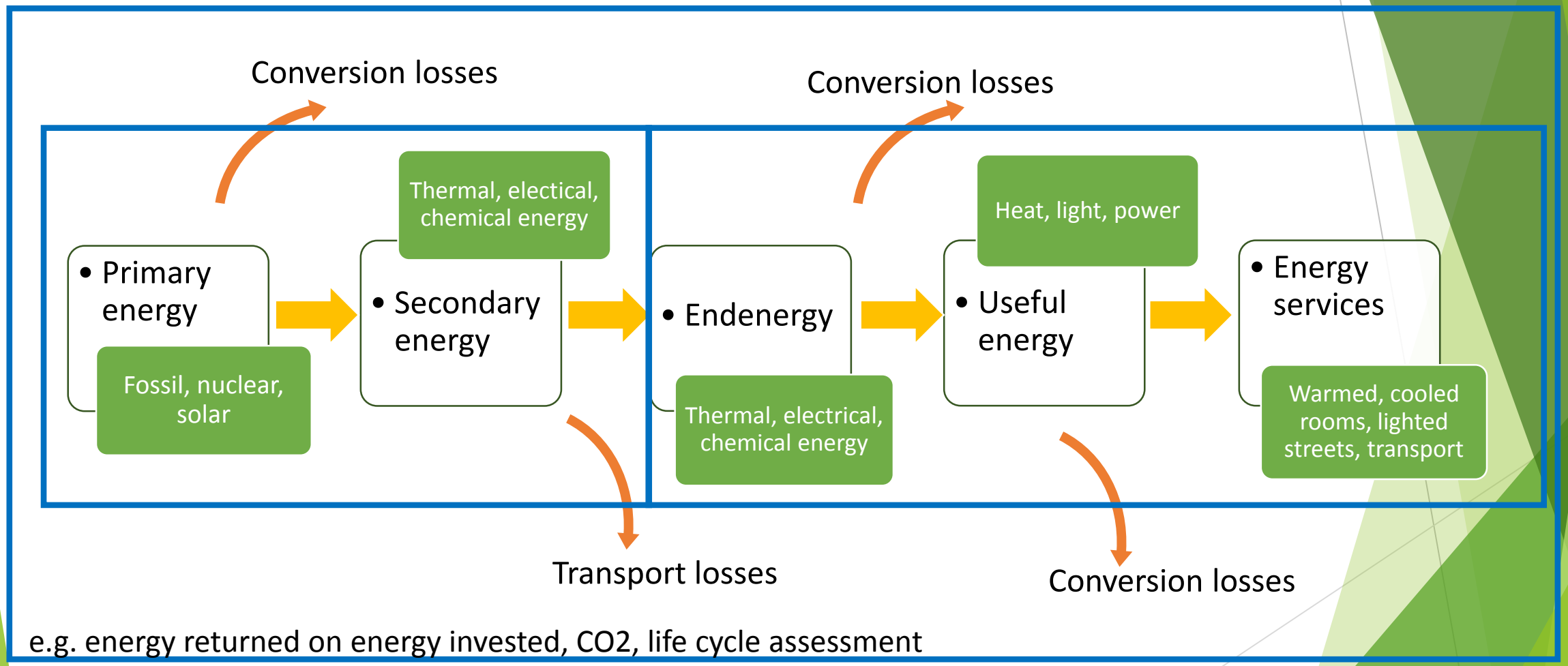
Puzzle

- Connect the dots by drawing four straight, continuous lines that pass through each of the nine dots, and never lifting the pencil from the paper.



- The setting of system boundaries lead often to our conclusions.

Energy Conversion Chain

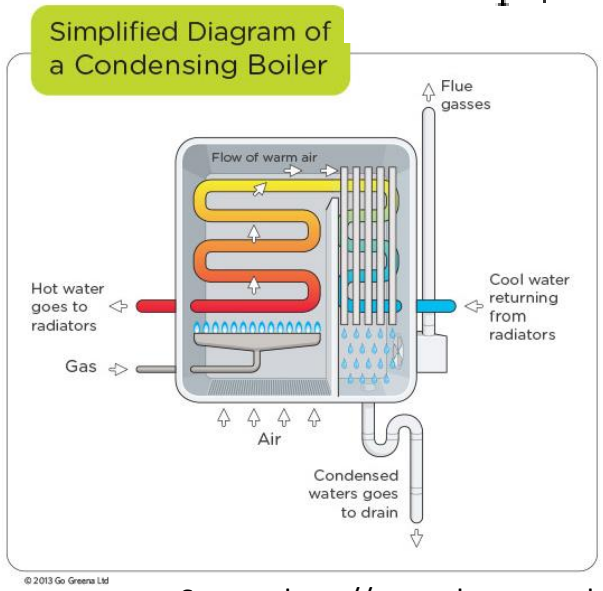


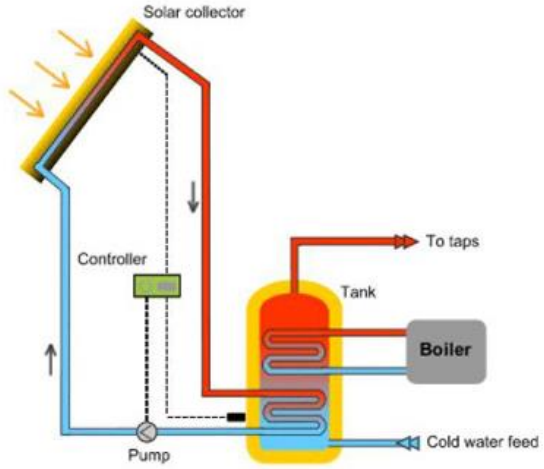
End Energy Efficiency

Modern Gas Technologies (combined with Solar)

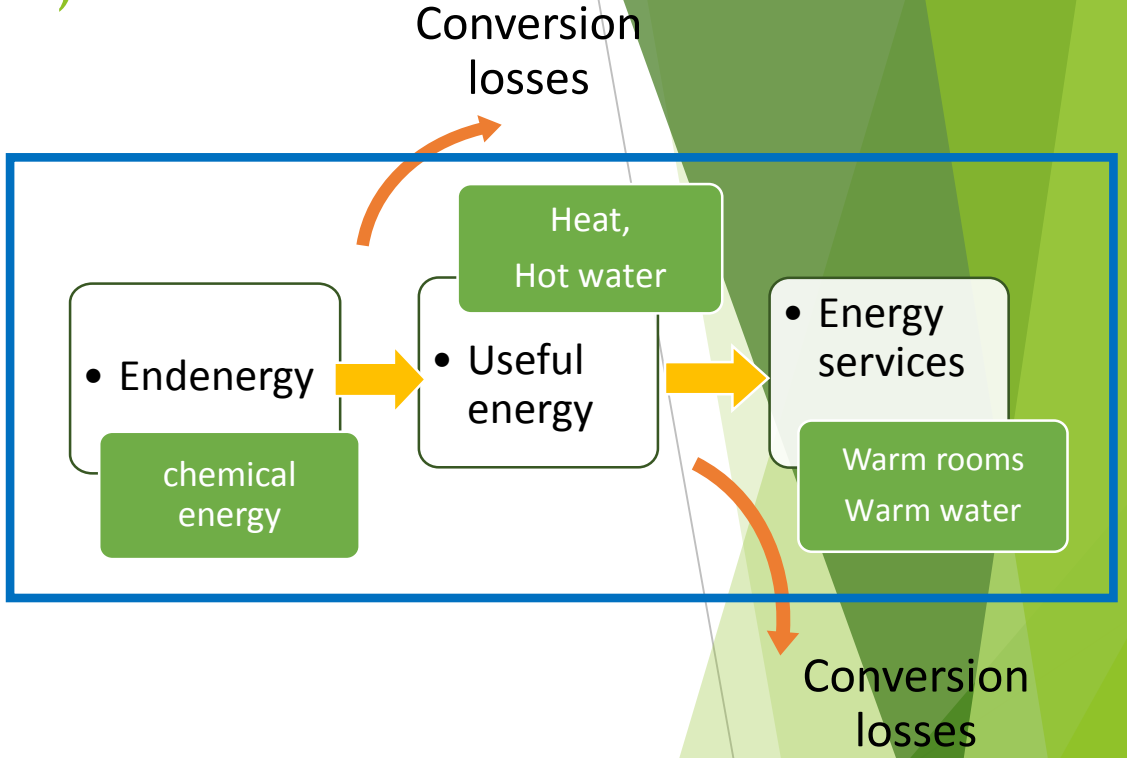
~100% efficiency

$$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$$





Source: http://www.therenewableenergycentre.co.uk/solar-heating/

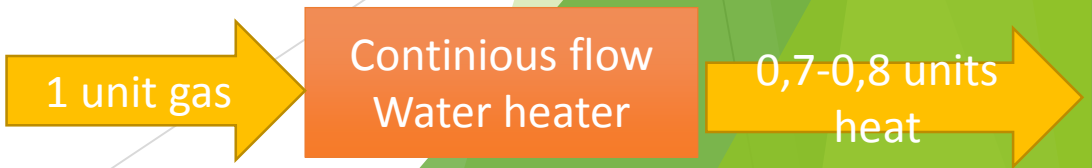


condensining boiler for spacehating, combined with storage tank and solar; or continious flow water heating

10,3 kWh/m³ versus 11,4 kWh/m³ (higher, lower heat value)

→ ~30% of low temperature heating is due to water heating

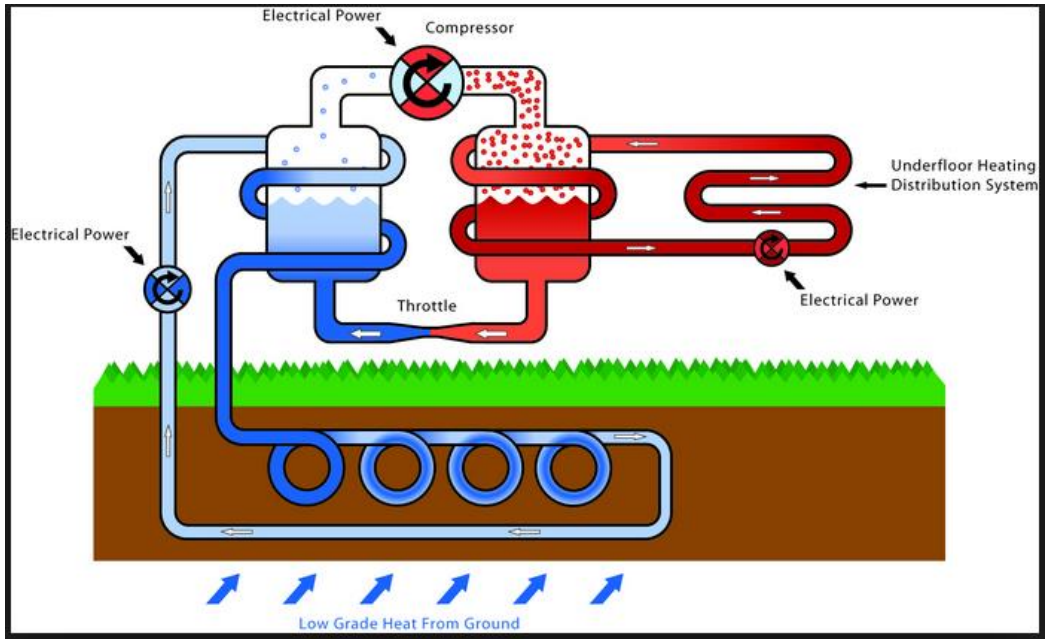
In Vienna 1m² solar panel spares 50% of the hot water production/flat.



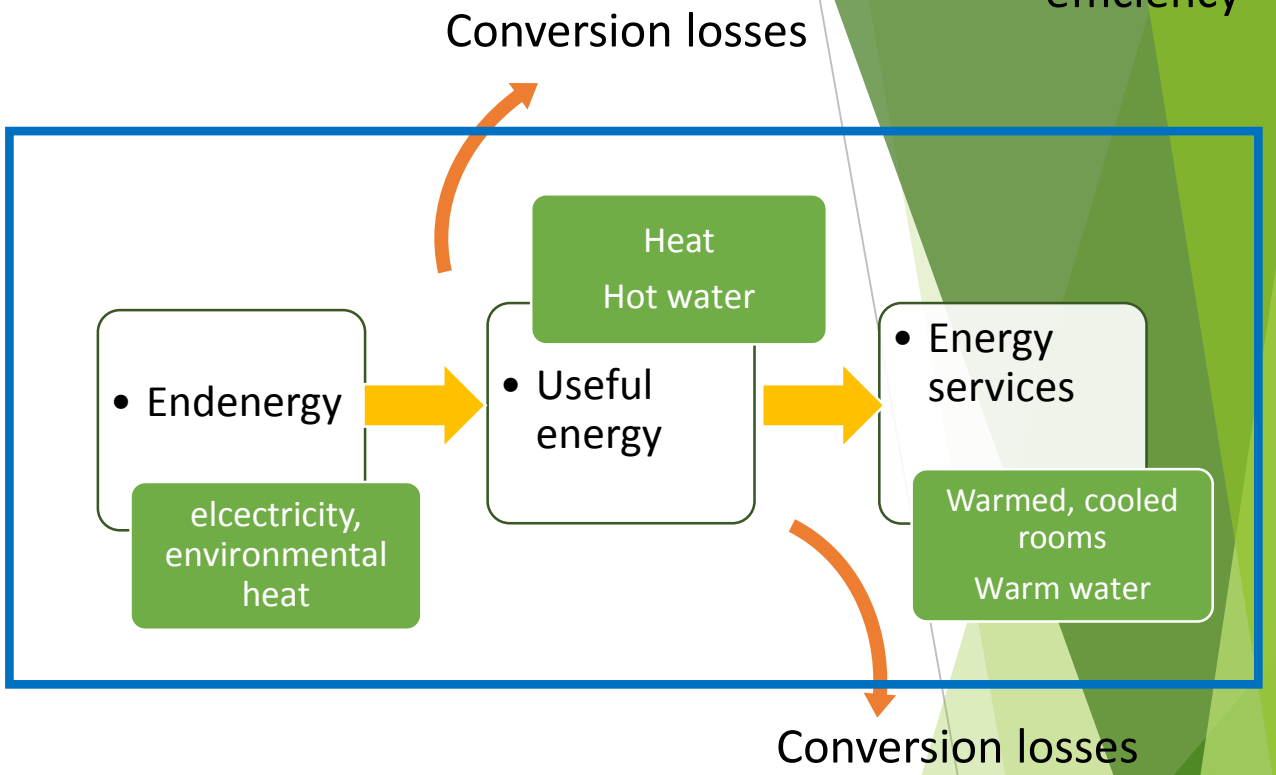
End Energy Efficiency

Heat Pumps

300-600% efficiency

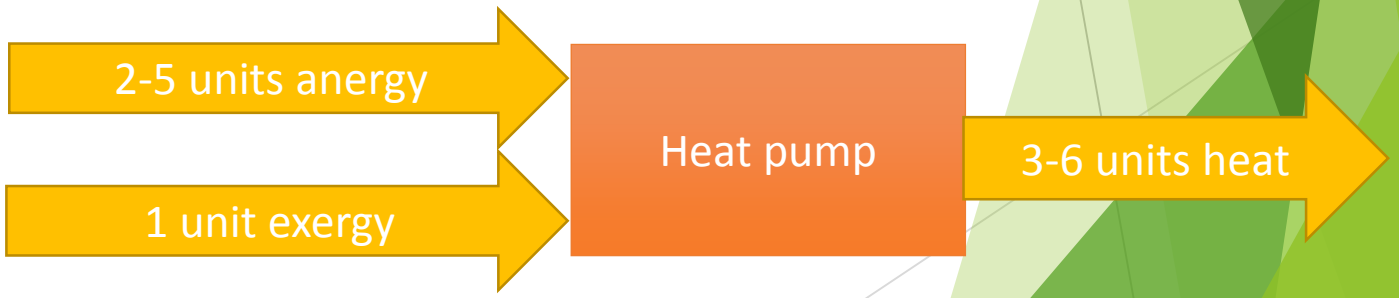


Source: http://www.moleenergy.com



3 basic types:

- Ground water heat pumps
- Ground Source heat pumps (soil, rock)
- Air source heat pumps



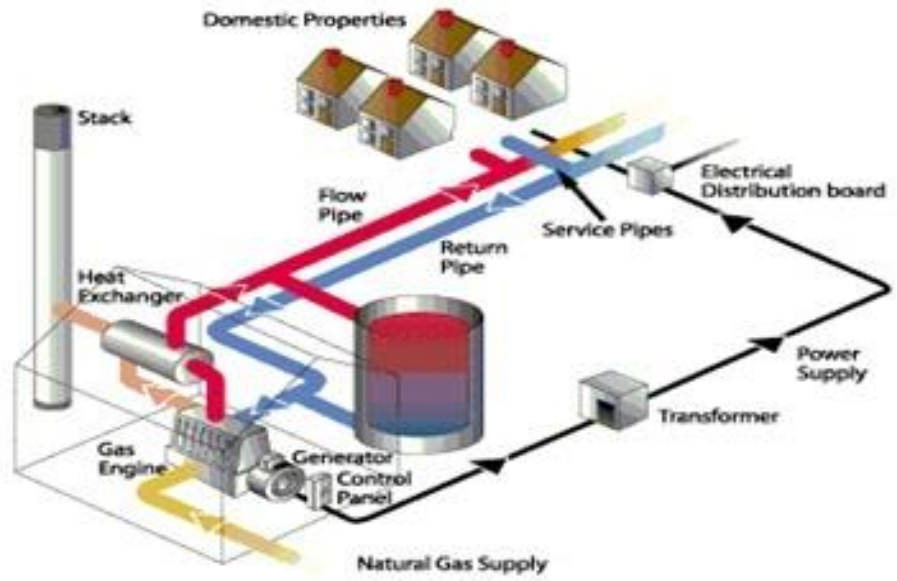
Exergy (electricity) versus anergy (low temperature heat)

→ $COP = \frac{dQ}{dP_{el}}$ coefficient of performence

COP ~ 3-6 (depending on type, temperature level, etc.)

Primary Energy Efficiency

District Heating with modern CCPP



Typical Combined Heat and Power (CHP) System

Source: blogs.worldbank.org

81 – 85% efficiency

Conversion losses (10%)

- Primary energy
  - gas, coal, nuclear, biomass, solar geothermal
- Secondary energy
  - Elcetrical and thermal energy
- Endenergy
  - Thermal, elcectrical, energy

District heating - Transport losses (5-10%)

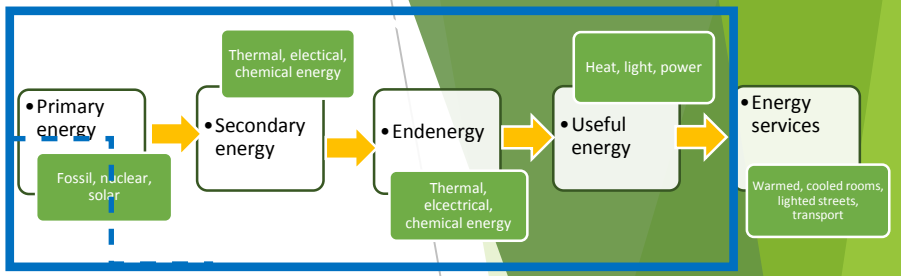
1 unit gas → Electric power plant → 0,3 -0,6 units electricity

1 unit gas → Combined cogeneration power plant → 0,5 units elect. + 0,4 units heat

Natural Gas contains ~ 10 kWh/kg energy
Lithium Ion accumulators ~ 0,2 kWh/kg energy

→ Natural gas is a valuable energy source.
It contains 50 times more energy as a Li-Ion accumulator

Interpretation



- A simplified thought experiment:

		input		production (COP=3;6; solar amount (max)= 10%=100 units)			
	Technology	efficiency	input gas [units]	electricity [units]	heat min [units]	heat max [units]	CO2
system 1:	gas condensining space heating	~1	1000		1000	1100	290
system 2:	Combined heat and power	~0,81 -0,85	1000	470	360	380	
	heat pumps (COP=4)	~3-6		470	1410	2820	
	sum		1000	0	**1770**	**3200**	**290**

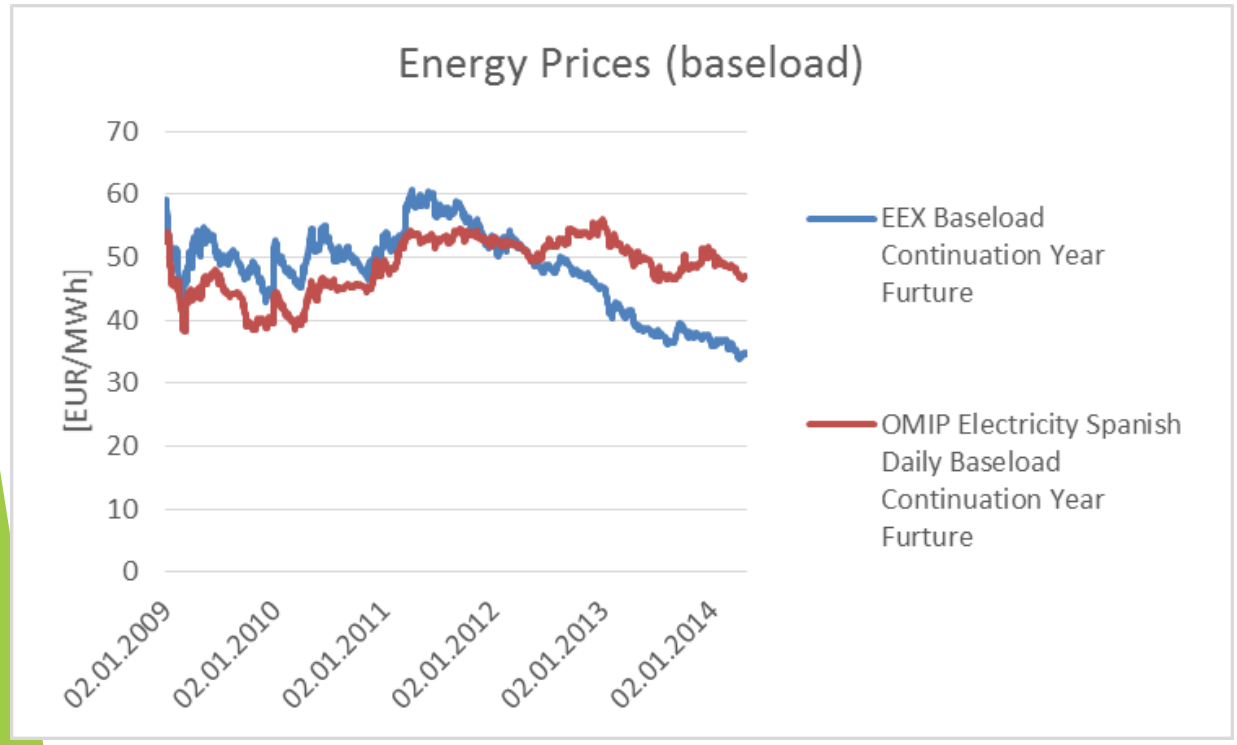
System 2: The produced electricity of the combined cogeneration power plant is used to drive the engines of the heat pumps (including 6% loss in transmission for electricity).

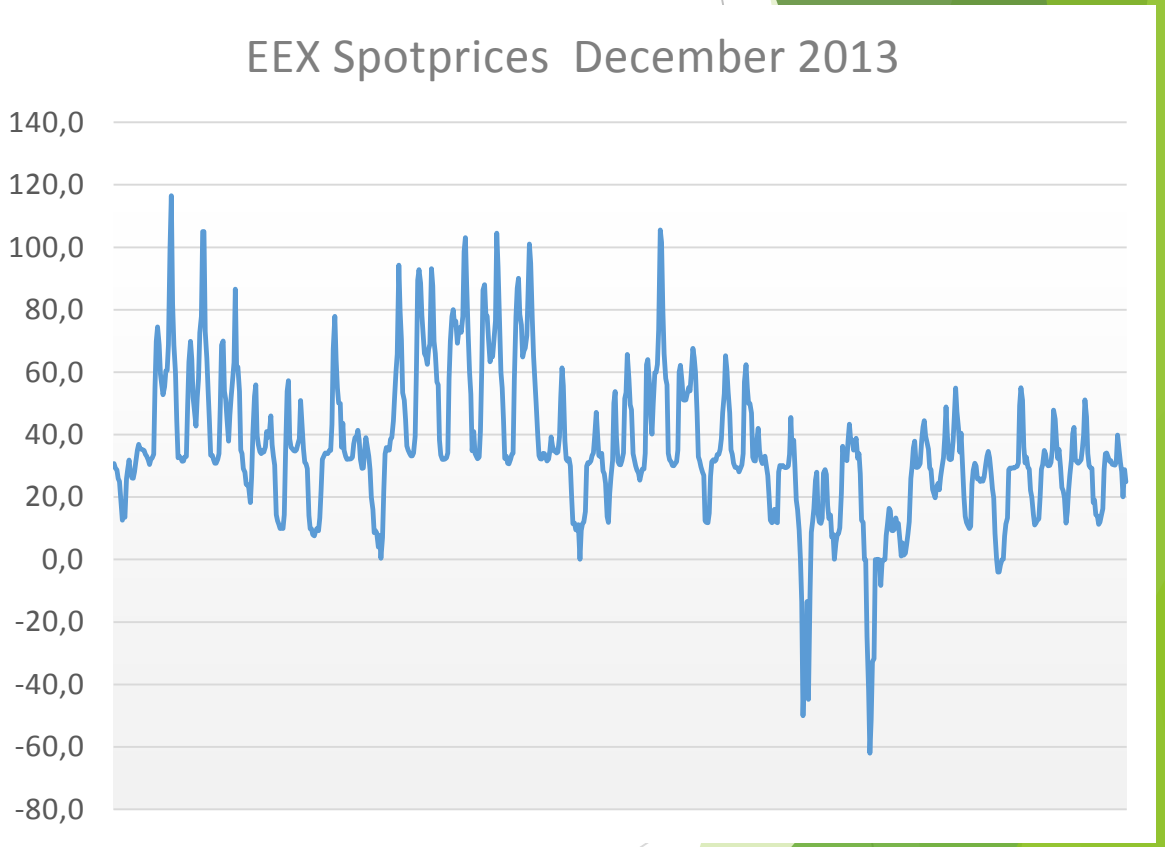
With 1000 Units gas it is possible to produce 1770– 3200 units heat.

Restrictions: how much anergy is availabe, which temperature levels is needed etc……

Economic Perspective

Price Development (European Energy Exchange)





Decreasing price development for Baseload Futures at EEX.
Base load price 35 Euro/MWh -- compared to gas price of approx. 25 Euro/MWh
Volatility of markets increase continuously – spot prices between 120 and – 60 EUR/MWh

Literature

- Radzicki & Taylor, 1997: http://www.systemdynamics.org/DL-IntroSysDyn/start.htm
- Winter, 2013: http://www.itshytime.de/hytime/Energiewandlungskette-Definitionen.pdf
- Sterman, 2012: http://jsterman.scripts.mit.edu/docs/Sterman%20Sustaining%20Sustainability%2010-2.pd