INTEGRATED ENERGY SYSTEMS

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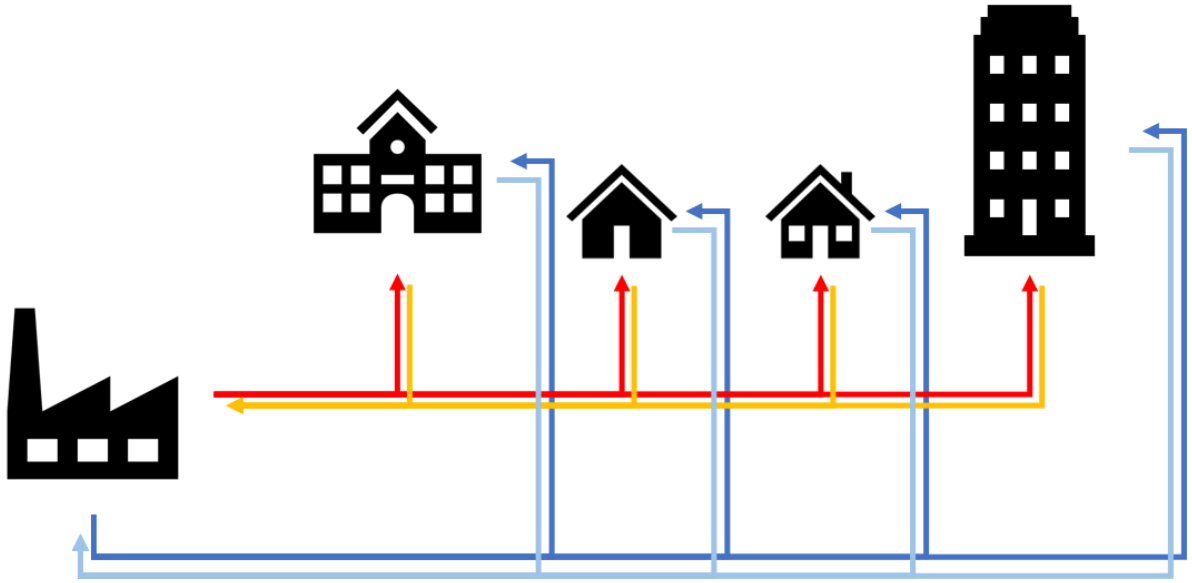
ABOUT ME

- Graduate from Universidade Federal do Parana (Brazil) in 2016.
- Undergraduate degree in Chemical Engineering with emphasis on Industrial Processes
- Worked as summer research student with Dr. Adams and Dr. Nease during academic exchange.
- Joined graduate school in 2017 integrating McMaster Advanced Control Consortium (MACC) group and currently pursuing PhD.

DISTRICT HEATING

- 1st system was built in New York in 1877 [1]
- It is widespread in Europe. Scandinavia it can cover 80-90% of the heating supply in main city area [2]
- In North America, 5,800 US cities and 112 cities in Canada [3]



(1) D.K. Baker, S.A. Sherif, Heat transfer optimization of a district heating system using search methods.
(2) Zinko H, Bøhm B, Kristjansson H, Ottosson U, Rama M, Sipila K. District heating distribution in areas with low heat demand density.
(3) Cooper L.T, Rajkovich N.B., An Evaluation of District Energy Systems in North America: Lessons Learned from Four Heating Dominated Cities in the U.S. and Canada.

DISTRICT HEATING

Pros

Lower and stable heating cost

More efficiency on fuel consumption

Reduced thermal losses*

Cons

Complicated retrofitting

Geography restriction

Restricted flexibility

- Piping
- Equipment

ELECTRICITY GENERATION AND DISTRIBUTION

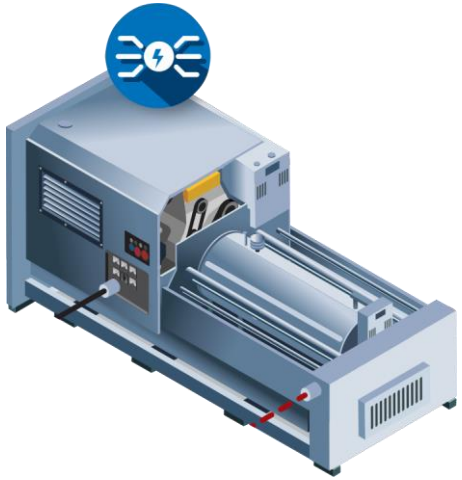
Where it is generated

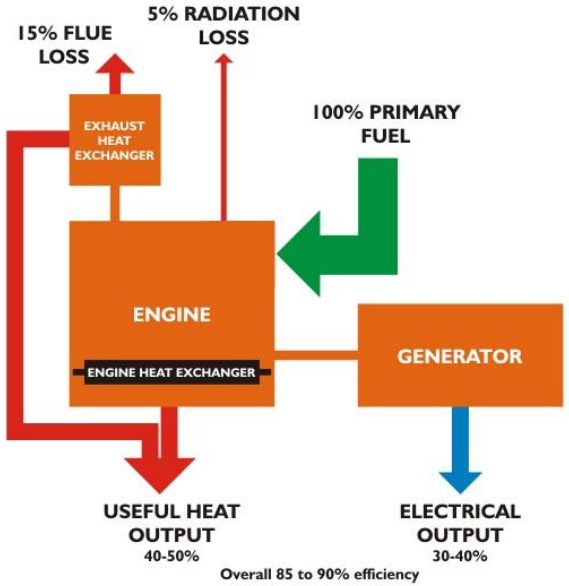
Transport losses

Source: http://www.powerlinehardware.com/

INTEGRATED COMMUNITY ENERGY (ICE)

Heat and electricity generation:
Combine Heat and Power (CHP)





Energy balance for a typical gas engine

Source: https://www.ruralenergy.co.uk/file/1305

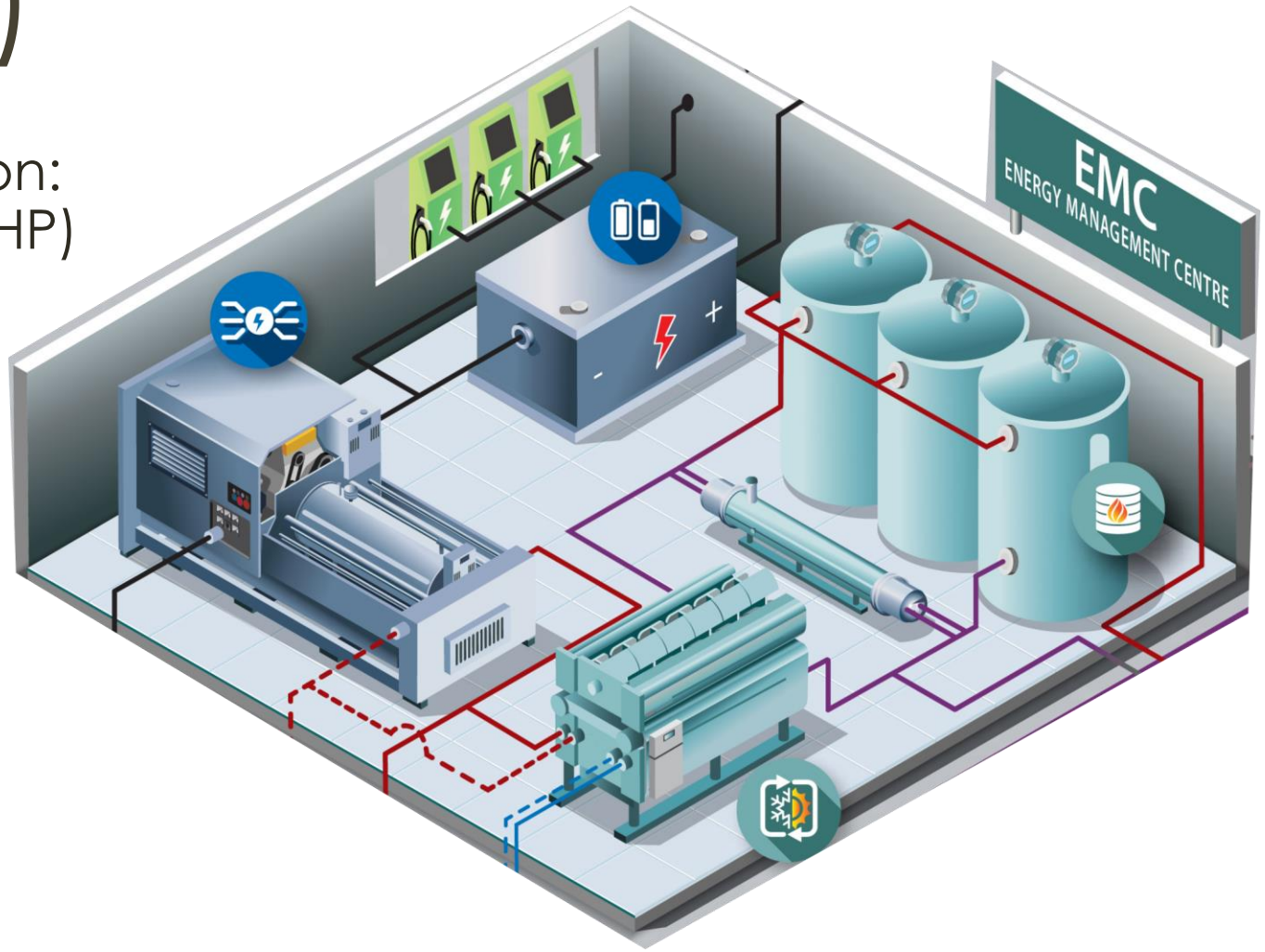
INTEGRATED COMMUNITY ENERGY (ICE)

Heat and electricity generation:
Combine Heat and Power (CHP)

- Co-generation

- Tri-generation
  - Thermal driven chillers
  - Heat pumps

$$COP = \frac{Q}{W}$$



WASTE HEAT: UNUSED RESOURCE

A commercial pizza oven has an exhaustion flowrate of $42.5\ \mathrm{m^3/min}$ and 400 ℃. Consider air properties:

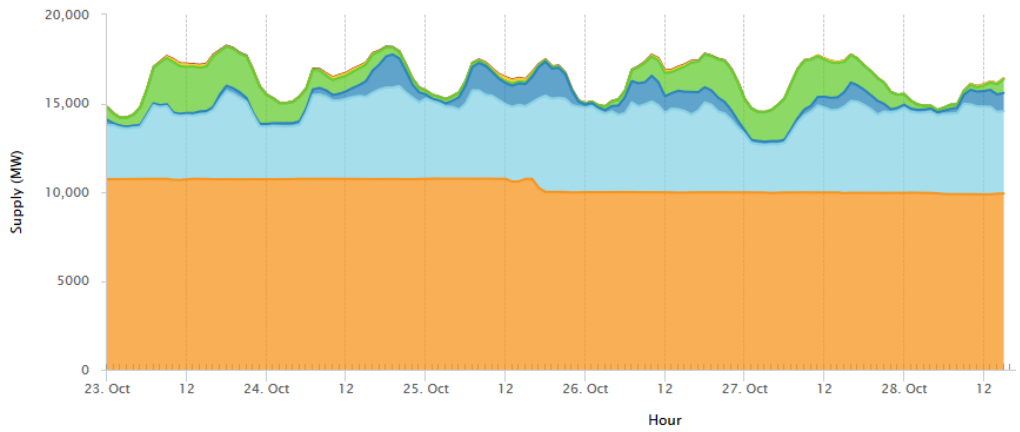
$$\mathrm{T_{amb}} = 15℃ \quad \mathrm{cp} = 1.075\,\frac{\mathrm{kJ}}{\mathrm{kg.\,K}} \quad \rho = 0.523\,\frac{\mathrm{kg}}{\mathrm{m^3}}$$

Calculate the cost per hour of NG to heat up this airflow. Consider:

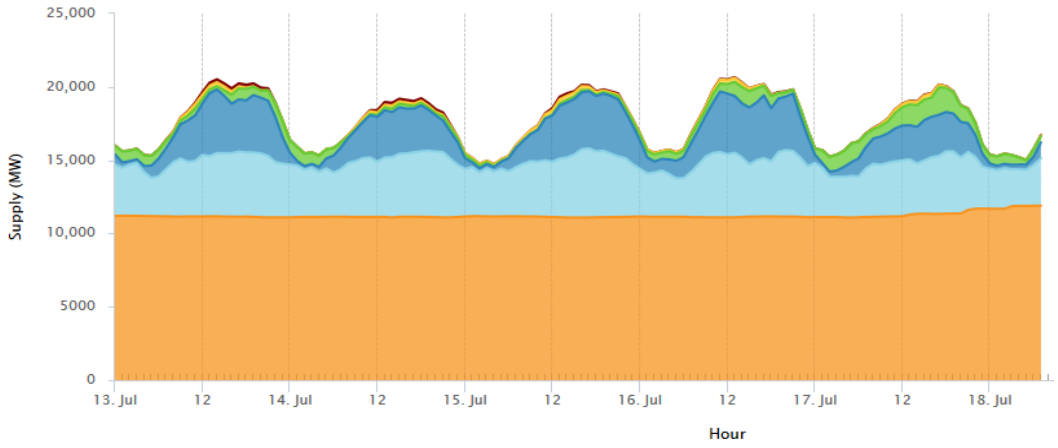
$$\eta_{\mathrm{combustion}} = 55.2\% \qquad \mathrm{NG_{price}} = \$4.00/\mathrm{GJ_{HHV}}$$

ICE – THE ROLE OF STORAGE

Fall



Summer



Today **27-29 Oct** **23-29 Oct**

Today **17-19 Jul** **13-19 Jul**

Generation By Fuel Type - Hourly

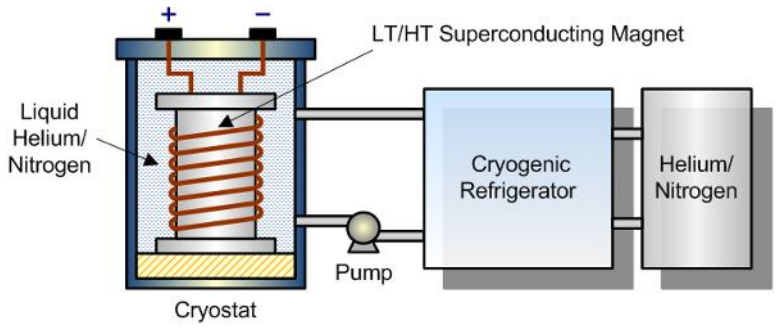
Nuclear Hydro Gas

Wind Solar Biofuel

Source: http://www.ieso.ca/power-data (2018)

STORAGE: ELECTRICAL

- Superconducting Magnetic Energy Storage (SMES)
  - Stores electrical energy directly into electric current
  - Storage efficiency: >97%



Source: http://energystoragesense.com/superconducting-magnetic-energy-storage-smes/

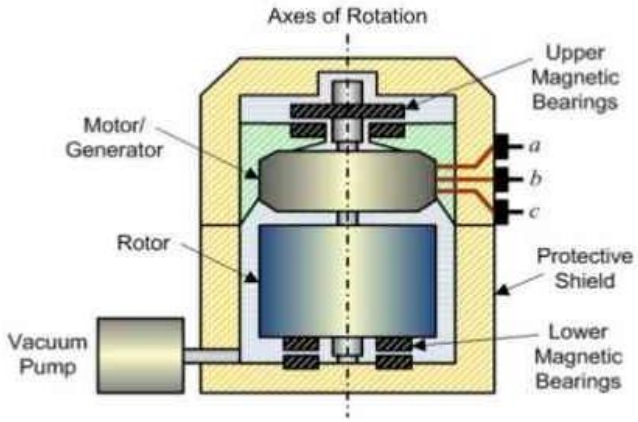
- Batteries
  - Mature technology
  - Many many types
  - Li-ion: 50% of the small portable devices market
- Fuel cells
  - Reversible fuel cell
  - Consume reactants
  - Electrodes are relatively stable
  - Many types

Chen H., Cong T. N., Yang W., Tan C., Li Y., Ding Y., Progress in electrical energy storage system: A critical review

STORAGE: ELECTRICAL

Kinetic energy

- Flywheels
  - Several hundred of thousands of fully charge/discharge cycles



Potential energy

- Compressed Air Energy Storage (CAES)
  - Conventional gas turbine
  - Peaking delivery
- Pumped Hydroelectric Storage
  - Mature technology
  - Baseload delivery

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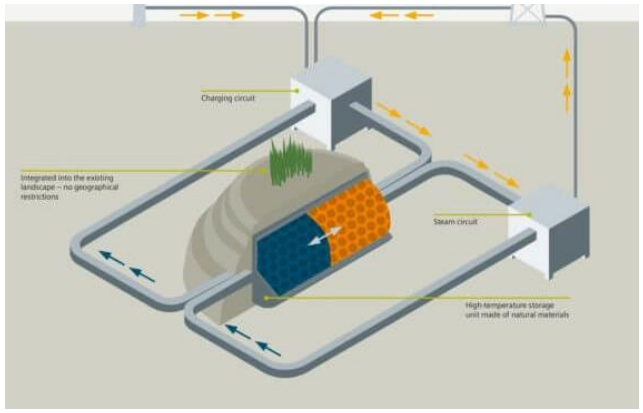
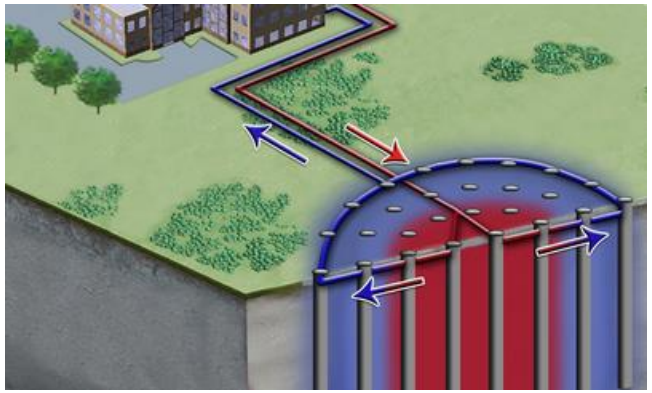
STORAGE: THERMAL

- Hot/Cold Water tanks
- Phase Changing Material (PCM)
  - Wax molten
- Geothermal storage
  - Borehole storage
  - Hot rocks



Source: https://www.windpowerengineering.com/electrical/power-storage/



Source: http://underground-energy.com/our-technology/btes/

Chen H., Cong T. N., Yang W., Tan C., Li Y., Ding Y., Progress in electrical energy storage system: A critical review