Ground Source Heat Pump Association Webinar Series 2021

Electrification of Heat

Efficiency at the Limit!

8th July 2021

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Nicolas Léonard Sadi Carnot

- Second Lieutenant & Mechanical Engineer in the French Army, Military Scientist and Physicist
- Reflections on the Motive Power of Fire (Paris,1824)
- 1st June 1796 – 24th August 1832
- The Father of Thermodynamics!

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Further Reading…

- Laws of thermodynamics – Wikipedia
- 0th Law – Defines Temperature
- 1st Law – Energy is Conserved
- 2nd Law – Disorder (Entropy) Must Increase
- 3rd Law – Defines Absolute Zero Temperature

Carnot's Theorem

- A consequence of the Second Law of Thermodynamics
- Carnot's Principle,
  "The efficiency of a quasi-static or reversible Carnot cycle depends only on the temperatures of the two heat reservoirs, and is the same, whatever the working substance. A Carnot engine operated in this way is the most efficient possible heat engine using those two temperatures."

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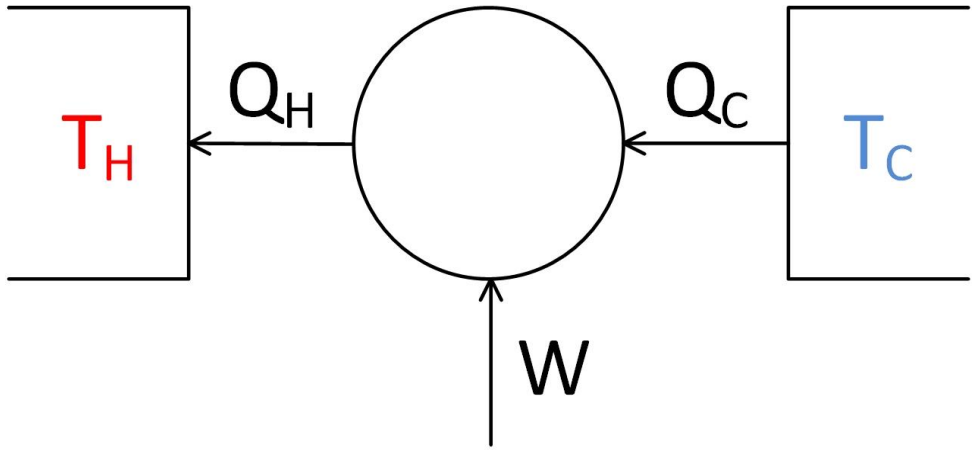
- Fine if you are studying steam turbines but what about Heat Pumps?

There IS a Maximum Efficiency!

- $\frac{T_H}{T_H - T_C} = COP_{Heating,Carnot}$
- Temperatures in Kelvin,
  - $T_{Kelvin} = T_{Celsius}$+ 273.15
  - Or we live around 300 K
- BUT we cannot achieve the Carnot Efficiency without removing all losses and friction which is impossible!
- So why are you wasting our time with this?



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It’s all about percentages…

Technology	Direct Electric	Air Source	Ground Source

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Everything above is about COP at a specific condition, not SCOP which is a different animal!

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What about Carbon then…

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SAP 10.1	136.0 g CO_2/kWh	136.0 g CO_2/kWh	136.0 g CO_2/kWh

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CO_2/kWh – Carnot	136 g CO_2	19.2 g CO_2	19.2 g CO_2
CO_2/kWh - Typical	136 g CO_2	48.6 g CO_2	35.8 g CO_2

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So why the difference between Air & Ground Source?

- Specific Heat Capacity of Air vs Water,
  - C_{pv} Air = 0.001297 $J \cdot cm^{-3}K^{-1}$
  - C_{pv} Water = 4.1796 $J \cdot cm^{-3}K^{-1}$
  - So water is 3,222 times more effective at transferring heat by volume than air
- Fans are also less efficient than water pumps,
  - Air is squidgy – water is incompressible
- We can design in the minimum ground loop temperature but not the minimum air temperature
- The humidity of air causes frosting on air coils which has to be defrosted
- Heat Recovery – Instantaneous & Inter-Seasonal

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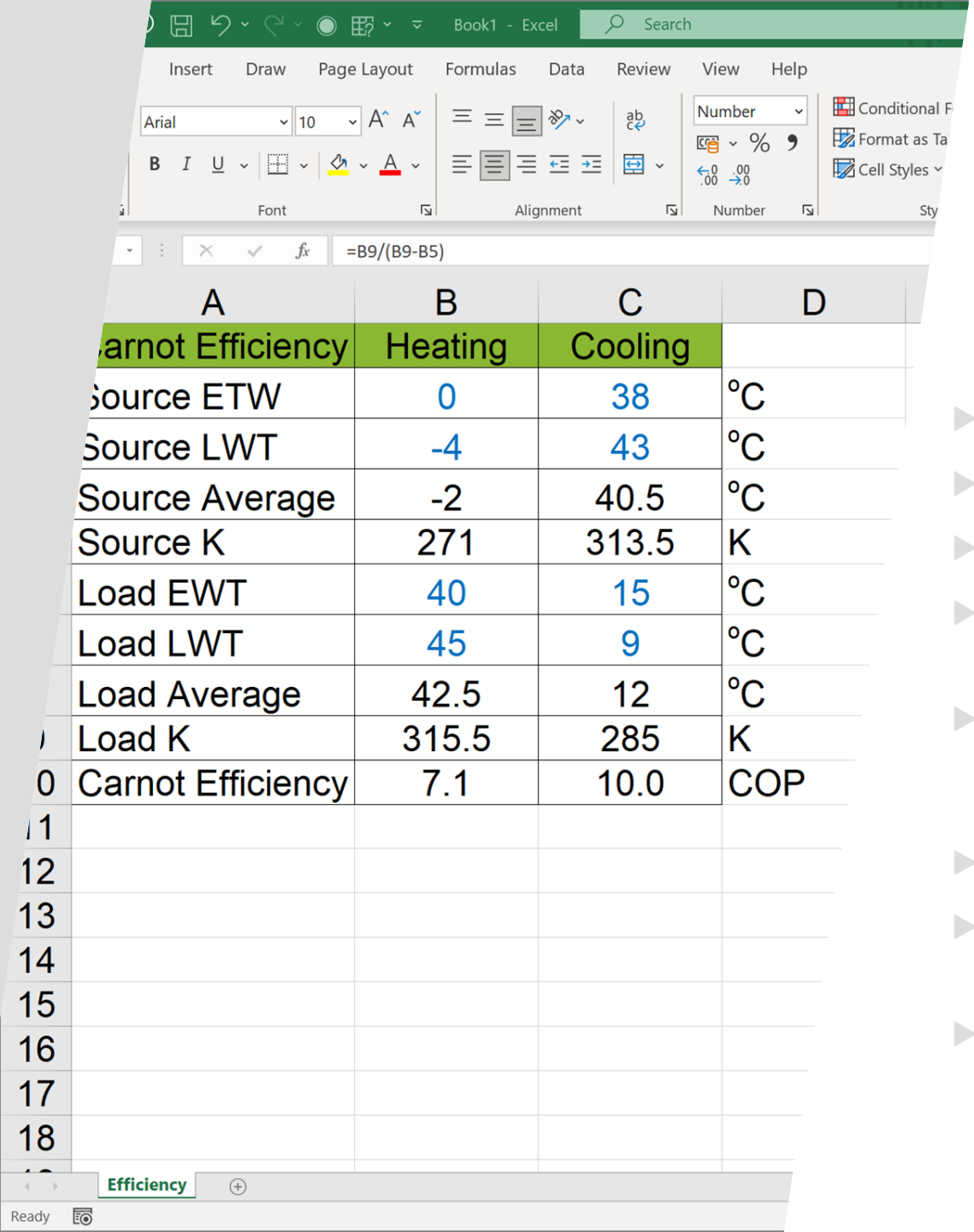

So how to rumble a "Snake Oil" Sale…

- "Our heat pumps have a COP of 6!"
- Ask at what design conditions…
- "0/45!"
- Build yourself a little spreadsheet to calculate the Carnot Efficiency…
- Calculate the percentage…

$$\frac{6.0}{7.1} = 84.5\%$$

- Really?
- With Air Source you are doing really well at 35-45%
- With Ground Source 55-65% is good

Questions…..

and thank you for listening &
thank you 2nd Lieutenant Carnot!
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