



**South Africa, Skukuza
HEFAT, July 21, 2015**

High-Quality CHP Definition, Measurement and Regulation

Aviel Verbruggen, University of Antwerp

**Energy & Environmental economics & policy, technically sound
IPCC (Intergovernmental Panel on Climate Change) 1998-2014
Latest: sustainability assessment of nuclear power (climate policy)**

www.avielverbruggen.be



CHP Definition

CHP is

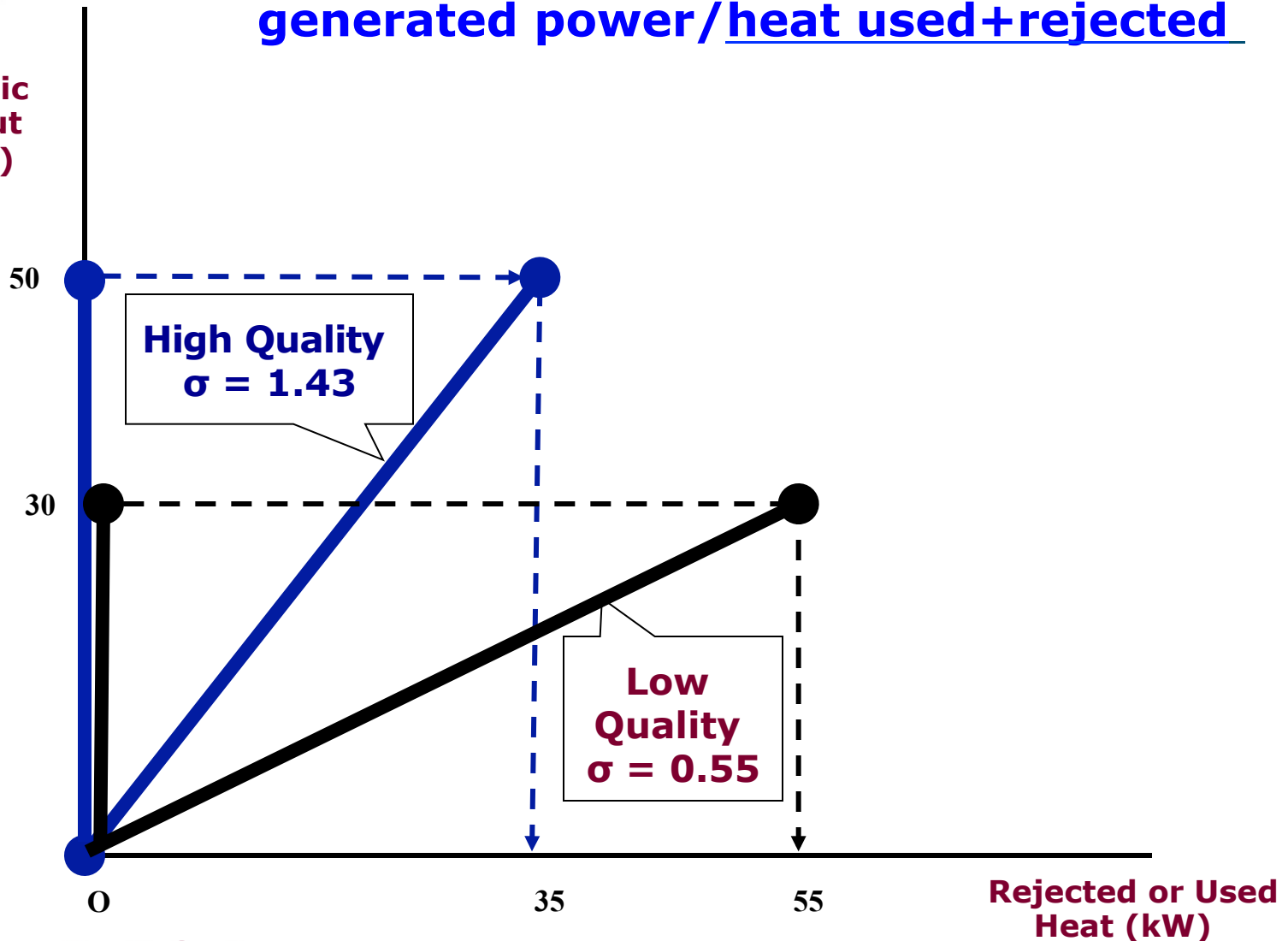
- **an Activity**
- **Added on / Embedded in a thermal power unit**
- **recovering and using**
- **all or part of**
- **Point-source heat exhausts**

i.e. CHP is (mainly) a thermal pollution mitigation activity



Quality of thermal power unit, measured by ratio $\sigma =$ generated power/heat used+rejected

Electric
output
(kW)





Quality of thermal power unit with CHP

Hierarchy

Thermal power unit

$\sum$ CHP activities [0, 1, 2, ...]

Interaction electric output – heat recovery?

If T° used heat $>$ T° of heat exhausted

β = used heat for power substitution rate
= power loss factor

CHP activity

- added on: $\beta = 0$ (gas turbines, IC Engines)
- embedded: $\beta > 0$ affects σ (steam turbines)



CHP Merit

Maximize used heat flow Q_{CHP}

(i.e. Heat recovery at thermal point-source pollution)

+

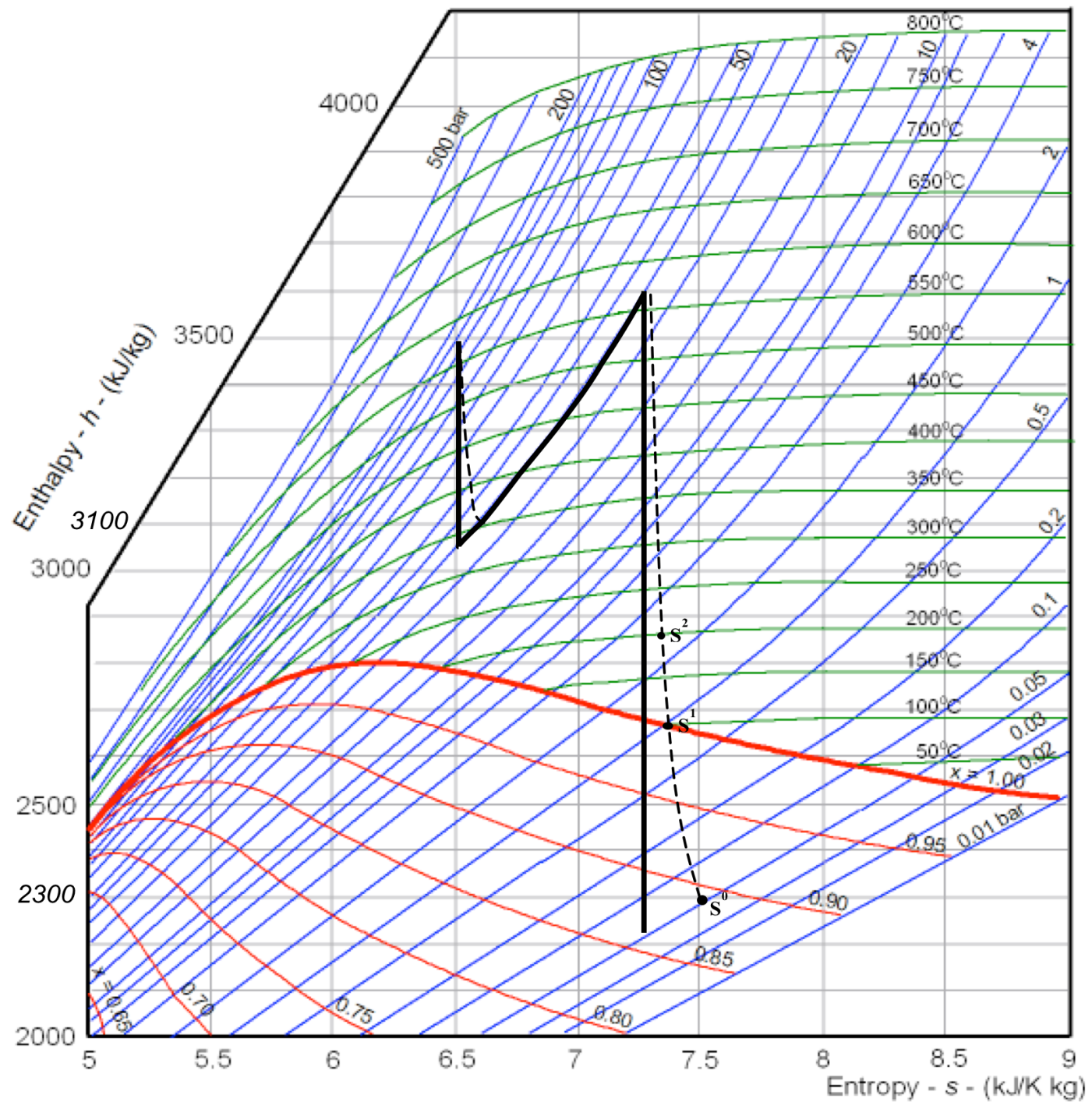
Maximize ratio σ of power cycle with CHP activity

(i.e. minimize recovery impact on power output = keep β 'as low as possible')

Merit indicator: cogenerated electricity $E_{\text{CHP}} = \sigma \cdot Q_{\text{CHP}}$

① E_{CHP} not observable when CHP activity is partial
(e.g. extraction-condensing cycles as main case)

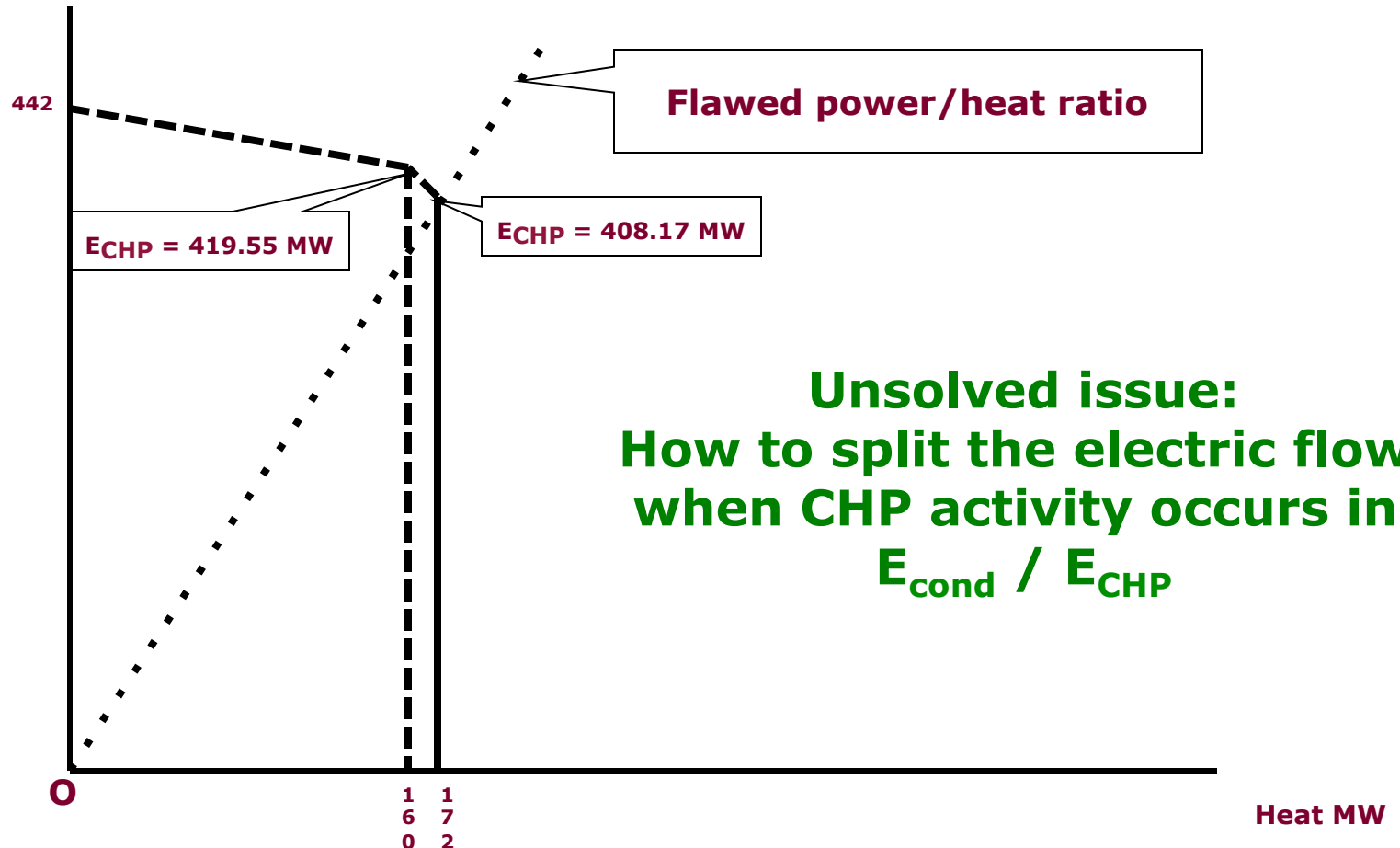
⊙ Calculate $E_{\text{CHP}} = \text{measured flow } Q_{\text{CHP}} \times \sigma \text{ of specific CHP activity}$





Power and Heat generation capacities (MW) of an Extraction-condensing steam turbine: total mass flow = 260 kg/s with a maximum 60kg/s extraction over both hot condensers

Electricity MW

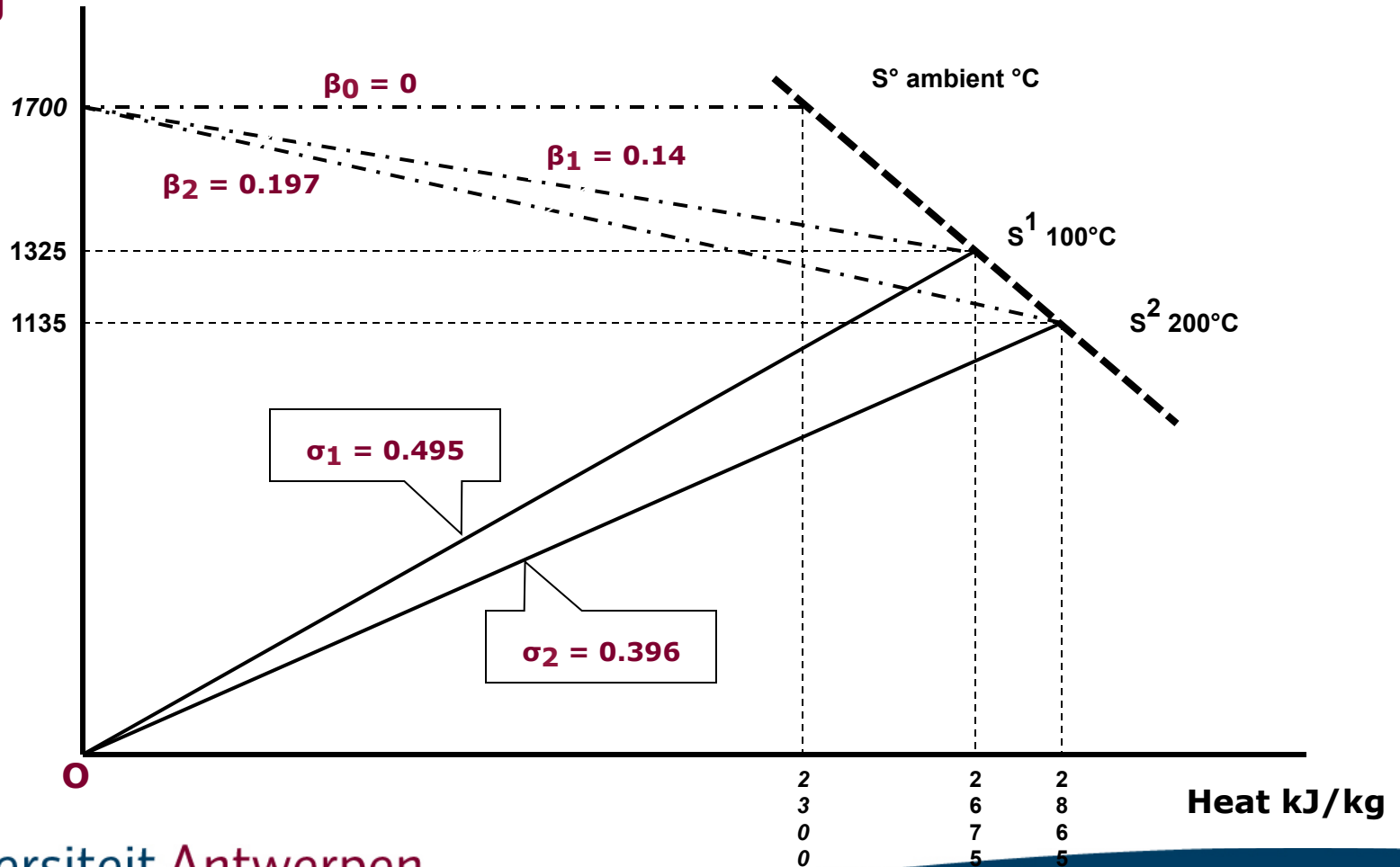


Unsolved issue:
How to split the electric flow
when CHP activity occurs in
 E_{cond} / E_{CHP}



Unit mass analysis of extraction-condensing steam turbine with two CHP activities

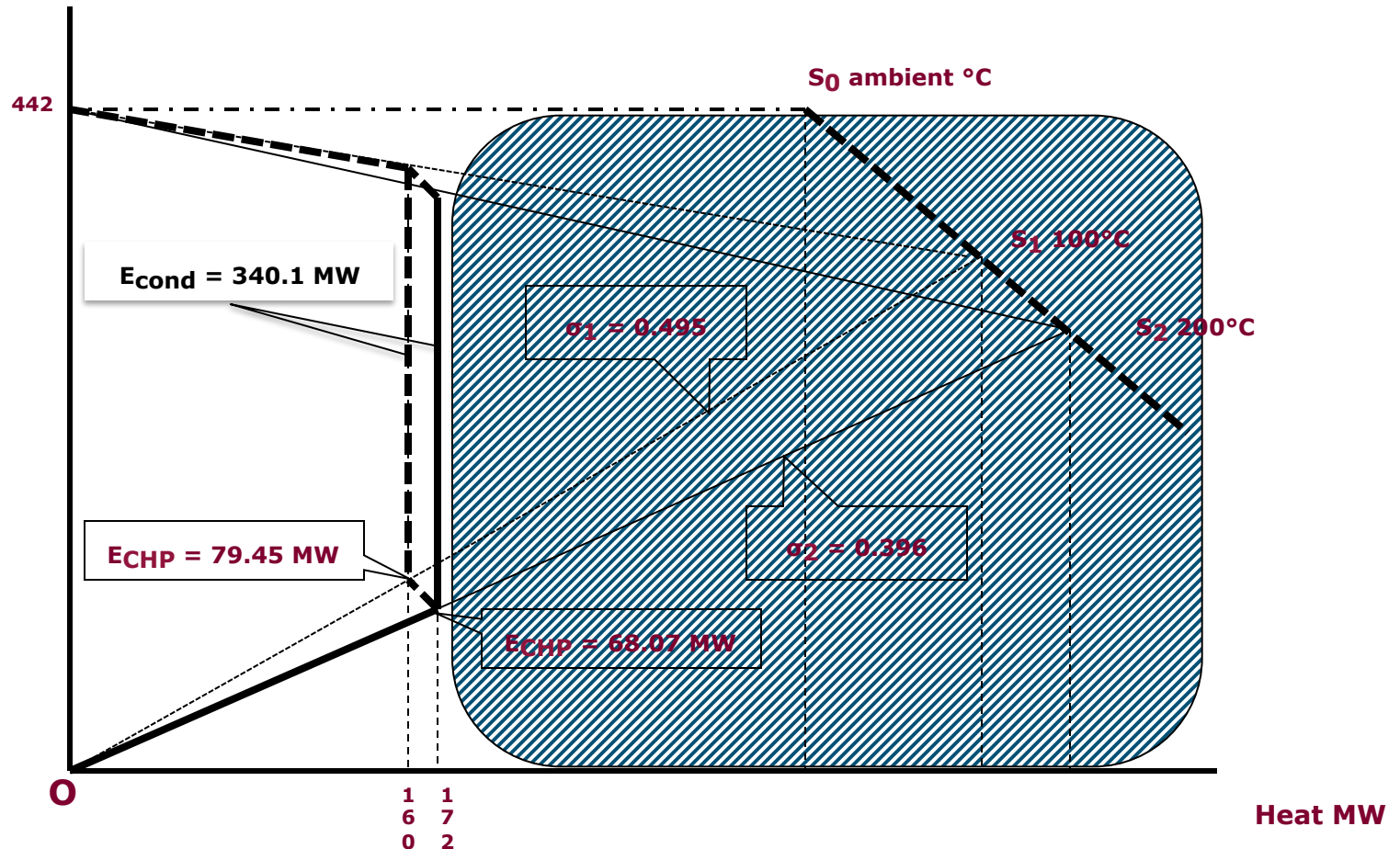
Electricity
kJ/kg





Proper solution of the division problem

Electricity MW





Conclusion

Shown E_{CHP} calculator solves a long-standing issue in science, operations, statistics, policy, regulation

E.g. flaws in EU Directives 2004, 2012 & High-quality CHP conundrum, with inaccurate separate heat and power generation benchmarks, obstructs CHP activity

Higher clarity about CHP by:

- **Proper vocabulary (e.g. *CHP activity*)**
- ***Design* power/heat ratio per CHP activity**
- **Define proper *merit* of CHP**
- **Identify *partial CHP activity* (mixed condensing – cogeneration operational modes)**



Epilogue

- 1. Irreversible climate change imposes fast deployment of renewable, fire-free power & heat supplies = almost full energy service by power from solar, wind, water, ...**
- 2. Combustion & explosion processes dwindle, so will waste heat point-sources = vanish CHP opportunities**
- 3. Join an industrial archeology club preserving obsolete thermodynamic power generation machinery of the 20th century?**

Thank you for listening
Detail is available in the conference paper
+ on site www.avielverbruggen.be