INNOVATIVE SOLUTIONS FOR HEAT EXCHANGE AND HEAT RECOVERY IN ADVANCED CYCLES

"A TECHNO-ECONOMIC ANALYSIS FOR GEOTHERMAL APPLICATION"

Ph.D IN ENERGY, SYSTEMS, TERRITORY AND CONSTRUCTION ENGINEERING

XXXVII° CYCLE

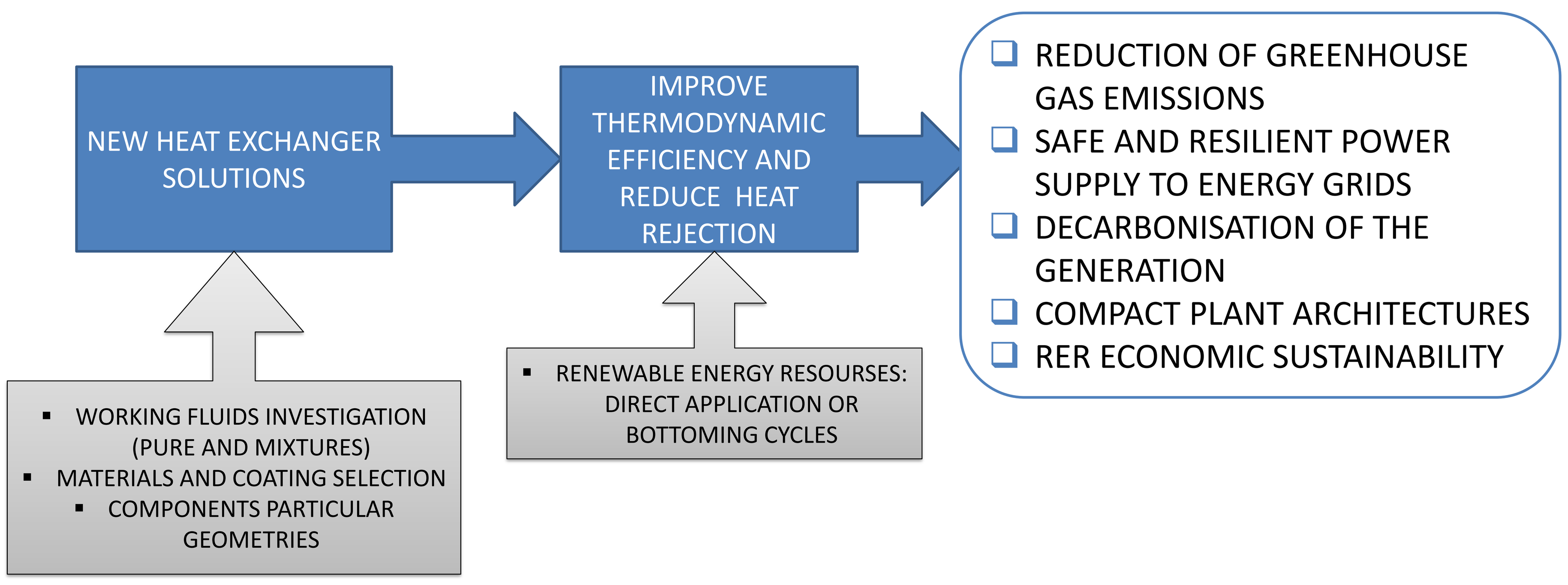
PhD student:

Dago Gnandjuet Gaston Brice

Supervisors:

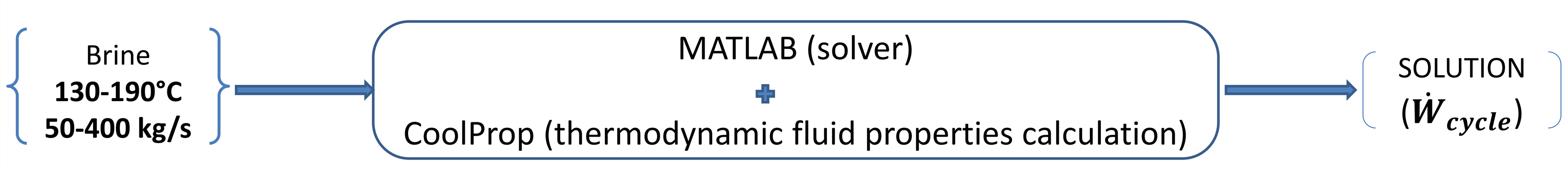
Desideri Umberto; Ferrari Lorenzo

I) Research Interests and Objectives



III) Methods and Materials

- **PART 1: NET POWER OPTIMIZATION**



- subcritical and transcritical: $\dot{W}_{cycle} = \dot{W}_{exp}\eta_{el,gen} - \dot{W}_{pump}/\eta_{el,mot} - \dot{W}_{fan}$ [kW]
- two-pressure levels: $\dot{W}_{cycle} = (\dot{W}_{exp}\eta_{el,gen} - \dot{W}_{pmp}/\eta_{el,mot})_{hp} + (\dot{W}_{exp}\eta_{el,gen} - \dot{W}_{pmp}/\eta_{el,mot})_{lp} - \dot{W}_{fan}$ [kW]

- **PART 2: COST ANALYSIS (HEXs DESIGN)**

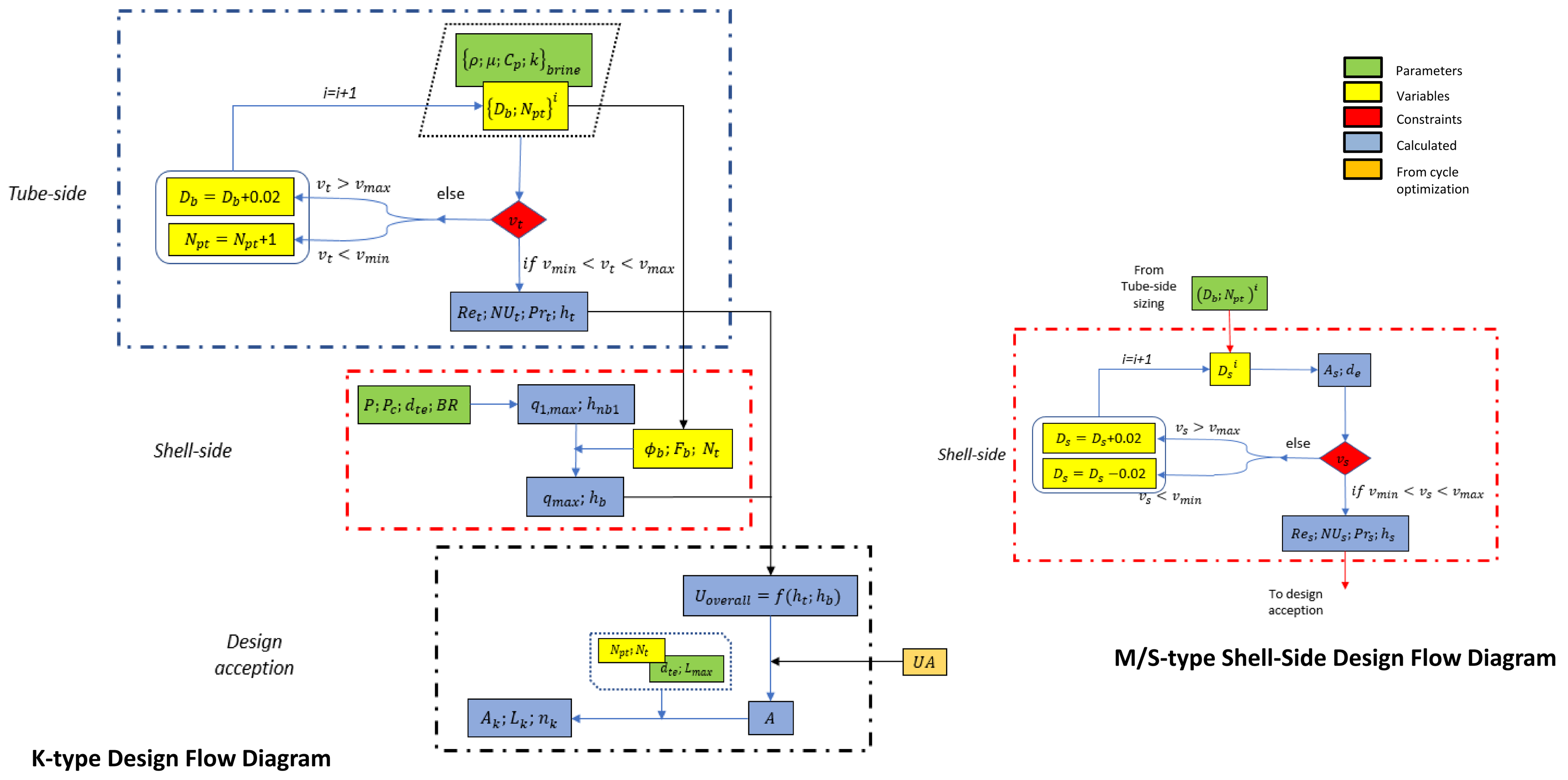
COST CORRALATIONS	CAPACITY EXPONENT RATIO	Pump; Condenser; Generator and Expander	$C_i = F_L \cdot \sum C_e$ (€); $C_e = C_0 \cdot (\frac{P_e}{P_0})^n$
	PURCHASE EQUIPMENT COST	High-T heat exchangers	$C_i = \sum C_p^0 \cdot f$; $C_p^0 = 10^{K_1+K_2 \cdot log_{10}(A)+K_3 \cdot log_{10}{}^2(A)}$

- $C_{index} = \sum C_i / \dot{W}_{cycle}$ [€/kW]

DETAILED DESIGN TO FIND U

∆ For subcritical and 2-pressure levels **Kettle-Reboiler (K-type)** is used as evaporator because of his capability to support operating pressure less than the critical pressure favoring a good nucleate boiling heat transfer.

∆ For transcritical, **Fixed-tube or floating head M/S-type)** are selected due to their versatility.



II) Introduction

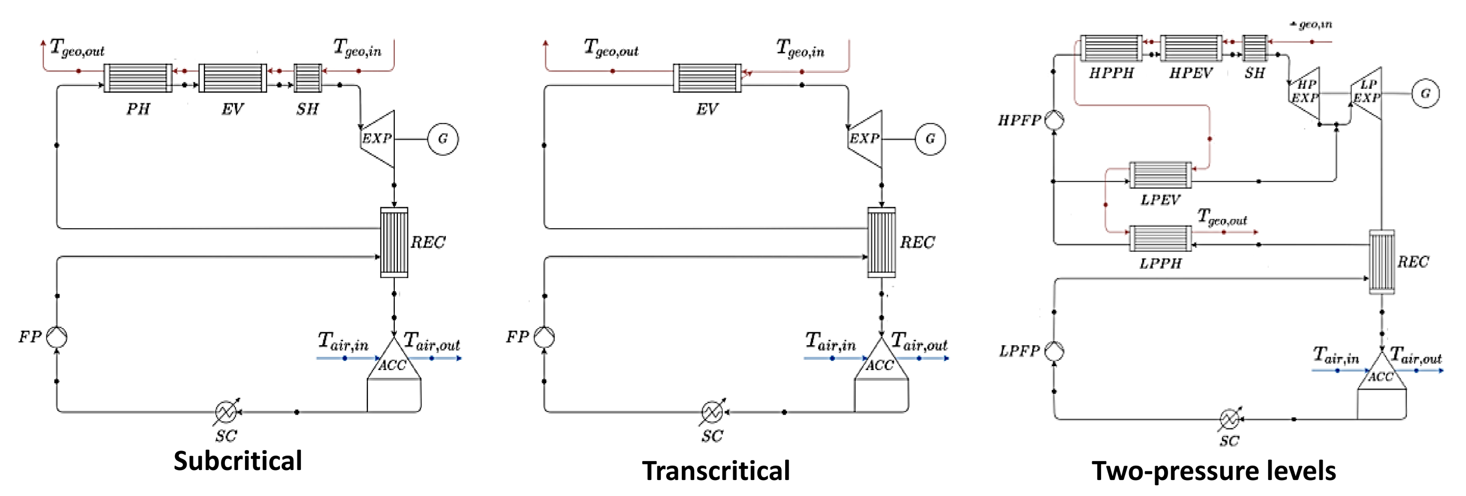
Alkanes	Flammable + Low GWP		Cyclo-Pentane; Iso-butane; Iso-Pentane; n-Pentane; n-Butane; Propane
Refrigerants	non flammable	High GWP	R1233zd (E); R245fa; R365mfc; R245ca
		Low GWP	R1224yd (Z); R1336mzz(Z); Novec649

(Investigated Pure Working Fluids)

The study is structured as following:

➢ An optimization in terms of cycle performance of three configurations of ORC: subcritical; Trans-critical and Two level of pressure: providing the optimal working-fluid for each pair of heat-source temperature and geothermal brine mass flow (T_{geo}; $\dot{m}_{geo}$);

➢ A cost analysis made through an intrinsic heat exchangers design and using a mixed method (different cost method calculation for each component of the cycle) : to provide the working fluid which minimizes the specific cost.



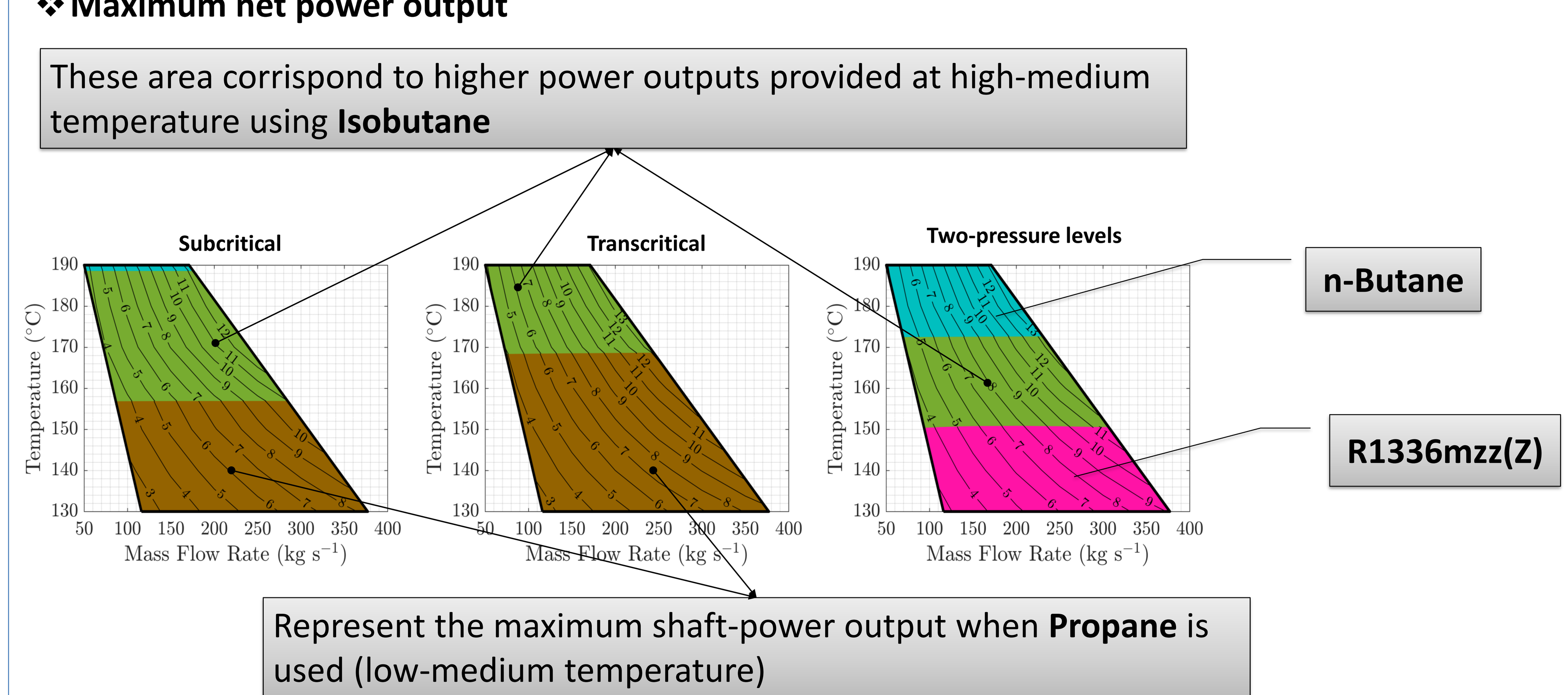
Results demonstrate that:

➢ the optimal ORC power outputs vary considerably, from 4 MW up to 30 MW with brine mass flow, fluid nature and ORC layout

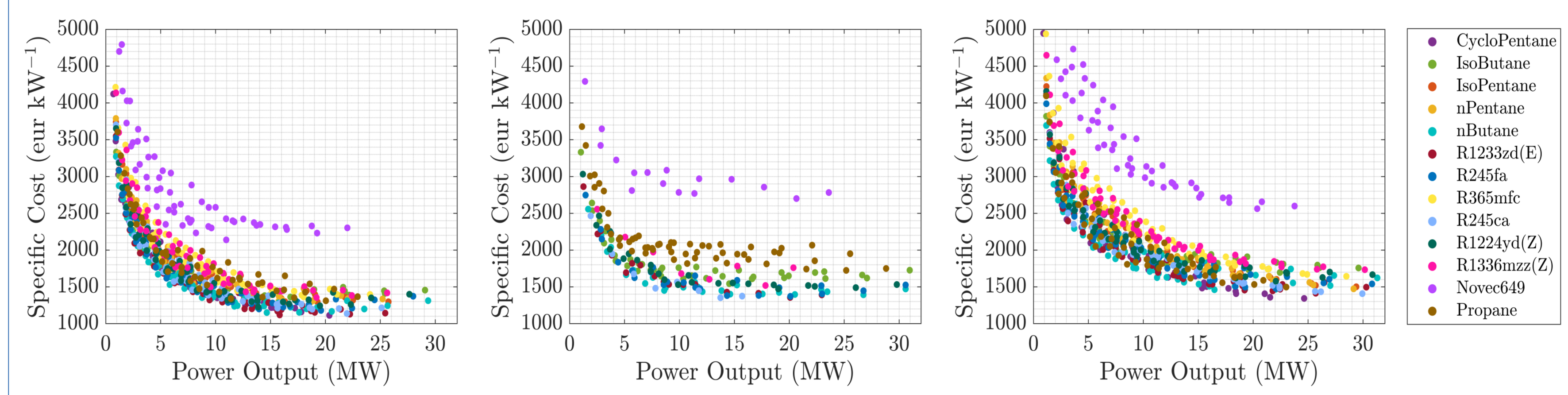
➢ the specific cost don't exceed 5000 €/kW.

IV) Results and Discussions

❖ **Maximum net power output**



❖ **Specific cost in function of power**



❖ Subcritical: nButane should be used for low power and R1233zd(E) for high power;

❖ Transcritical: R245ca; R245fa and nButane minimize the specific cost;

❖ Two-pressure levels: Specific cost is minimized using nButane for low power output; Cyclopentane and R245ca for power over the range 15-30 MW.

V) Preliminary Findings

✓ Fluids that maximizes the power produced for determinated operating conditions differ from those that minimize the specific cost;

✓ **Subcritical configuration and R1233zd(E) combination** is preferred from an economic perspective.

VI) Plan Continuation

The topic deserves further study:

✓ Use of mixtures as working fluids: that could require the application of advanced EoS formula for preventing the thermodynamics fluid properties behavior.

✓ An extended and most detailed Heat Exchanger Design and efficiency optimization applied to mixtures.

Contacts

Dago Gnandjuet Gaston Brice
DESTeC, University of Pisa, L.go Lucio Lazzarino 1, 56122, PI
gnandjuet.dago@phd.unipi.it
+39 3512010945

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