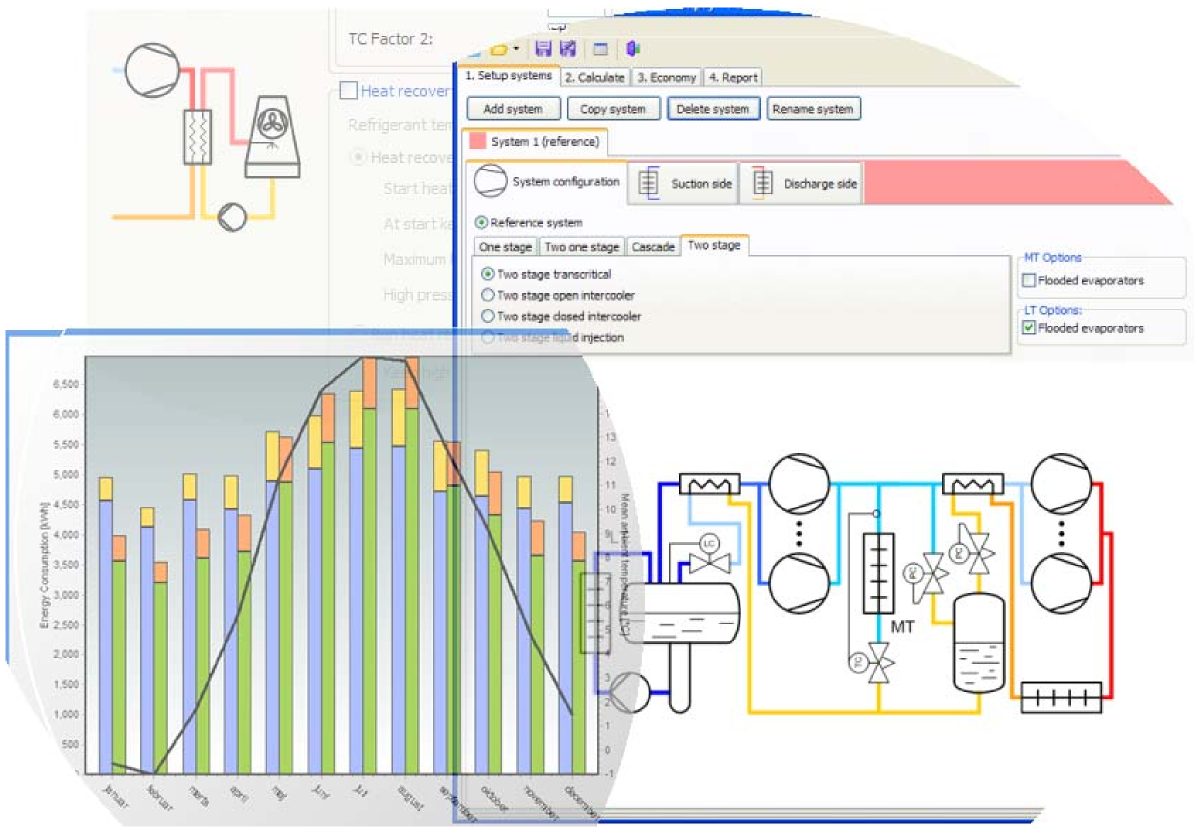
Pack Calculation II



IPU

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PackCalc Basics

- Yearly energy consumption of refrigeration systems
- Calculates every hour throughout the year – i.e. 8760 calculations
- 12 different cycles
  - 3 transcritical cycles
  - 1 heat pump
- Each cycle can be modified by optional
  - Internal heat exchanger
  - Flooded evaporators
  - Secondary circuit on the evaporator side

- 5 different condenser configurations
  - Air cooled, dry cooler, evaporative, cooling tower, water cooled
- Free cooling and heat recovery is available (not at the same time though…)
- Groundwater cooling an option
- 4222 models of commercially available compressor included
- Climate data for 707 cities around the world

- Economics (payback), LCC, TEWI

Background

- Developed through different public financed projects with the following participants

Project Group

- Danfoss
- IPU
- Johnson Controls
- Danish Technological Institute
- Grundfos
- Advansor by Hill Phoenix
- Knudsen Køling
- Rambøll
- SBi – Danish Building Research Institute, Aalborg University
- ttc
- Carrier – A United Technologies Company
- systemair
- Vestas industrial cooling

The following companies have generously supported the project by donating data for compressors:

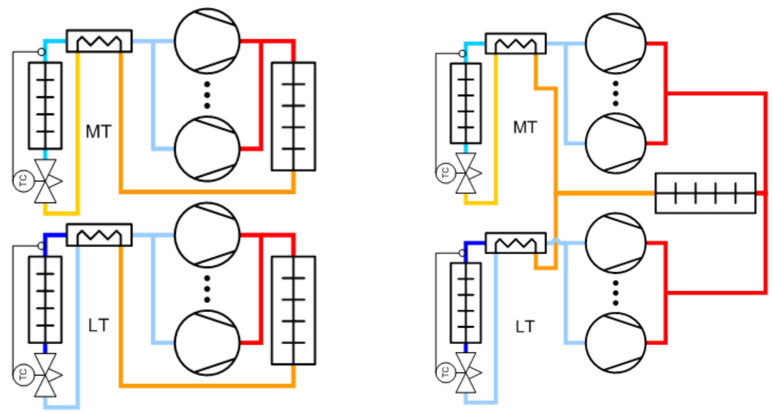
- Bitzer International
- Dorin innovation
- Bock Compressors
- Emerson Climate Technologies

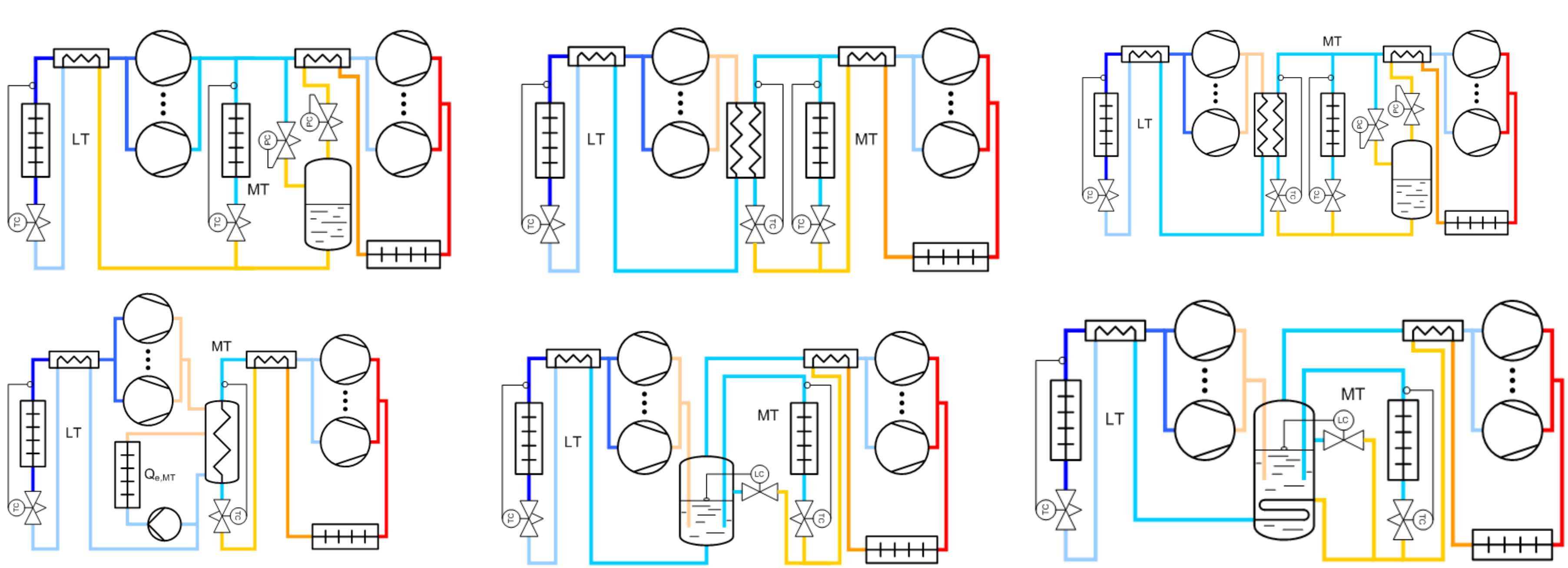
Background

- **First phase**
  - Illustrate energy savings using variable speed compressors in supermarkets
- **Second phase**
  - Qualifying comparison of (transcritical) CO_2 systems with standard systems
- **Third phase**
  - Using PackCalc as “simulation engine for technical systems” for building simulation tool

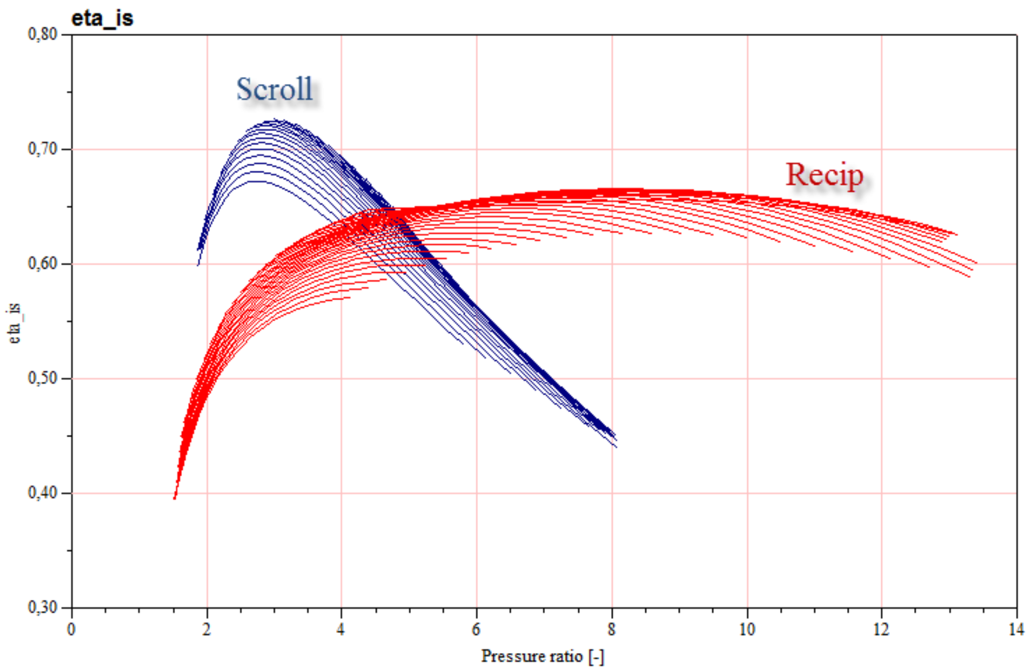
- All public financed projects => PackCalc is freeware.

- **Base**: basic thermodynamic cycles:



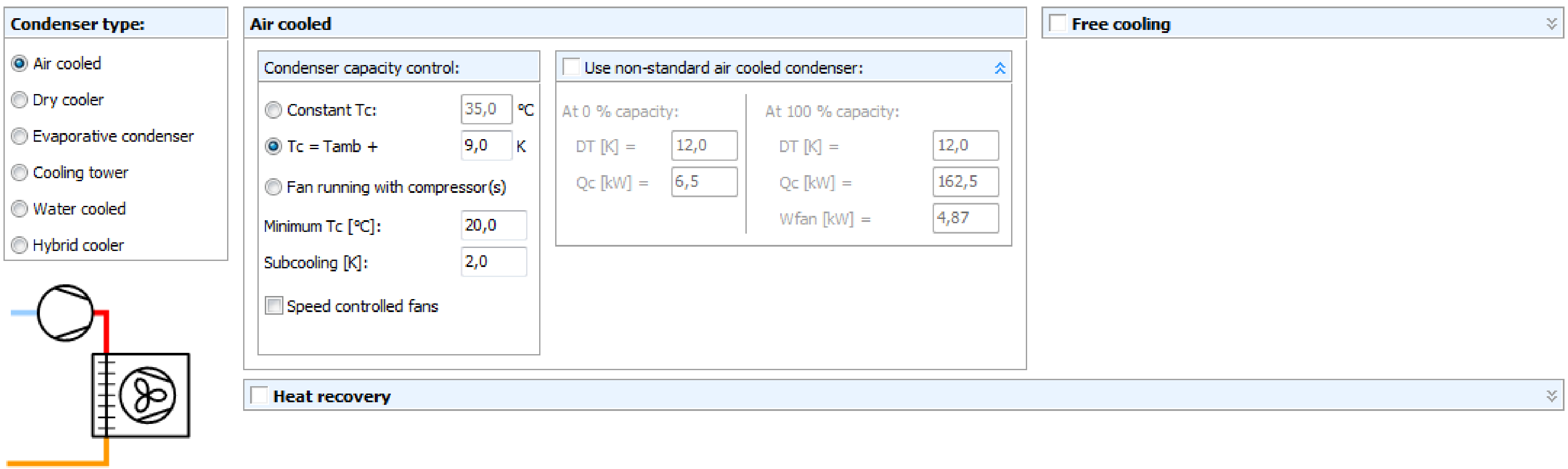


- **Compressors**: polynomials (ISO 9309) from manufacturers. If part load polynomials are not available (cylinder unloading, speed, slide,…), general models are used based on available data.
  - Rating condition from polynomials changed to isentropic and volumetric efficiency which are kept constant (independent of superheat)



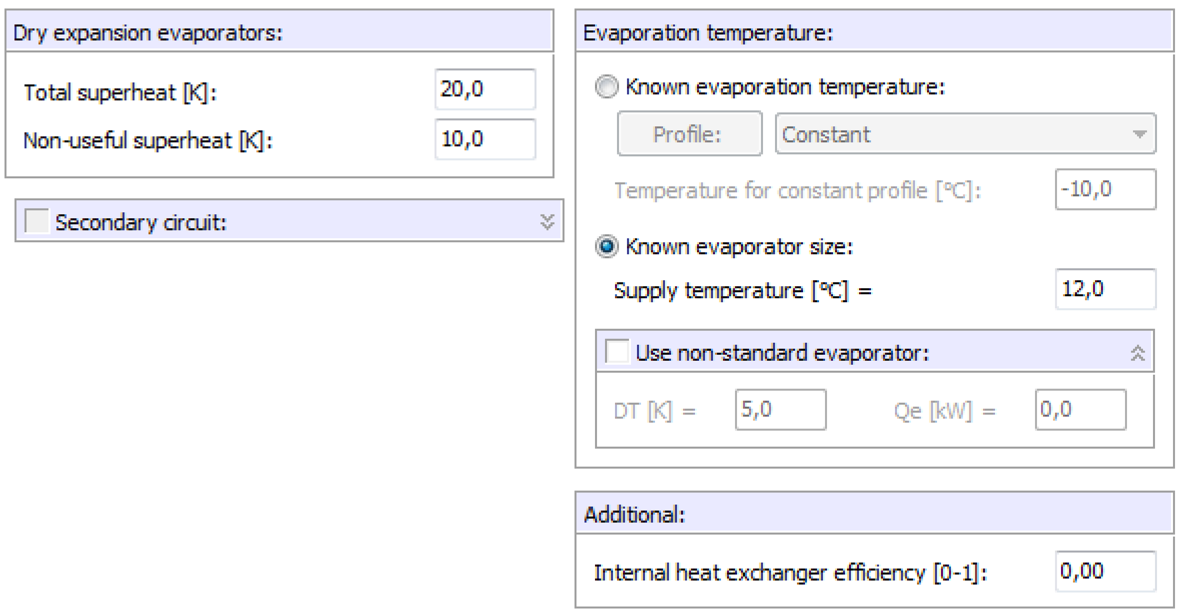
Modelling

- **Condensers**: different models for different condenser types (from simple UA model to Merkel-equations for cooling towers).
  - Condensing temperature is in general controlled, and condenser fan/pump power consumption is calculated based on the controlling strategy.
  - Condensing temperature is automatically raised if condenser is to small at high ambient and high load



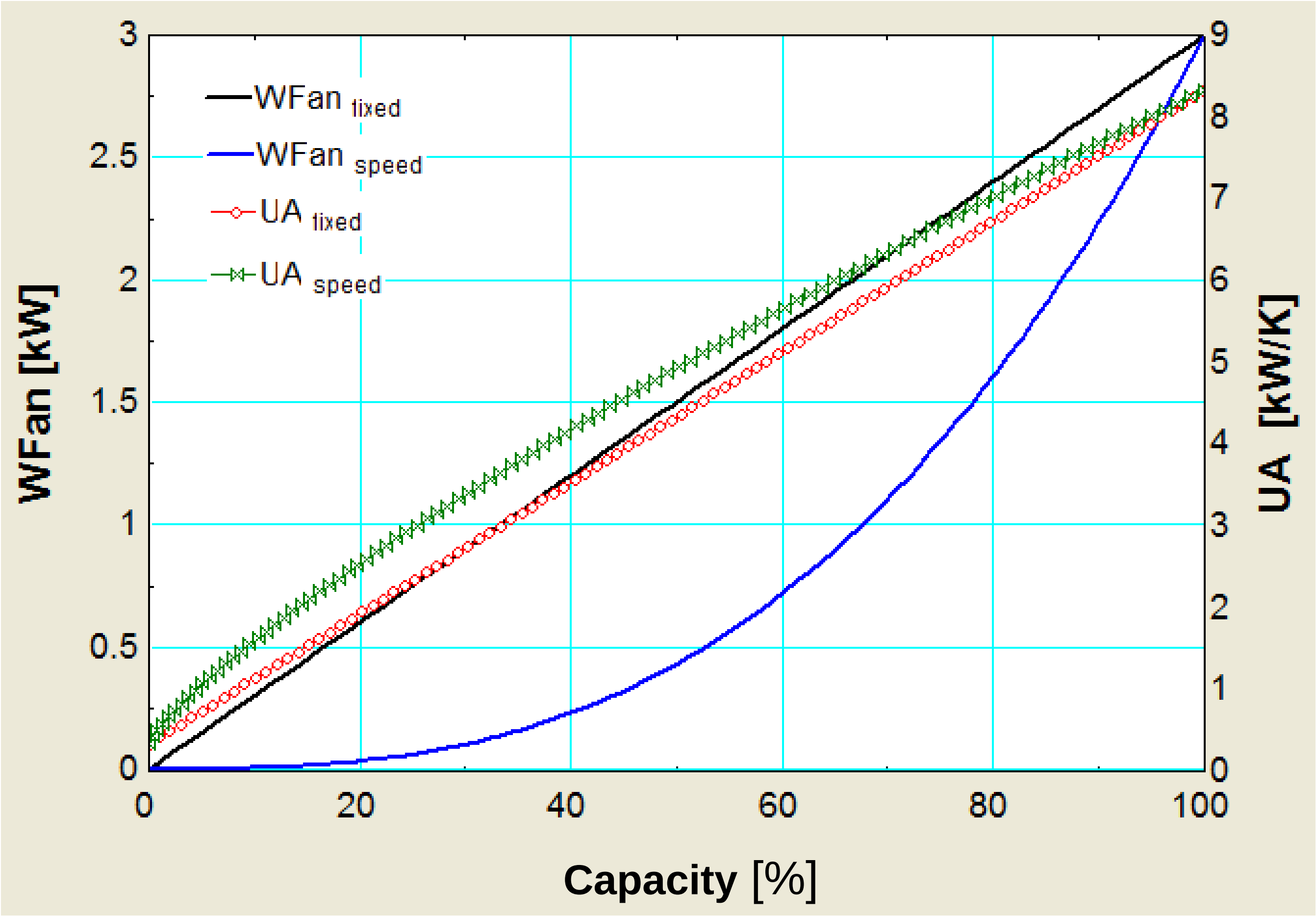
Modelling

- Evaporators
  - Typically not modelled if cooling (evaporation temperature is given), and as condensers if heat pump
  - User can let evaporation temperature float an instead give supply temperature, in this case evaporator is modelled using simple UA model



Modelling

- Fan (and pumps)

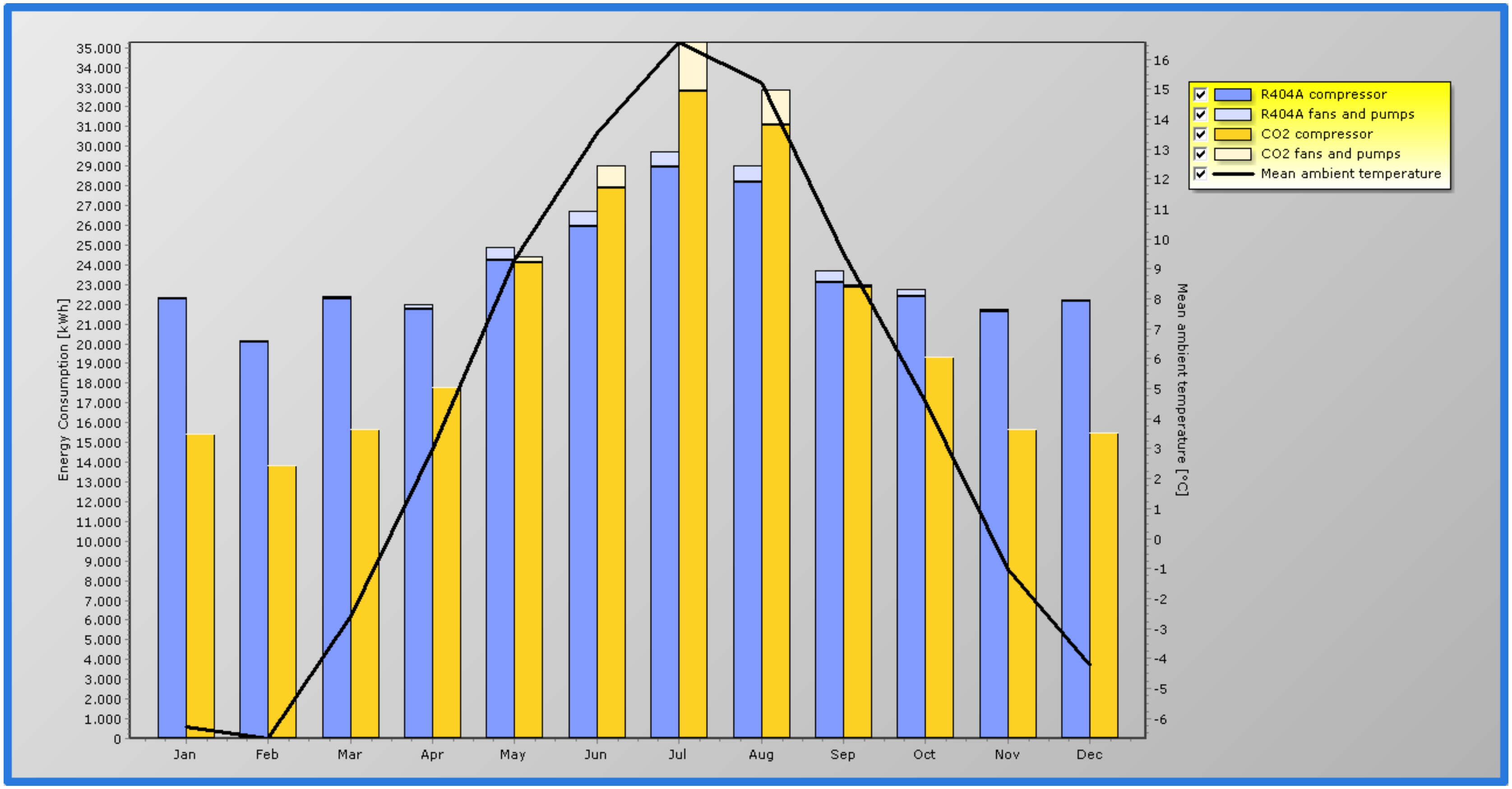


Modelling

- Calculation process
  1. Define system
  2. Set up compressor pack
  3. Define heat exchanger sizes
  4. Define load profile (cooling or heating)
  5. Define operating conditions
  6. Calculate (balancing system every hour of the year)

Modelling

- Result is the system yearly energy consumption (below R404A & CO_2).



- PackCalc is made so that different solution can be compared.
    - Savings in % is a better number (more accurate) than savings in kWh.

Life Cycle Costs

- Basic LCC calculation:

Life Cycle Costs | CO2 Equivalent Emissions

Currency: €

Expected average interest rate [%]: 3

Expected average inflation rate [%]: 2

Expected average energy cost [€/kWh]: 0,12

Expected lifetime [years]: 10

Update

Initial cost:

	R404A	CO2
Cost of equipment [€]	75.000	120.000
Cost of installation [€]	140.000	100.000

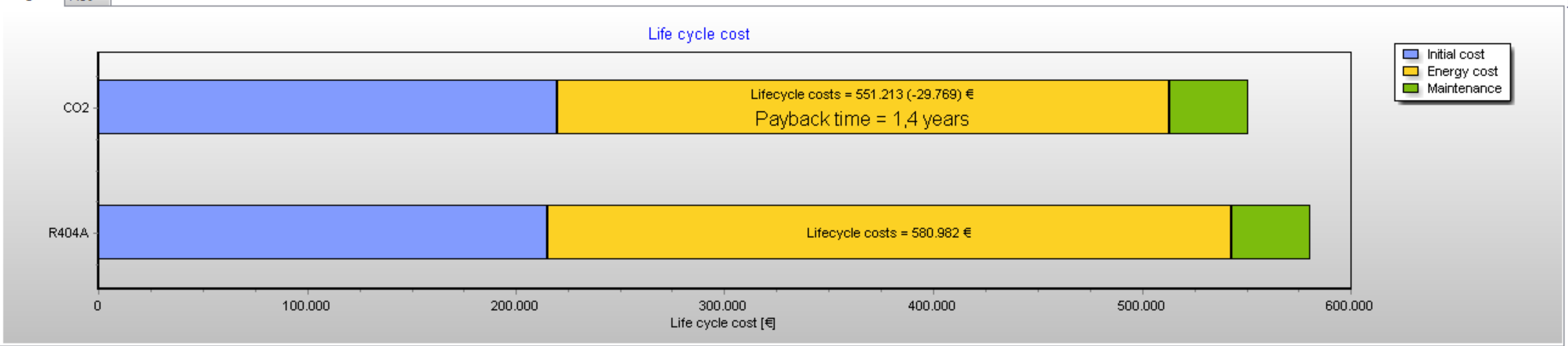
Annual operating cost:

	R404A	CO2
Energy consumption [kWh]	288337,69	257778,10 (-30.560)
Cost of maintenance [€]	4.000	4.000

Result:

	R404A	CO2
Effective interest rate [%]	0,98	0,98
Internal rate of return [%]	-	73,04
Total annual cost [€]	38.601	34.933 (-3.667)
Payback time [years]	-	1,4
Total initial cost [€]	215.000 (37%)	220.000 (40%)
Present value of maintenance cost [€]	37.925 (7%)	37.925 (7%)
Present value of energy cost [€]	328.057 (56%)	293.288 (53%)
Life cycle cost [€]	580.982	551.213 (-29.769)

Diagram | Plot



- CO2 emissions can be calculated in lifetime (TEWI)

Life Cycle Costs | CO2 Equivalent Emissions

CO2 release, electricity generation [kg/kWh]: 0,53 Update

	R404A (R404A)	CO2 (R744)
Refrigerant charge [kg]	200	200
Recycle rate [%]	50	0
Leakage rate [%/year]	10	5

	Leakage [kg CO2]	Recycle loss [kg CO2]	Indirect [kg CO2]	Total [kg CO2]
R404A	784.400 (29,0%)	392.200 (14,5%)	1.528.190 (56,5%)	2.704.790
CO2	100 (0,0%)	200 (0,0%)	1.366.224 (100,0%)	1.366.524