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Development of technologies for new cryoplant concepts

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CERN

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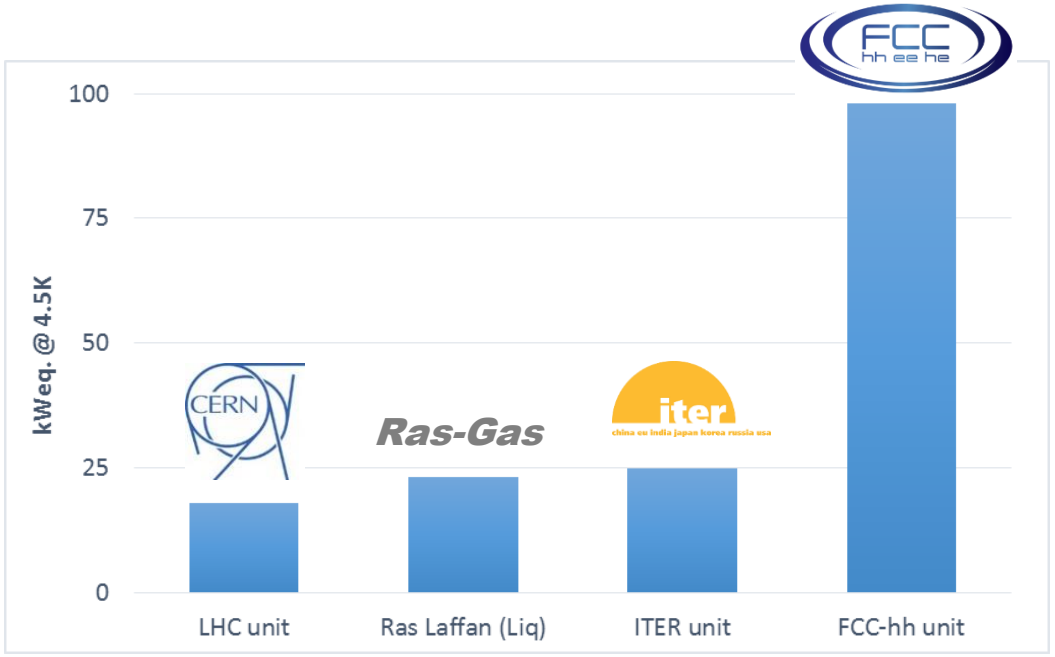
FCC cooling needs : Towards 1 MW @ 4.5 K with 10 units of 100 kW at 4.5K

>230 MW *of electrical consumption with conventional cryoplants*



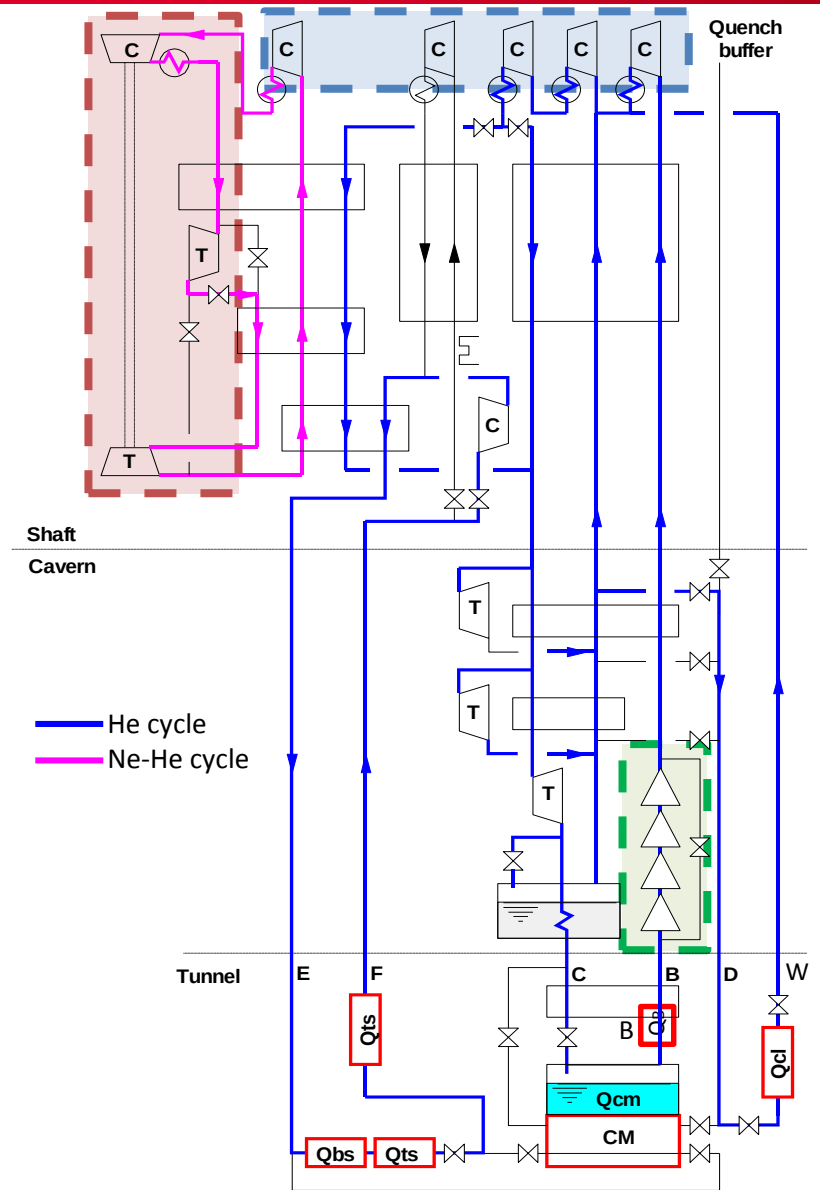
Assessment of the preliminary conceptual design for FCC cryoplants with industry :

- Confirmation of process cycles and performances for large-scale cryoplants

  see for details presentation « Industrial engineeering study of FCC-hh refrigerators »

- Lists of required R&D efforts to develop more reliable & energy-efficient cryoplants

Main engineering study results



Cold circulator

Industrial engineering studies confirm :

- **Process cycle with:**
  - Advanced precooling stages with MR Turbo-Brayton Fridges
  - Helium Refrigerators for magnets cooling
- **Cryoplant performances with :**
  - Electrical consumption in nominal conditions **< 200 MW**
  - Turndown factor for transient operations > 3 to 6
- **Identified R&D efforts:**
  - Reliable and efficient warm turbo-compressors (1 to 10 MW)
  - Energy recovery for large turbo-expanders (0.1 to 1 MW)
  - Large-capacity cold compressors (600 to 1000 g/s)

By courtesy CERN & LINDE

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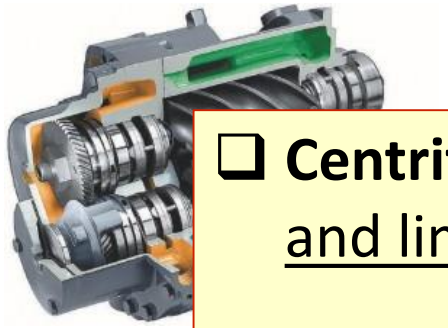
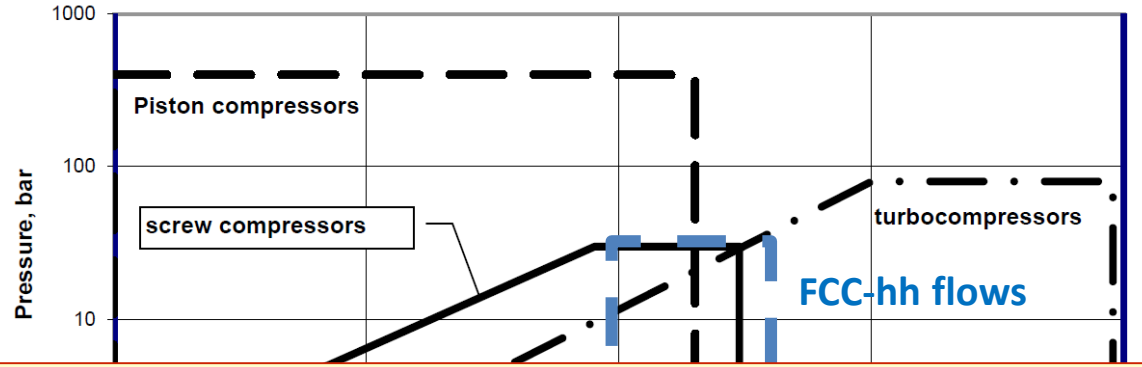
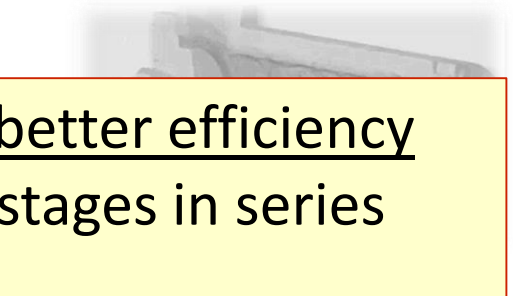
Technology for compression

Present technology : screw compressors



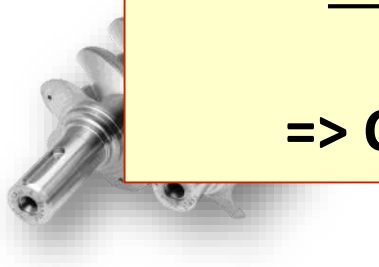


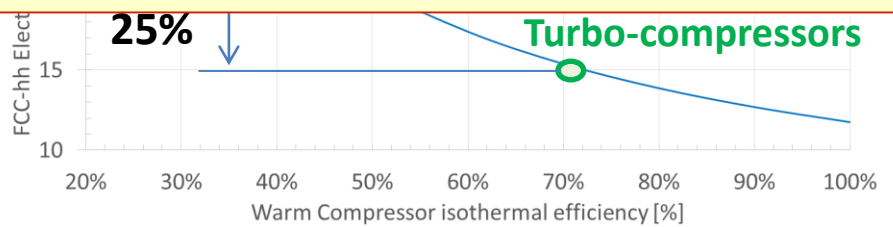
Proposed development: turbo-compressors

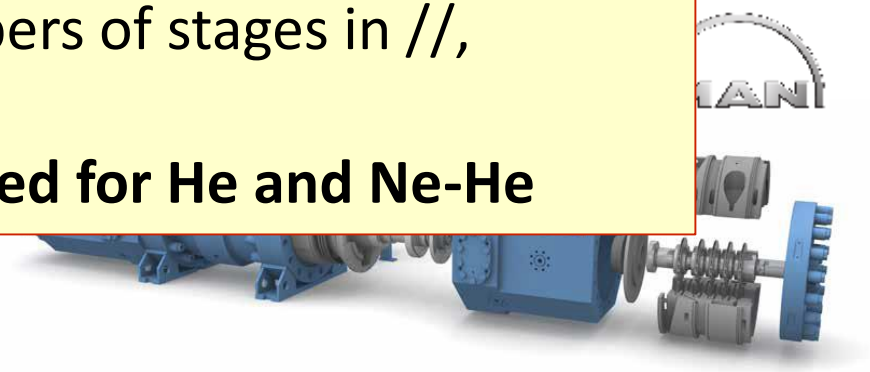


- **Centrifugal warm compressors** offer <u>larger flow capacity</u>, <u>better efficiency</u> <u>and limited pressure ratio</u> per stage requiring numbers of stages in series whereas
- **Conventional screw compressors** offer <u>larger pressure ratio</u>, <u>lower efficiency</u> and <u>limited flow capacity</u> per stage requiring numbers of stages in //,

=> Centrifugal compressors have to be developed for He and Ne-He

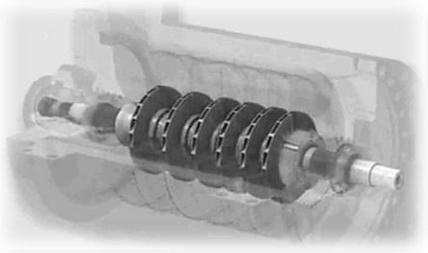


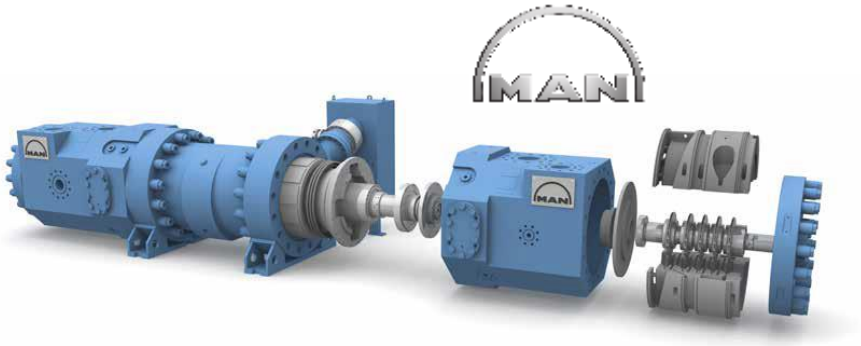


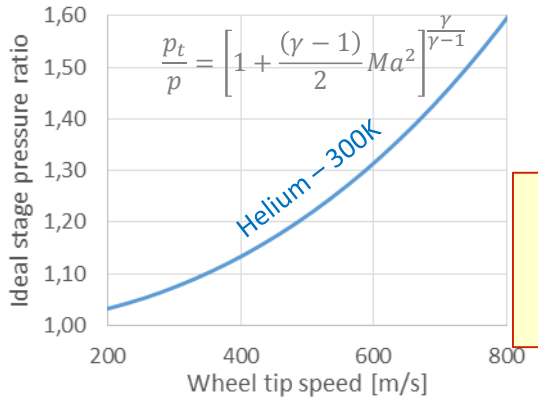


By courtesy LINDE + TUD + *Alekseev A. Basics of low-temperature refrigeration. CAS-CERN Accelerator School: Superconductivity for Accelerators, arXiv:1501.07392:29 p, 2014. Erice, Italy, 2013*

Warm Turbo-Compressors







- **Reliable and efficient products**
  - **Oil free**
  - **Magnetic bearings**
  - **Compact design**
- **Already commercially available for natural gas and air separation**
- **However developments required for light gases** *(pure Helium or Helium mixture with Neon)*

=> Expected gain for FCC : 25% of electrical power consumption and more reliable components (oil free, magnetic bearings)

By courtesy LINDE + TUD/USTT

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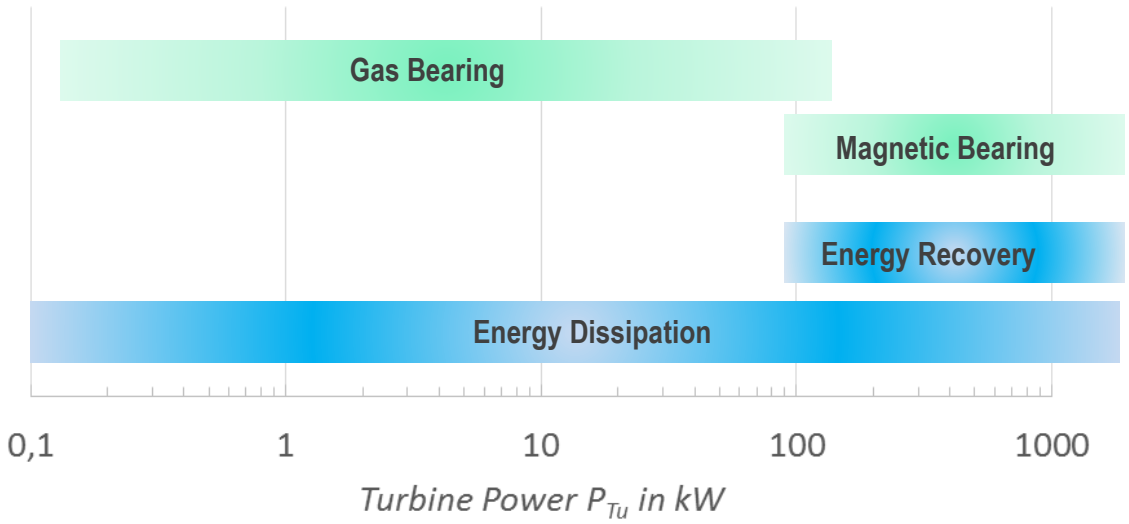
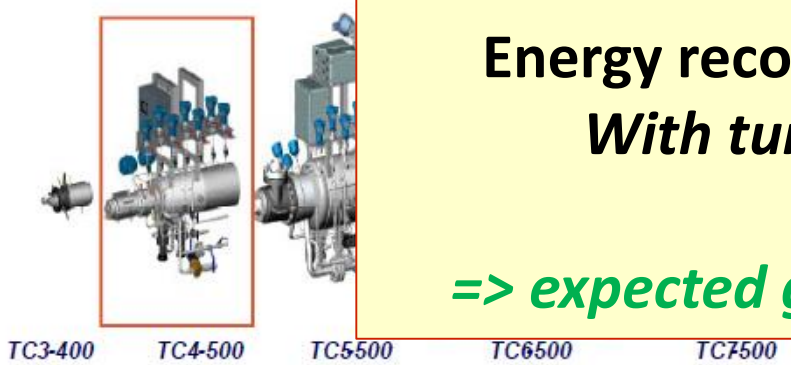
Turbo-expanders

FCC-hh turbines (5 kW < Pw < 1 MW – Eff. > 80%)



Large turbo-expanders for Ne-He and He have to be developed
including
Energy recovery already existing for turbines > ~100 kW
With turbine-generators or turbine-compressors

=> expected gain for FCC > 1 MW/cryoplant => 7% of Pelec



By courtesy LINDE & Air Liquide + *Cardella U et al. Aspects of hydrogen liquefier scale-up – Process and equipment design. Proceedings of the 14th CRYOGENICS 2017 IIR International Conference, Dresden, 2017*

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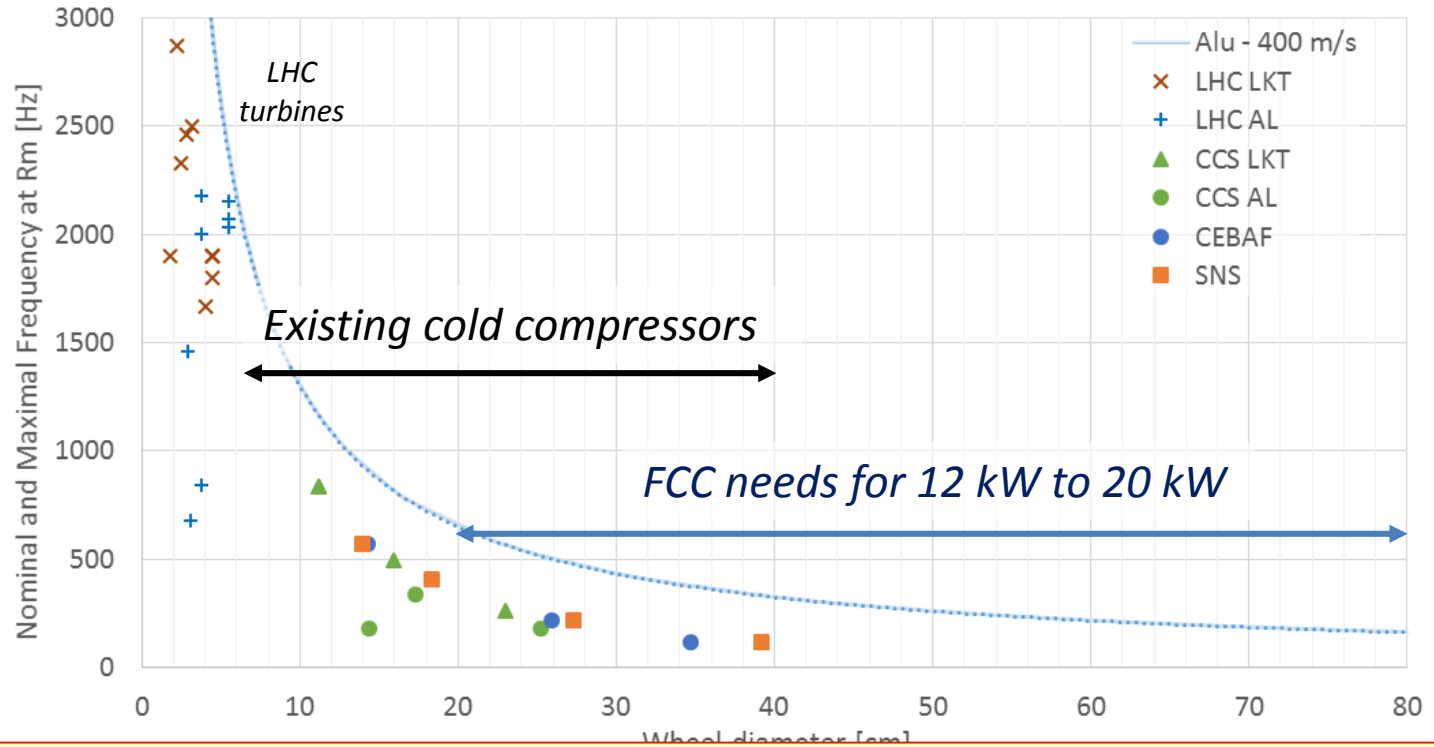
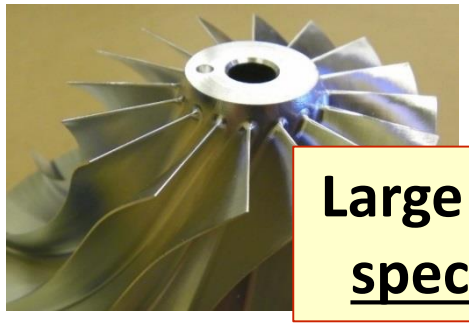
FCC-hh cold compressors (200 g/s < Qm < 1 000 g/s – Eff.> 75%)





Large cold compressors have to be adapted with <u>larger wheels</u> with <u>special attention to rotor-dynamics with large motors & bearings</u>

Air Liquide
creative oxygen

THE LINDE GROUP
Linde

By courtesy LINDE & Air Liquide

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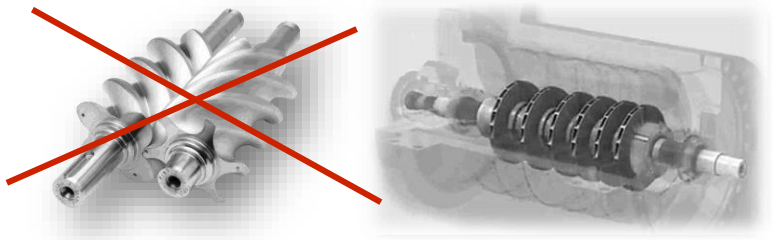
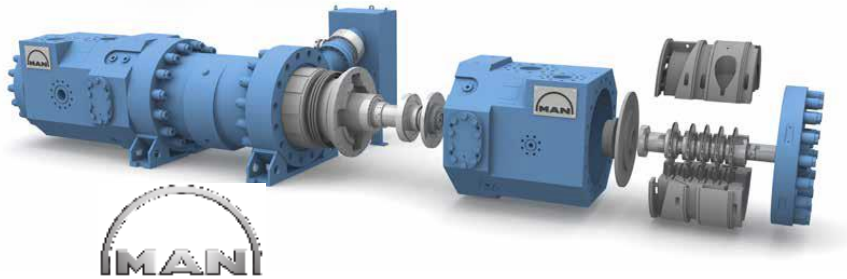
❑ Identified R&D efforts :

- **Reliable and efficient turbo-compressors (-25% of Pelec)**



- **Energy recovery for turbo-expanders (-7%)**



- **Cryoplant with optimized precooling stage**

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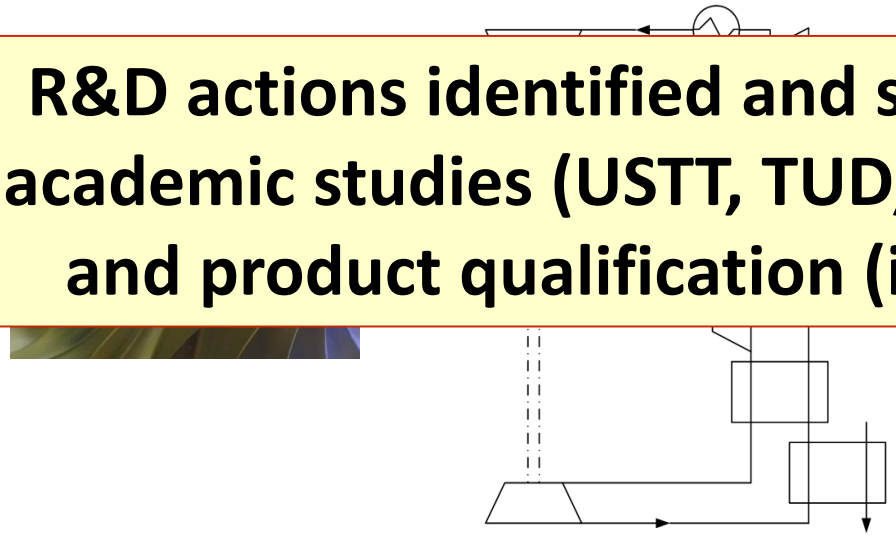
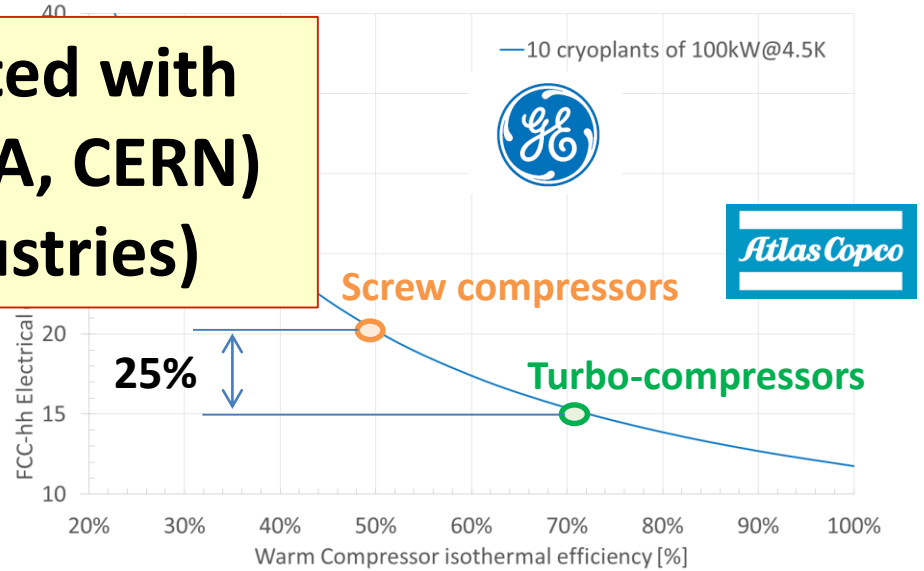
Air Liquide creative oxygen



R&D actions identified and started with academic studies (USTT, TUD, CEA, CERN) and product qualification (industries)



By courtesy LINDE + TUD

Thank you for your attention