Future Circular Collider

Technical Infrastructure

Cooling and Ventilation systems for the new FCC configuration

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FCC week 2022

2/ June / 2022

Outline

- Introduction
- Cooling of the new eight point configuration of the FCC-ee surface and underground
  - Primary cooling
  - Raw water *(needs only)*
  - Demineralised water distribution
  - Chilled water
- New parameters of the FCC tunnel ventilation system
- RF for FCC-ee cooling and ventilation
  - Point H
  - Point L
- Further steps

Introduction

- Cooling:
  - Environmental aspects
  - Energy consumption and waste heat recovery
  - Cost of installation for FCC-ee and cost of modification for FCC-hh
  - Safety aspects (firefighting water)
- Ventilation:
  - Connected to safety studies
  - Environmental aspects
  - Costs
  - Particular technical challenges in the tunnel and in the RF points.

European Strategy for Particle Physics 2020 update document

Core paragraph and main request "order of the further FCC study":

"Europe, together with its international partners, should investigate the technical and financial feasibility of a future hadron collider at CERN with a centre-of-mass energy of at least 100 TeV and with an electron-positron Higgs and electroweak factory as a possible first stage.

Such a feasibility study of the colliders and related infrastructure should be established as a global endeavour and be completed on the timescale of the next Strategy update." **(Feasibility study to be delivered end 2025 as input for ESPP Update expected for 2026/2027,)**

From Benedikt's talk last year referring to CERN DG:
Technologies of machine and experiments: First priority of feasibility study: magnets; minimise environmental impact; energy efficiency and recovery

Main topics and milestones for CV activities

Main system design activities

Feasibility Design Report

2021	2022	2023	2024	2025	2026

Review, collection and update of CV **user requirements for FCC-ee** for each surface point, including CV building and plants specification (assuming no change on FCC-hh requirements); this is

→ input for iteration in particular with safety concepts

→ starting point for external consultant contract(s) for CV concept plan and design

Refined concept design of CV infrastructures, also taking into account later evolution to FCC-hh; this is

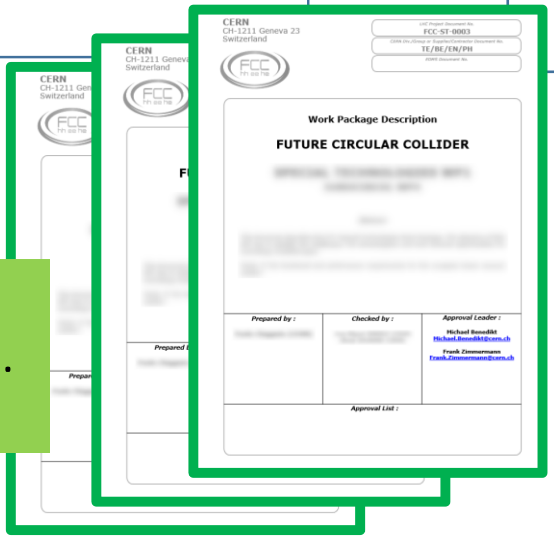
→ input for start of Environmental Evaluation process

(Pre-)technical design of CV infrastructures, installation time plan, cost estimate; this is

→ input for a full iteration of the design with all users, CE and other systems

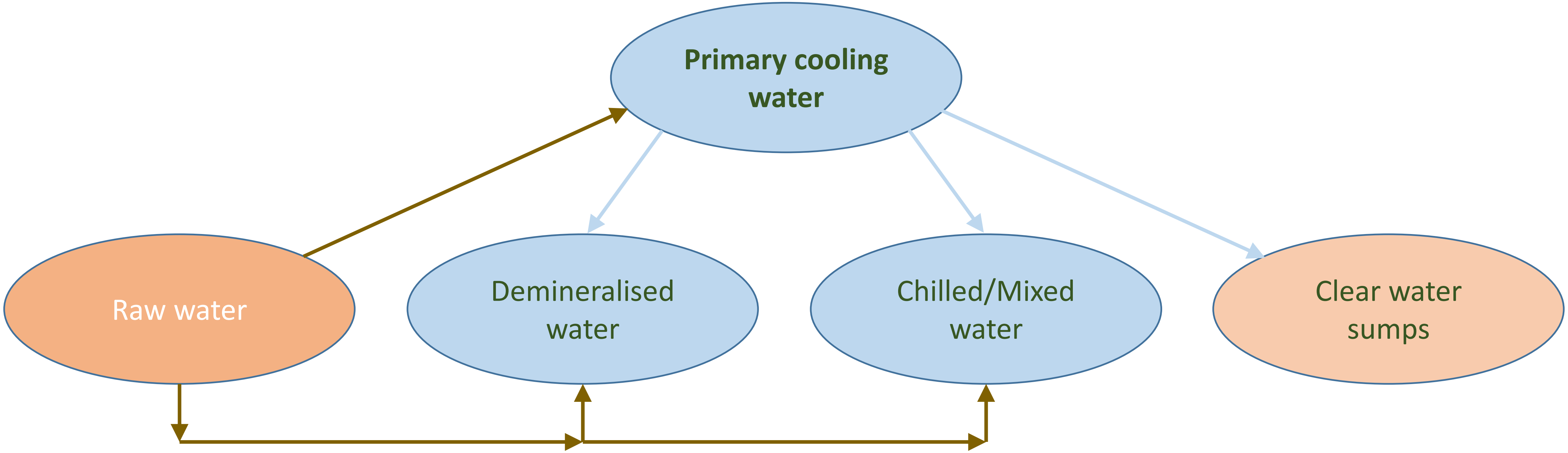
→ input for the Feasibility Design Report

«Work package descriptions»
with deliverables, planning/milestones, ...
(useful for planning and follow-up)



M. Benedikt, 18.1.2021

Cooling water FCC-ee



Primary Cooling Water

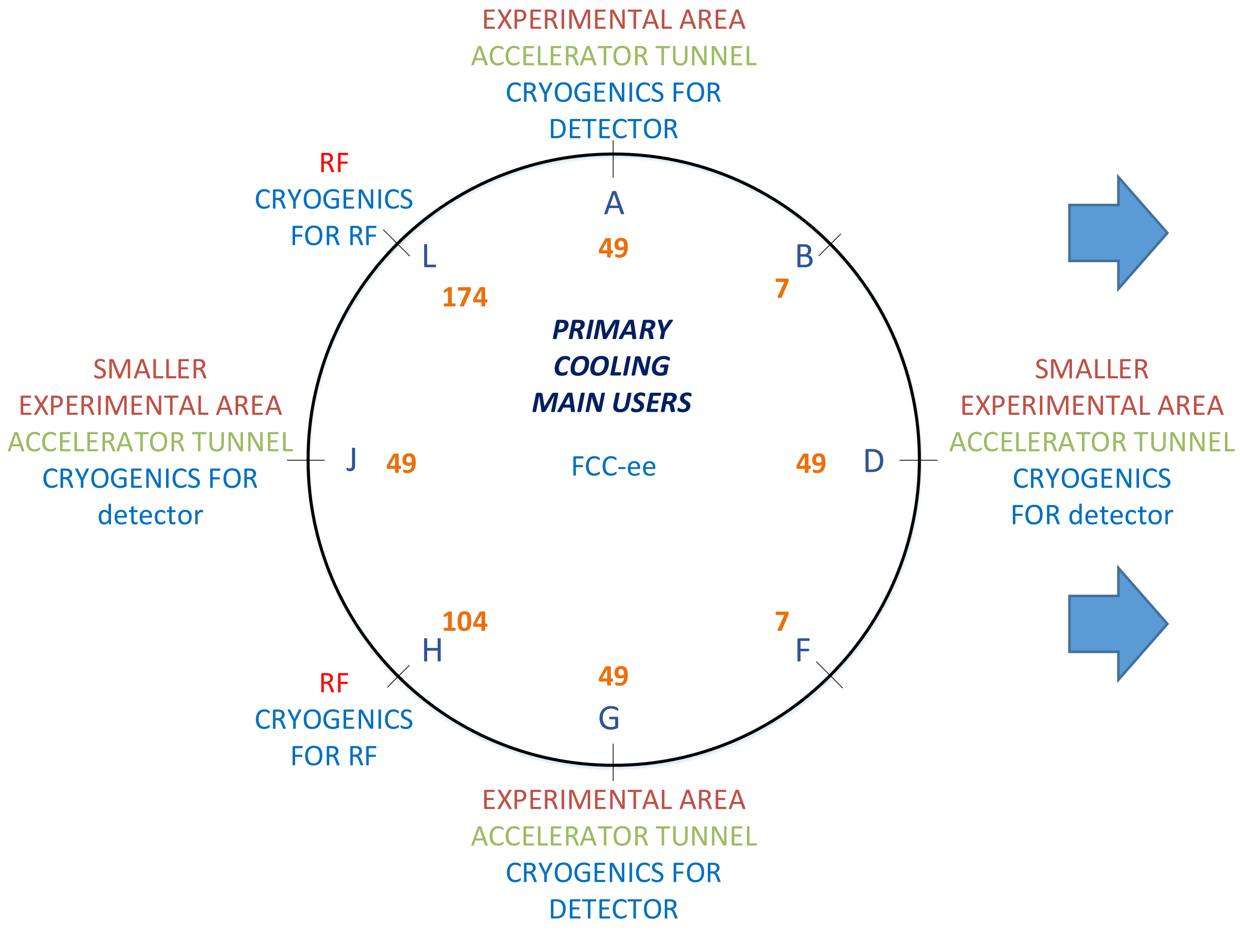
- Primary water
  - Cooling Towers combined with alternative cooling solutions
    - Reducing water consumption, visual pollution, noise…
    - Waste Heat Recovery options:
      - District heating as for LHC;
      - Other applications (medical, industrial, agricultural, leisure, …);
      - Combined or not with thermal energy storage.
  - Water treatment:
    - Reducing corrosion;
    - Scaling, fouling and legionella;
    - Environmentally friendly : smaller chemical footprint
- Blowdown water:
  - Finding reject water points;
  - Treatment before rejection.
- Maintenance strategies

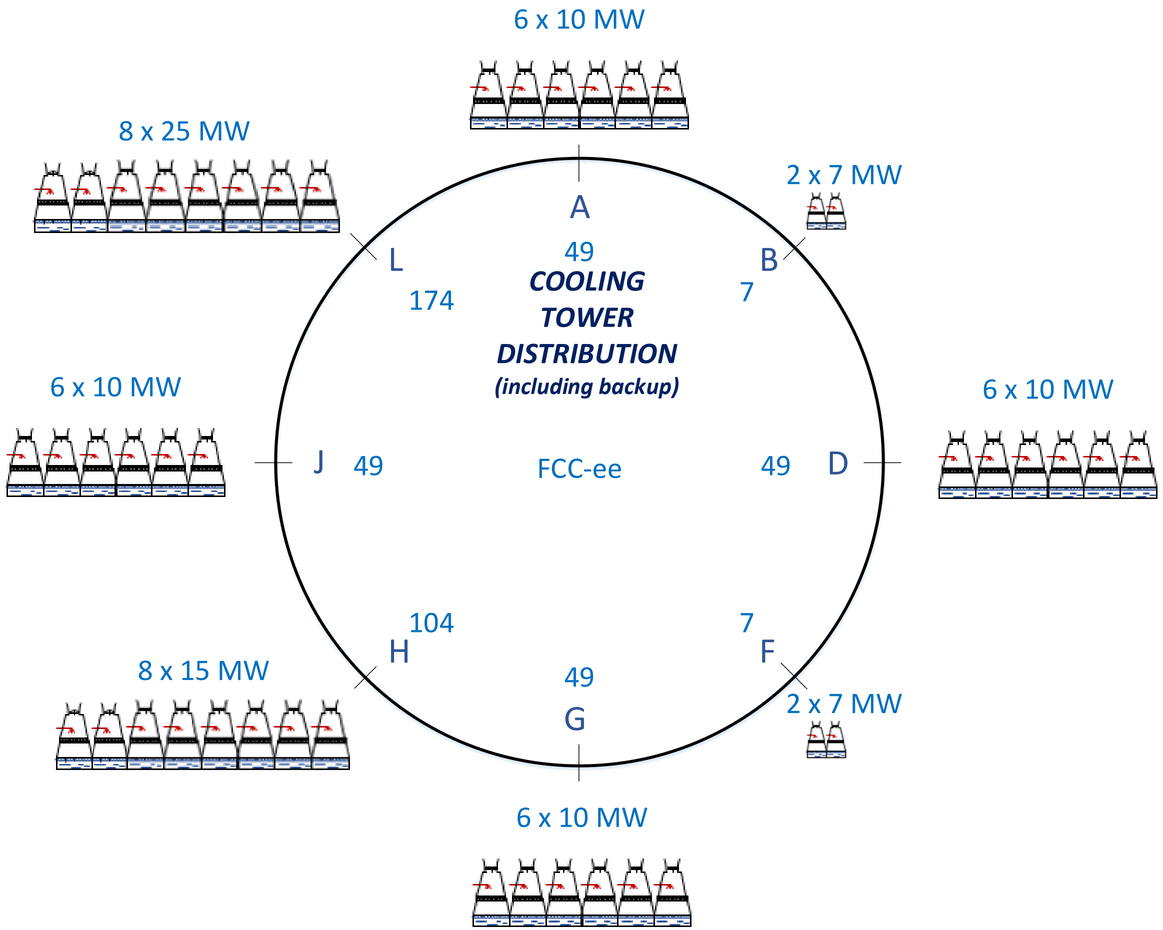
Primary Cooling Water

- The baseline consists of sets of cooling towers located at each FCC surface point
- The eight point FCC-ee configuration has “large” cooling towers at all points except for point B and F
- The estimative cooling power needed is:

FCC-ee COOLING POWER NEEDS FOR PRIMARY CIRCUITS (MW)							
Point	Cryogenics	Experiment	General Services	Power Converters (RF)	Chilled water	From underground	**TOTAL**
PA		0.5	2		4,6	41.5	**48.6**
PB			2		3,9	1.0	**7.0**
PD		0.5	2		4,6	41.5	**48.6**
PF			2		3,9	1.0	**7.0**
PG		0.5	2		4,6	41.5	**48.6**
PH	48		2	4	8.4	41.6	**103.9**
PJ		0.5	2		4,6	41.5	**48.6**
PL	95		2	6	10.3	60.9	**174.2**

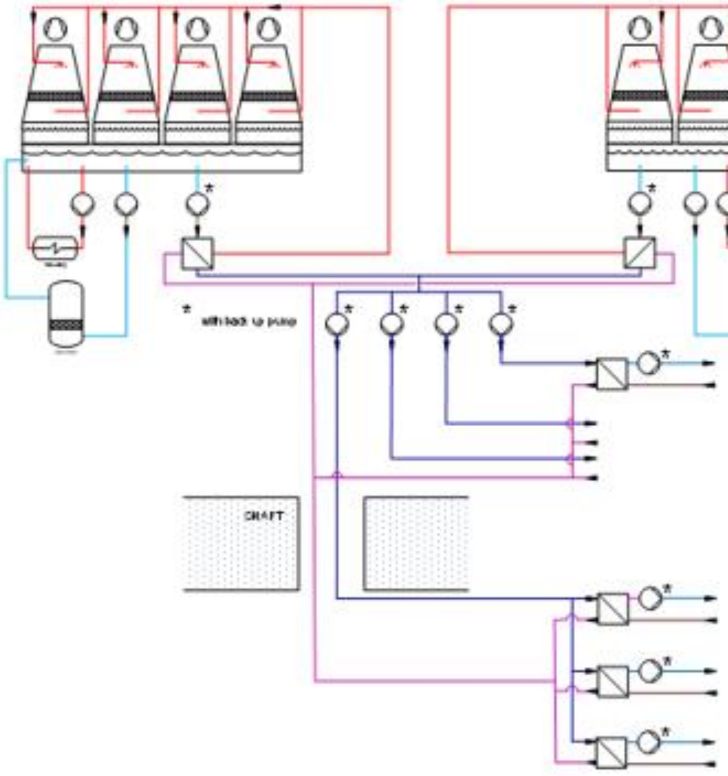
Primary Water : Cooling Towers (I)





Primary Water : CT Maintenance

Double Cooling Tower Circuit



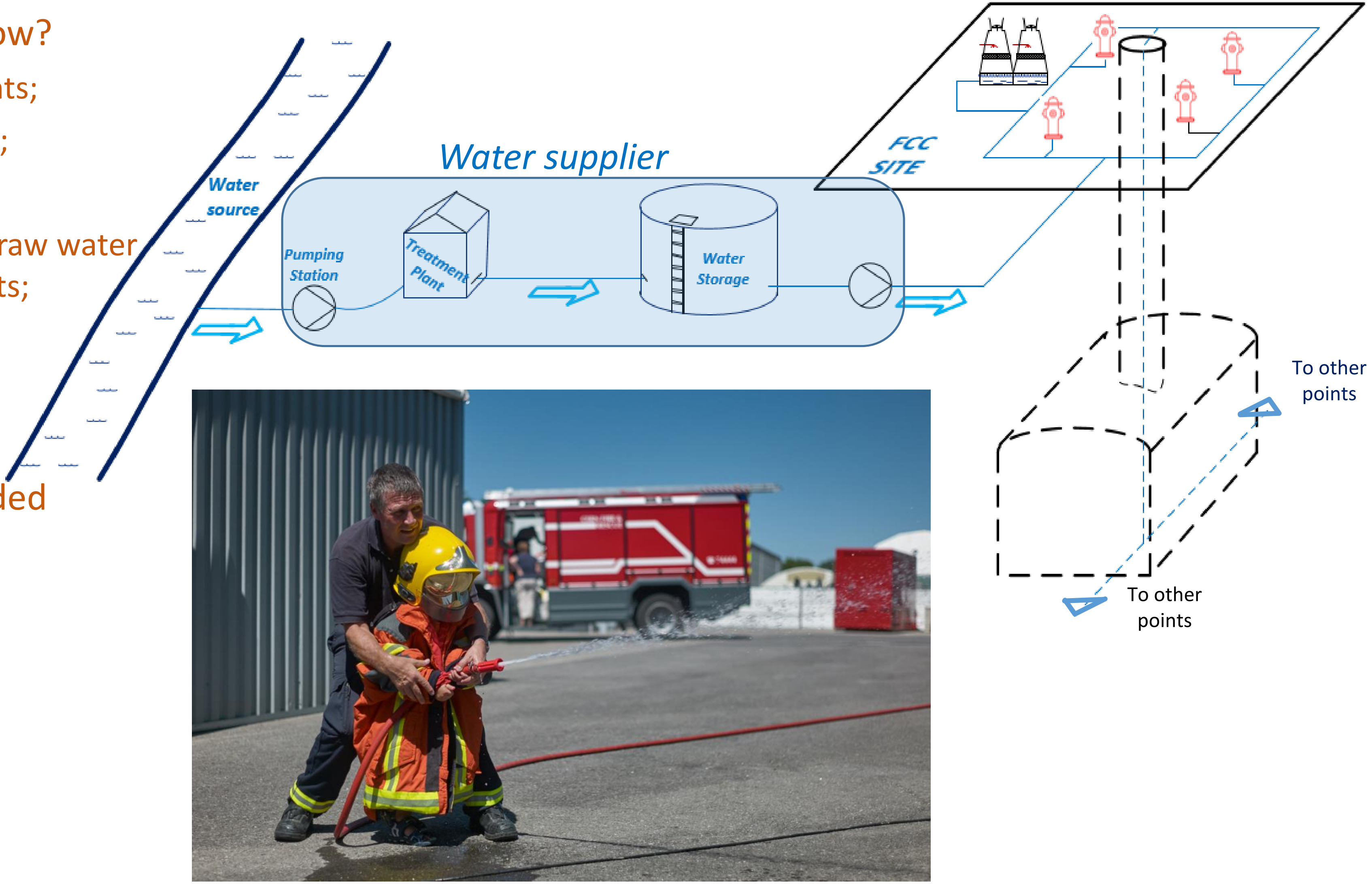
Wet Bulb T (ºC)		Avg	Std	Min	Max	95% L	95% H
Cold Season	Dec.	1.6	3.6	-13.1	12	8.7	-5.6
	Jan.	0.6	3.7	-18.7	11.6	8.1	[illegible]
	Feb.	0.9	3.8	-17.2	10.9	8.6	[illegible]
Mid Season	Mar.	3.5	3.7	-10.5	14.1	11.2	-3.5
	Apr.	6.8	3.3	-5.2	16.3	13.4	0.2
	Oct.	9.4	3.5	-4.6	17.7	16.3	2.4
	Nov.	4.4	3.6	-9.4	14.5	11.6	-2.9
Hot season	May	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Jun.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Jul.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Aug	[illegible]	[illegible]	[illegible]	22.7	21	[illegible]
	Sept	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

From: Weather Conditions in the Geneva Area, Doubek, EDMS 1714932 v 1.0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Normal CT	Maintenance	Maintenance	N_m+1	N_m+1	N_s	N_s	N_s	N_s	N_s	N_m+1	N_m+1	Maintenance
Back up CT	N_W+1	N_W+1	Maintenance	Maintenance	+1	+1	+1	+1	+1	Maintenance	Maintenance	N_W+1

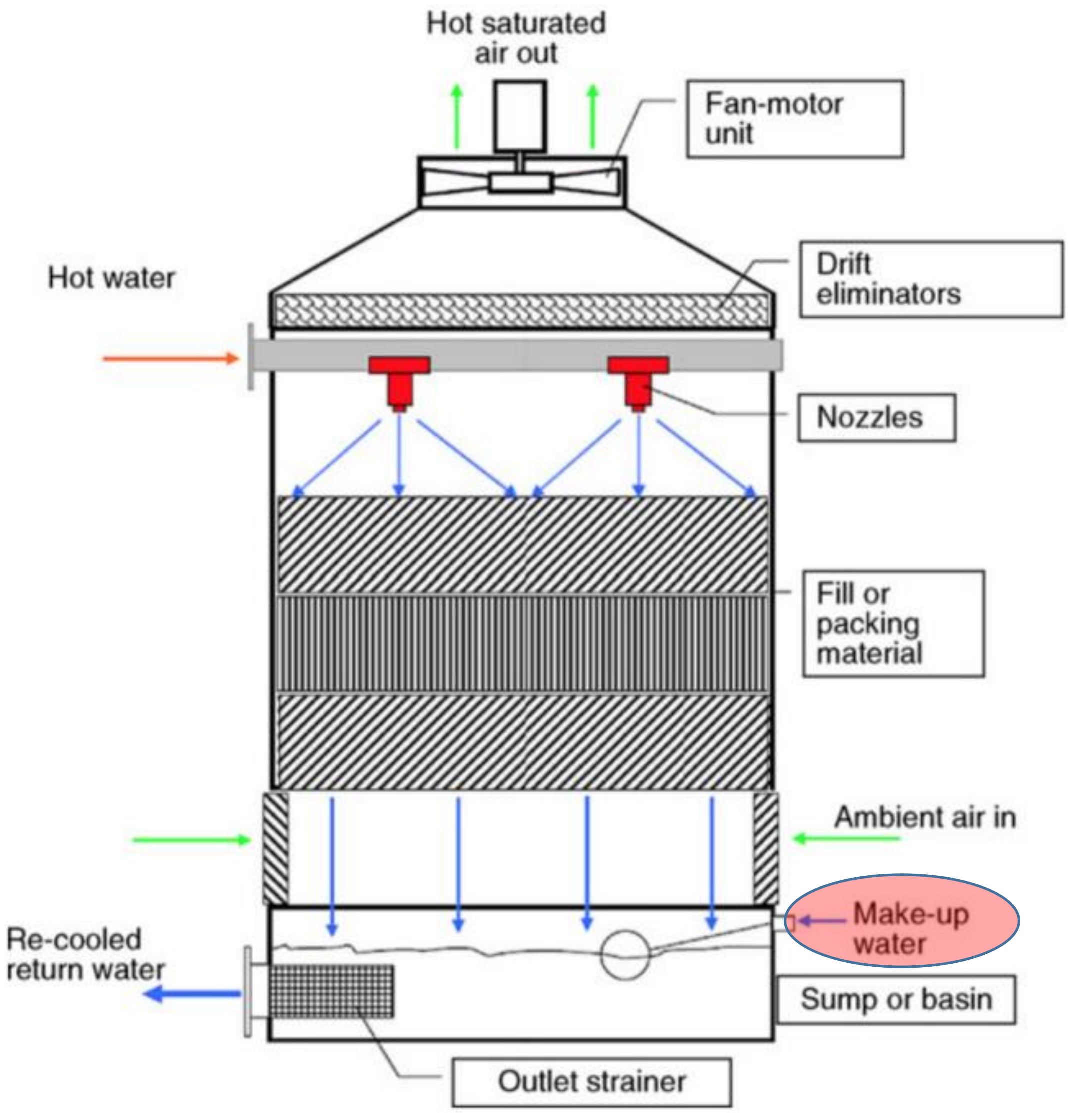
Raw water

- ❑ Raw water supply:
  - ❑ From which points ? What flow?
    - ❑ Position of the surface points;
    - ❑ Water availability per point;
    - ❑ Water need per point;
    - ❑ Maximum diameter of the raw water pipe in the tunnel and shafts;
    - ❑ FCC-hh needs.
  - ❑ Firefighting system;
  - ❑ Pumping Stations and distribution systems are needed



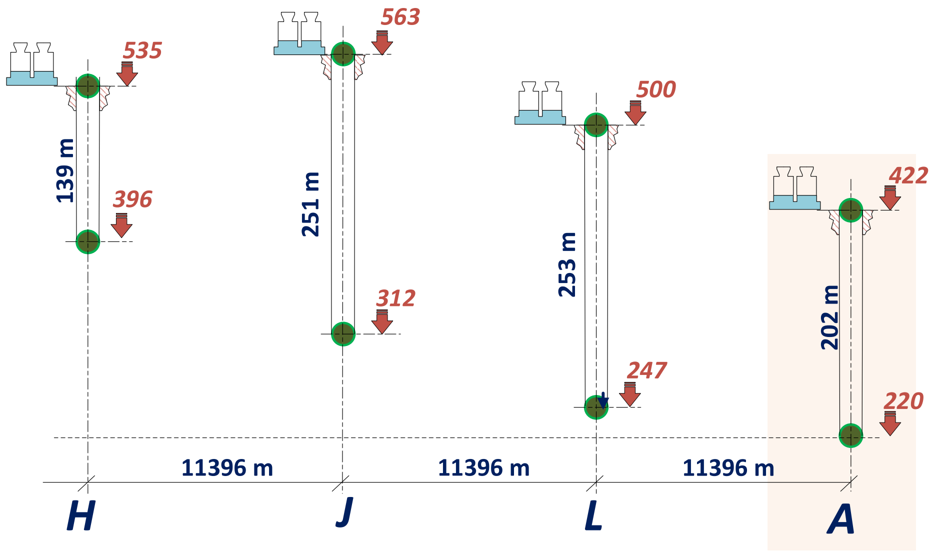
Raw water

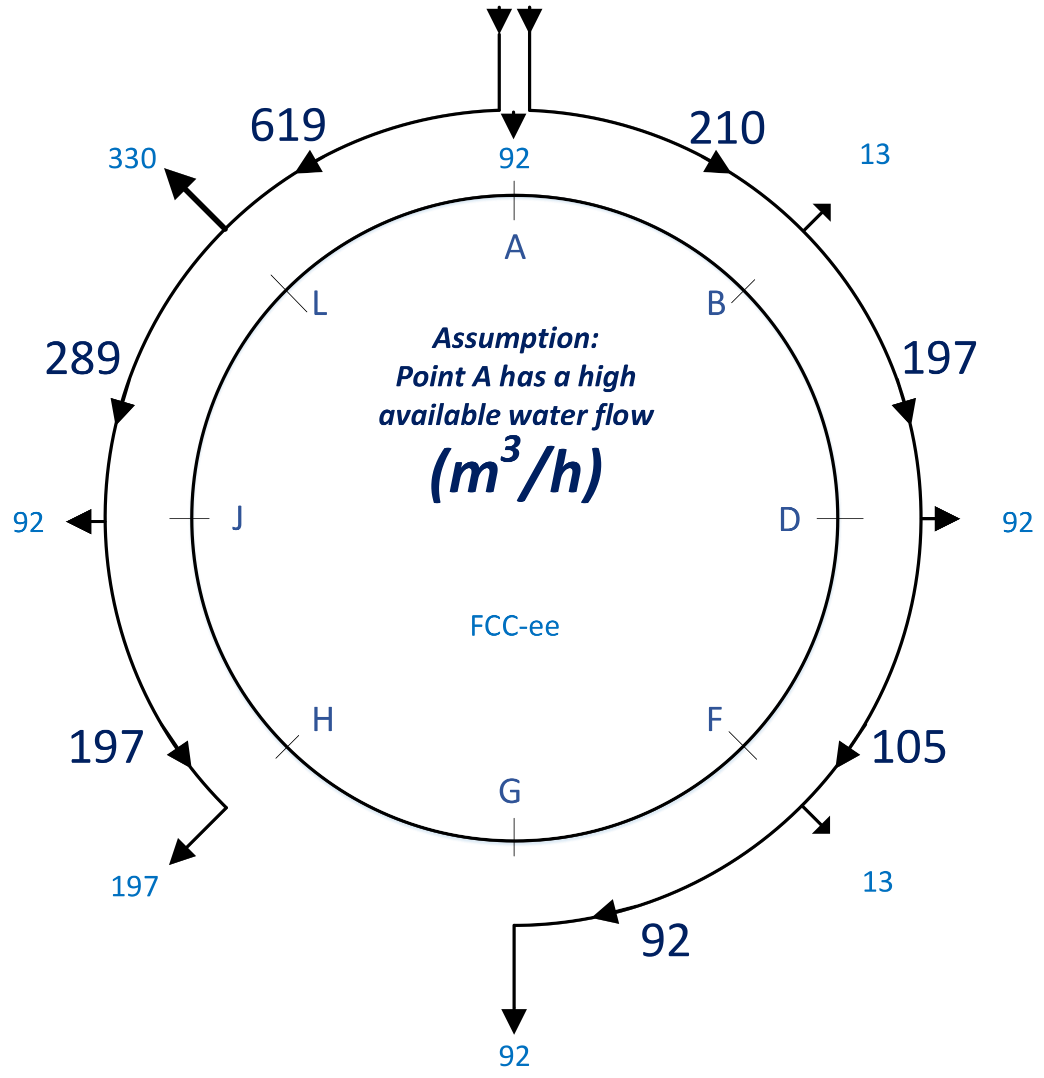
Make-up water needs (m^3/hr)		
Point	Classical cooling tower	Blowdown recycling
PA	140	92
PB	20	13
PD	140	92
PF	20	13
PG	140	92
PH	298	197
PJ	140	92
PL	500	330
TOTAL	**1,398**	**921**



Raw water: possible distribution

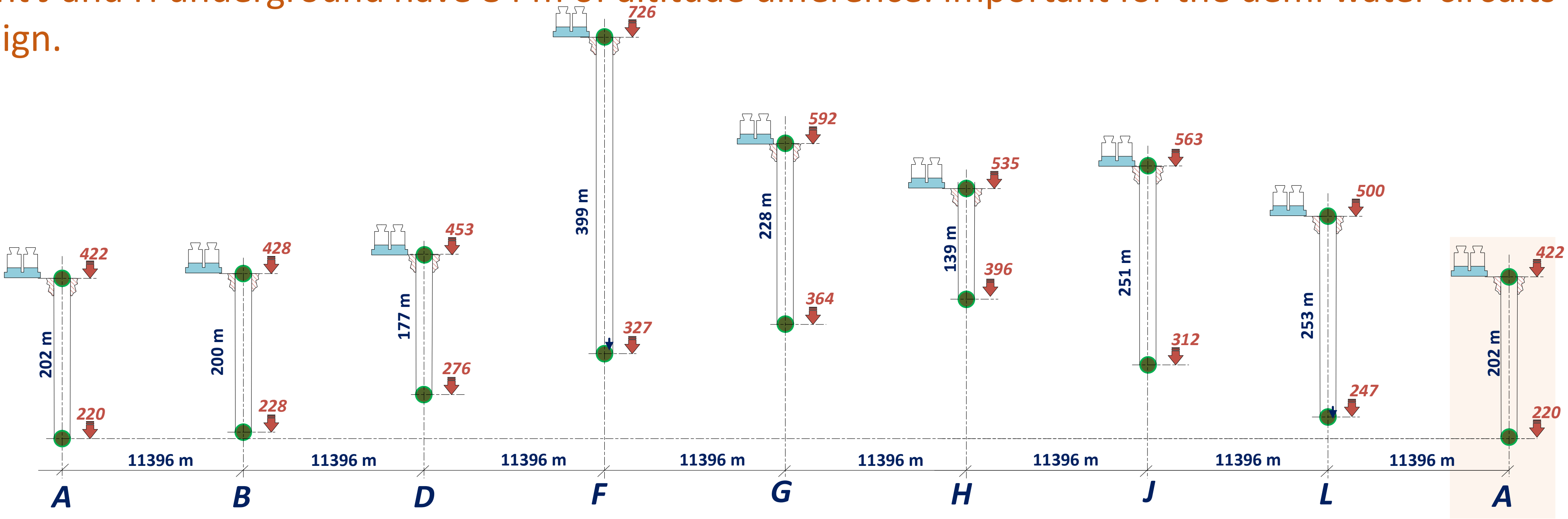
- Raw water supply:
  - Assumption: high flow available at point A, supplying raw water to all the surface points
    - DN450 pipe in the tunnel cross section: main drawback is the integration (pipe could also be used for firefighting purposes)
    - Need of a DN300 pipe (point L) in the shaft
    - Point A is at the lowest level of all: 141 m pressure difference between point A and J for example -> PN 16 is not enough
    - DN400, PN25 would be another option





Raw water: altitude to be considered

- Sumps and Raw Water transfer among points have to considered altitude differences;
- Surface points D and F have the highest altitude difference between two surface points : important to consider if sending water from D to F;
- Point F has the longest shaft : important to consider for dimensioning of sumps systems;
- Point J and H underground have 84 m of altitude difference: important for the demi water circuits design.



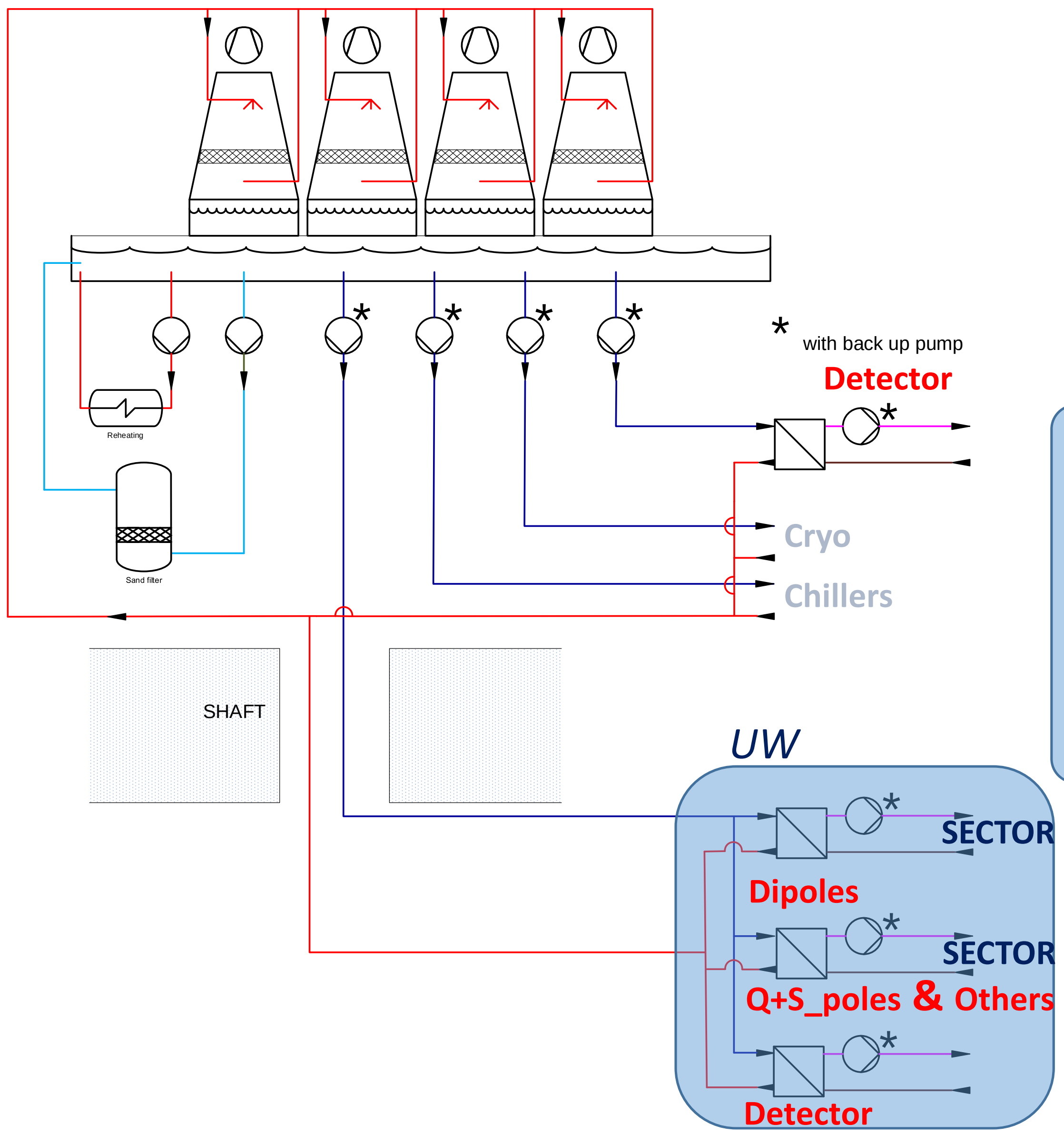
Demineralised Water

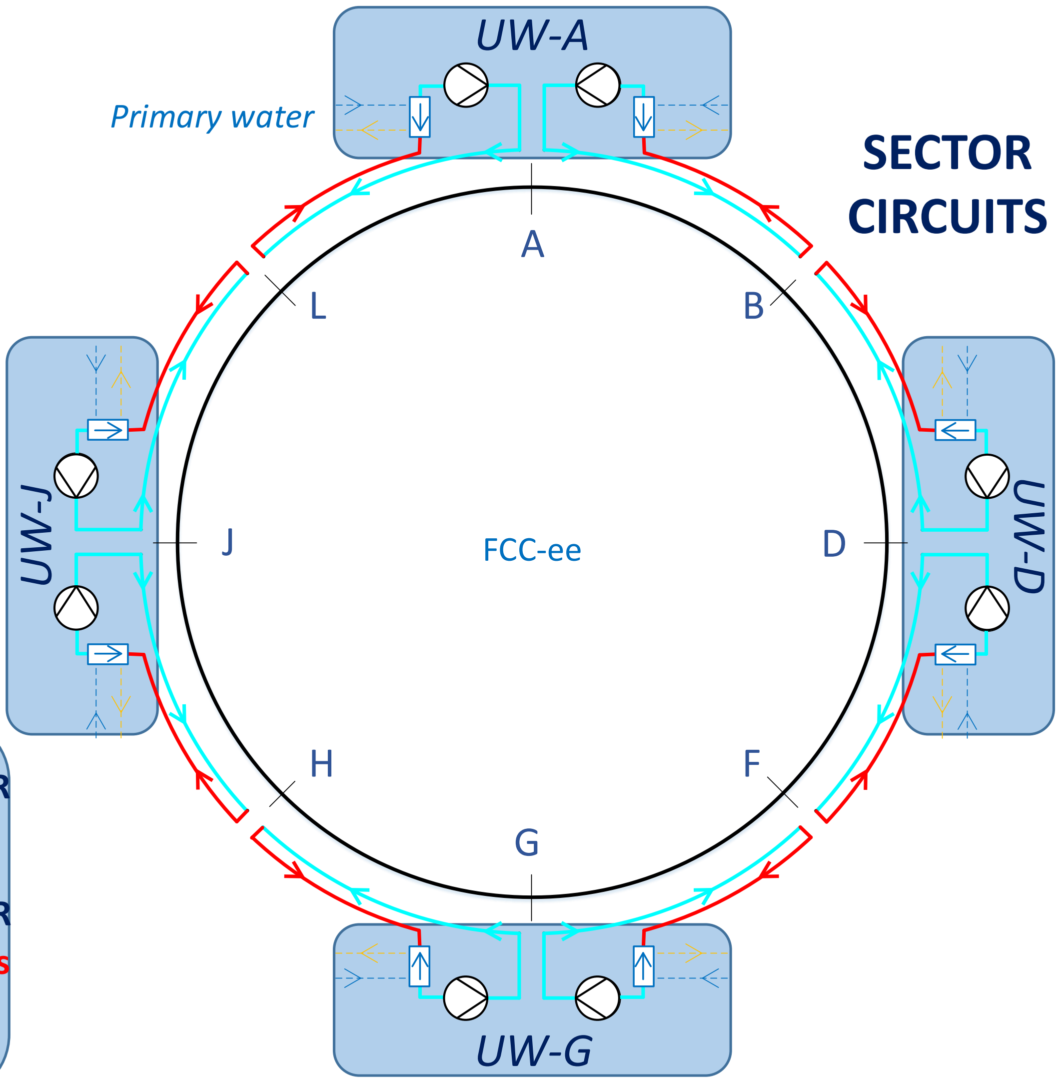
- Demineralised water
  - Production and distribution
    - Central production vs Local production vs On truck production
    - A mix of solutions to be used differently according to:
      - The need : first filling or coping with major or minor leaks
      - Access to the point (distance and access roads)
  - Main Cooling circuits in the FCC-ee underground
    - For copper circuits (quadrupoles, sextupoles, photon absorbers)
    - For aluminium circuits (dipoles)
    - RF cooling circuits
    - Experimental Area
    - … others ?
    - Pipes nominal pressure, circuit pressurisation, balancing, etc.

Demineralised Water Needs

FCC-ee COOLING POWER NEEDS FOR DEMINERALISED WATER CIRCUITS IN THE UNDERGROUND (MW)								
Point / Sectors	Magnets	Alcoves	Synchrotron Radiation Absorbers	Experimental Area	Power converters (for accelerator)	RF underground	Cryo RF	**TOTAL**
PA / L-A, A-B	2 x 6.6	2 x 0.9	2 x 12.5	0.5	1.05			**41.5**
PB					1.05			**1.05**
PD / B-D D-F	2 x 6.6	2 x 0.9	2 x 12.5	0.5	1.05			**41.5**
PF					1.05			**1.05**
PG / F-G G-H	2 x 6.6	2 x 0.9	2 x 12.5	0.5	1.05			**41.5**
PH					1.05	38.7	1.8*	**41.6**
PJ / H-J J-L	2 x 6.6	2 x 0.9	2 x 12.5	0.5	1.05			**41.5**
PL					1.05	58.1	1.8*	**60.9**

Demineralised Water Circuits at A, G, D, J





Chilled Water

- Chilled / Mixed water
  - Air cooling and dehumidification);
    - Temperature ranges, cooling power, location;
  - Production and distribution
    - Chiller alternatives;
    - Back up strategy;
    - Number of circuits.

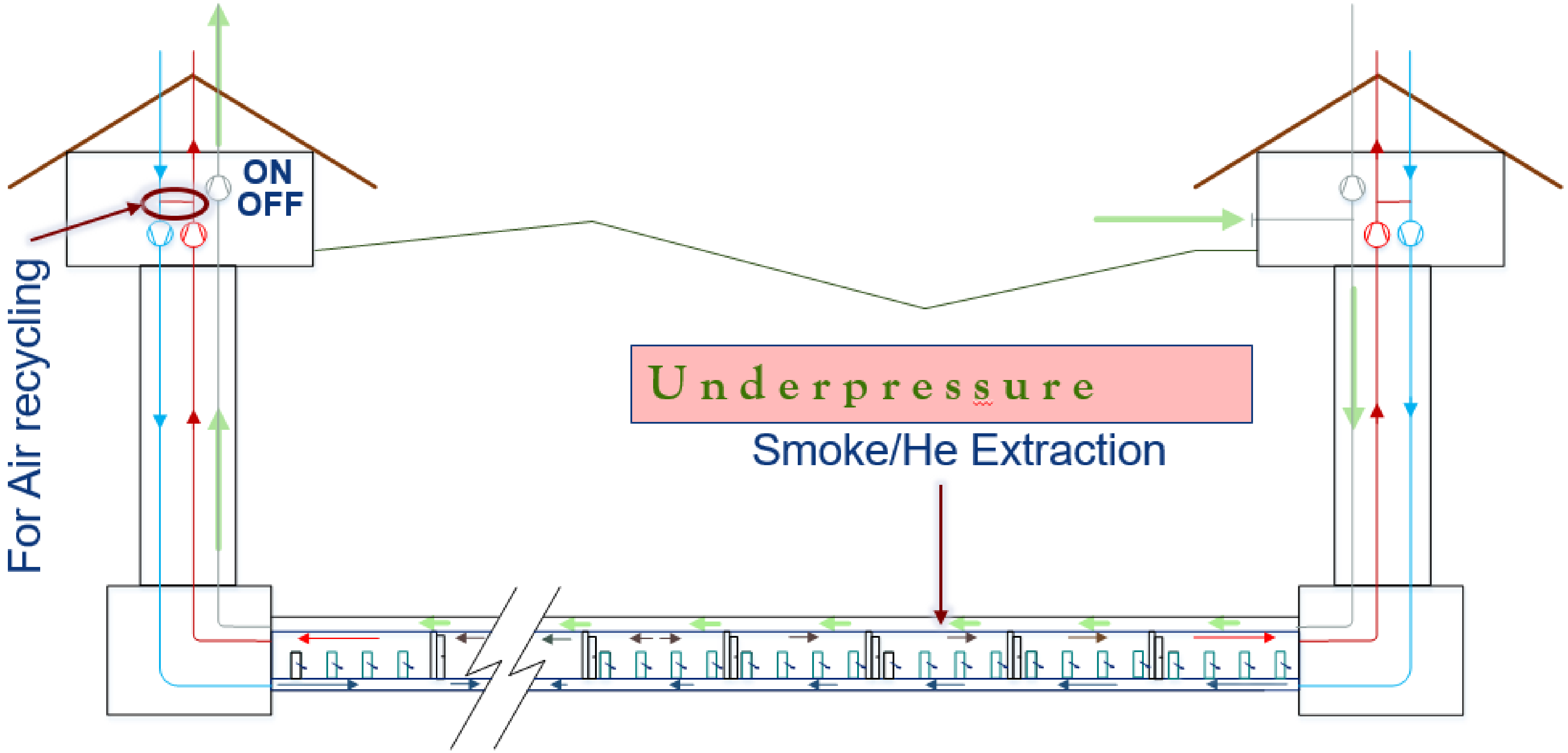
Point	Cooling power (kW)	Flow rate (m^3/h)	Number of chillers	Cooling power/ chiller (kW)
A	3,834	551	5	1,000
B	3,284	472	5	900
D	3,814	548	5	1,000
F	3,284	472	5	900
G	3,834	551	5	1,000
H	6,980	1,002	6	1,500
J	3,814	548	5	1,000
L	8,584	1,233	6	1,800

Tunnel Ventilation (Users' requirements)

- USER'S REQUIREMENTS (INPUT FOR CV)
  - Modes: Run, Flushing, Access;
  - Thermal loads to air from magnets, synchrotron radiation, electrical racks, cables, etc. ; (Run)
    - Location and value;
  - Air temperature constraints : maximum and minimum values (Run, Flushing, Access);
  - Maximum air speed (vibration) (Flushing);
  - Flushing mode:
    - Radiation rate at exhaust air and in the tunnel (HSE);
    - Delay between accelerator stop and access to the tunnel;
  - Air renewal rate, air quality requirements (Access);

Ventilation principle

- ❑ Air handling units configuration
- ❑ Back up units
  - ❑ Working strategy in case of breakdown



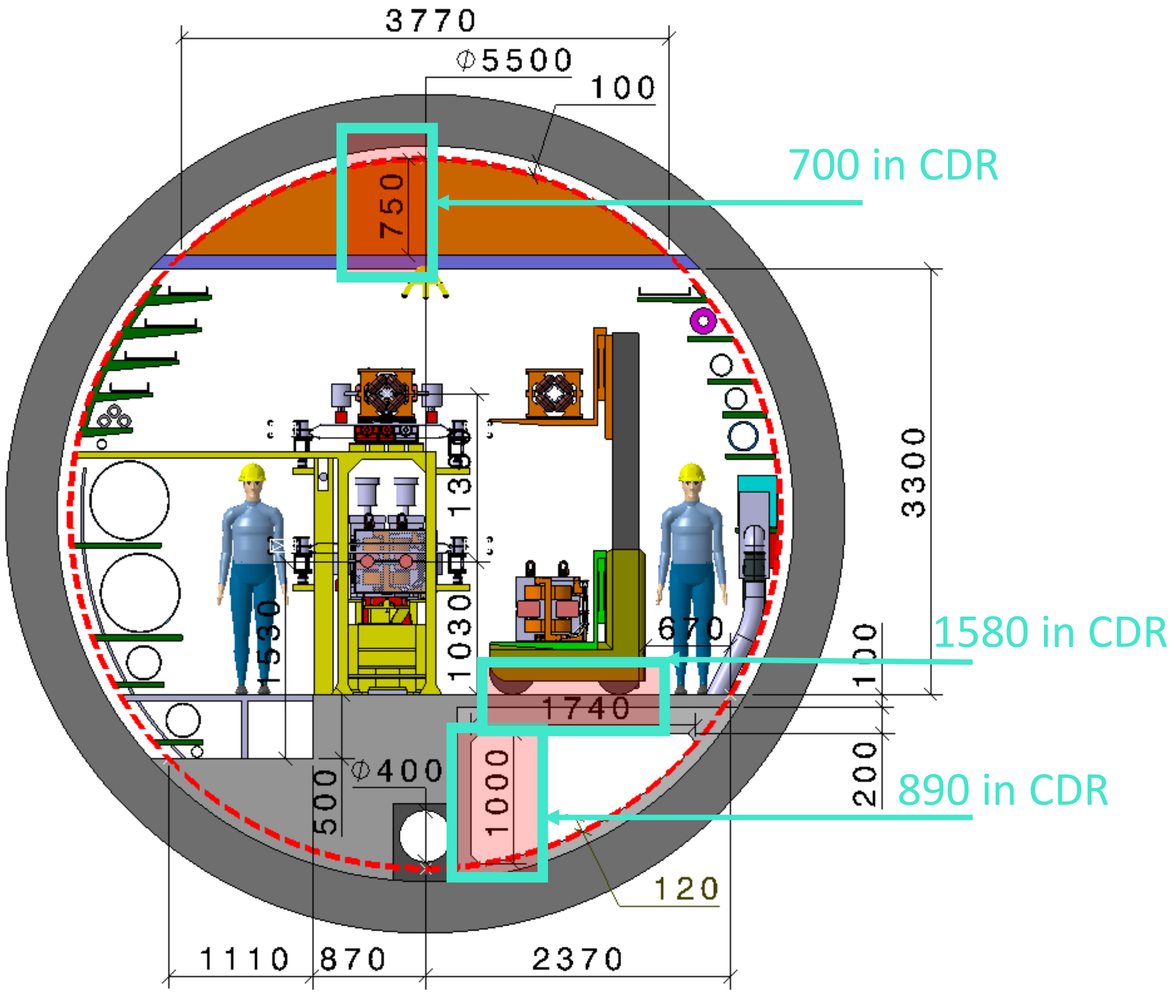
Tunnel Ventilation

General Input data	
Cross section area	15.2 m^2
Sector length	11,396 m
Max. Temperature (running conditions)	32°C (to be confirmed)
Max. dew point Temperature	12°C (to be confirmed

Compartment Input data	
Number of Compartments	26
Compartment length	440 m
Volume Compartment	6,688 m^3

Ventilation parameters	
Normal operation air flow per sector	2 x 27,000 m^3/h
Flushing air flow (longitudinal) per sector	100,000 m^3/h
Air supply points per compartment	4
Air flow per supply point (normal operation)	520
Time to complete air renewal (flushing)	1.7 h
Maximum air speed (normal operation – flushing)	0.5 m/s – 1.8 m/s
Cooling capacity in normal operation for ΔT = 15 K per sector	271 kW

Ventilation: new tunnel cross section



Heat loads on Air (kW)

On the surface

POINT	Cryogenics	Experimental Areas	General Services	Power Converters	Shaft pressurisation	Fresh air for underground areas	TOTAL
A		50	500		300	150	**1000**
B			500		150	50	**700**
D		40	500		300	150	**990**
F			500		150	50	**700**
G		50	500		300	150	**1000**
H	2,400 *		500	2,000 *	150	150	**5,200 (800 to CW)**
J		40	500		300	150	**990**
L	4,750 *		500	3,000 *	150	150	**8,550 (800 to CW)**

**** Extracted w/o chilled water***

In underground areas

POINT	Cryogenics	RF	Experimental Areas	Power Converters	Ventilation UW	TOTAL
A			50	220	200	**470**
B				220		**220**
D			40	220	200	**460**
F				220		**220**
G			50	220	200	**470**
H	180	3,200		220	200	**3,800**
J			40	220	200	**460**
L	180	4,800		220	200	**5,400**

… and for EACH SECTOR

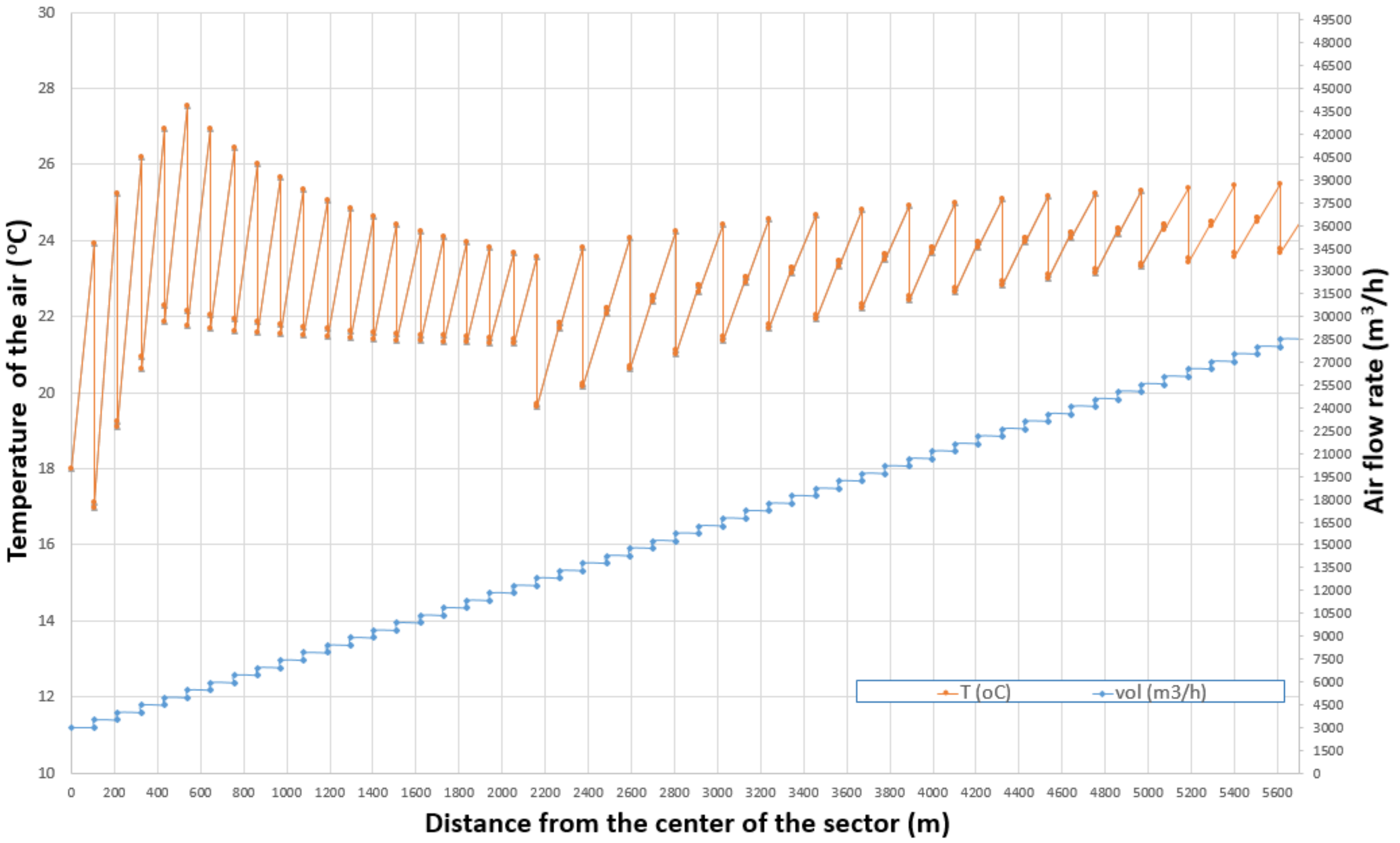
Magnets	Cables	Synchrotron radiation absorbers	TOTAL
352	1,763	250	**2,364**

Ventilation FCC-ee: Particular Aspects

- Extracting heat load without generating high temperature gradients (Survey constraints)
  - Heat loads distribution over the tunnel
  - Local cooling distribution over the tunnel

Example:

- Flow at the center of the sector: 3000 m^3/h
- Flow at an extremity of the sector: 28000 m^3/h
- Local cooling:
  - 4 x 7 kW,
  - 15 x 9 kW,
  - 17 x 16 kW
  - TOTAL Local air cooling: 435 kW
- TOTAL Main ventilation: 65 kW
- **TOTAL both systems: 500 kW**

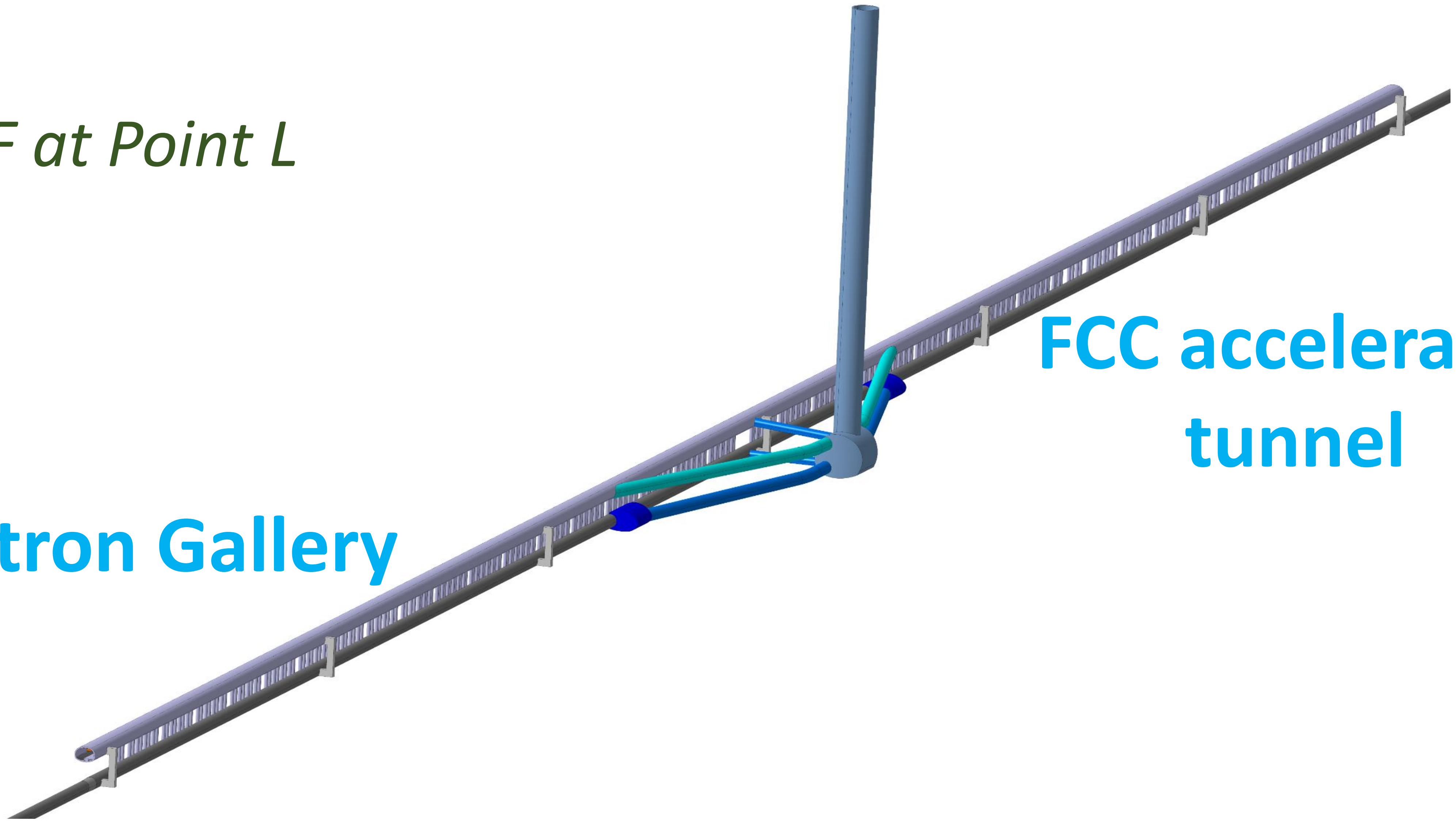


Other Ventilation Systems

- ❑Ventilation of the Experimental Caverns
- ❑Ventilation of the RF areas in the underground
- ❑Ventilation of the auxiliary areas
  - ❑Connecting caverns
  - ❑Alcoves
- ❑Pressure cascade between zones
  - ❑Sense and pressure difference between zones
  - ❑Air locks location

Other Ventilation Systems

RF at Point L



Ventilation of the RF areas in the underground of Pt. L

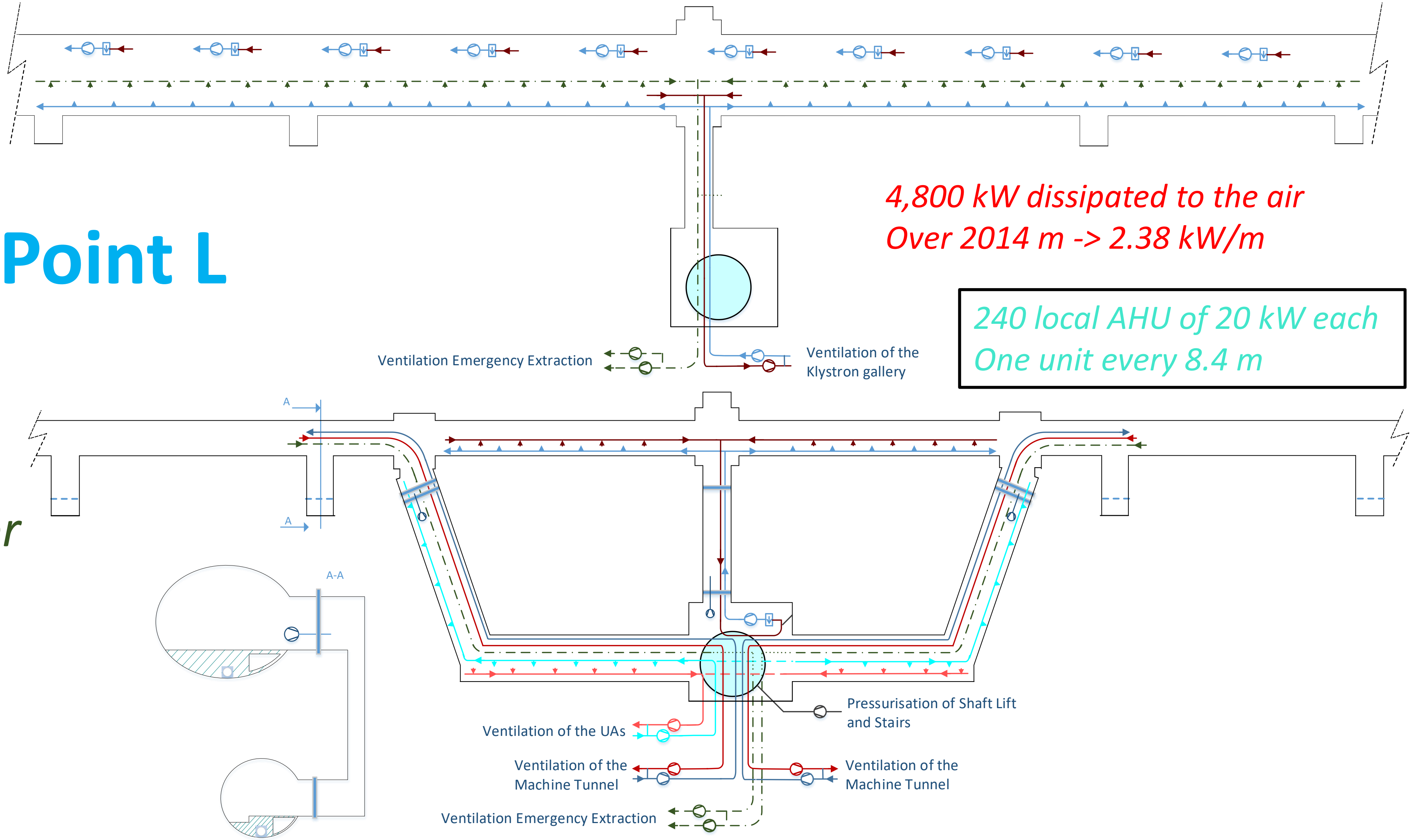
Level -1 Klystron Gallery

Point L

4,800 kW dissipated to the air
Over 2014 m -> 2.38 kW/m

240 local AHU of 20 kW each
One unit every 8.4 m

Level -2 Accelerator Tunnel



Ventilation of the RF areas in the underground of Pt. L

240 local AHU of 20 kW each
One unit every 8.4 m

Next Steps

- Get needed data from users and other services, including FCC-hh;
- Call for Tenders for consultants;
  - Selection criteria: Experience, Qualified Personnel, Software,…
  - Deliverables:
    - What :
      - Cost estimate of baseline design;
      - New design in search of efficiency;
    - Solid basis:
      - Calculations;
      - Previous experience;
      - Measurements.
- Accompany the consultants through the project and be a facilitator between them and the different stakeholders
- Produce documentation for the next Design Review.

Thank you
for your attention.