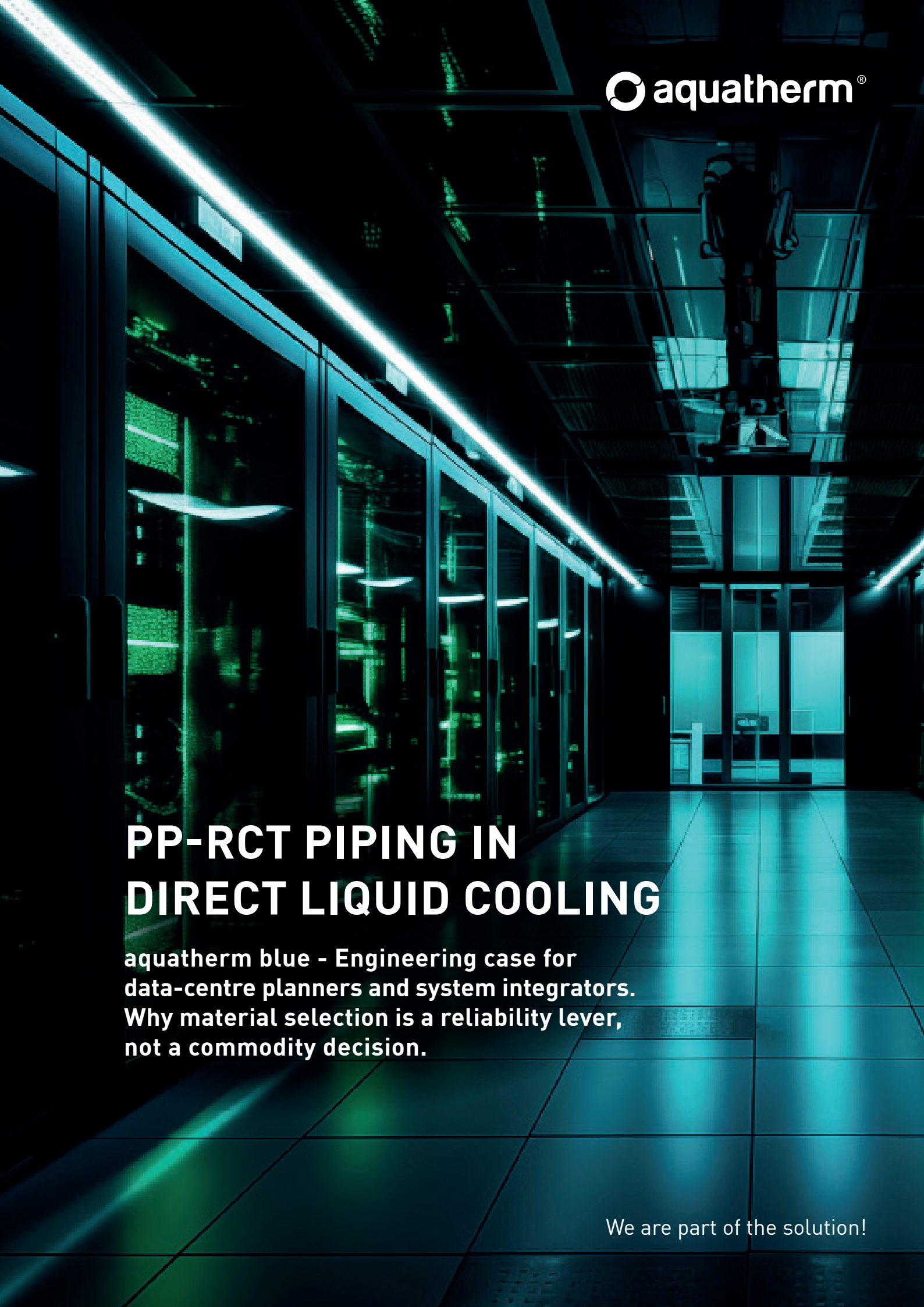


aquatherm®

PP-RCT PIPING IN DIRECT LIQUID COOLING

aquatherm blue - Engineering case for data-centre planners and system integrators. Why material selection is a reliability lever, not a commodity decision.

We are part of the solution!

The Density Inflection Point

~27 kW	50 -100+ kW	⩾ 30 kW	3,500 x
Avg. rack density, hyperscale 2025-26	AI & HPC clusters, operational today	Threshold: air cooling non-viable	Vol. heat capacity water vs. air

Above 30 kW/rack, air cooling requires mechanical investment that exceeds the cost of a DLC system - at lower reliability and higher PUE. At 60-100 kW/rack, air cooling is not a design option: it is a failure mode. Direct liquid cooling (DLC) with cold-plate loops is now the default for all AI and HPC infrastructure. The piping system that carries coolant between CDU and racks is not a background line item. It is a reliability-critical component in continuous contact with fluid that touches chip-level micro-channels.

The secondary fluid network (SFN / TCS) operates as a closed loop at 20-30 °C supply / 30-45 °C return under the facility water system (FWS). Every material decision in the SFN has a direct consequence on cold-plate performance, coolant life, CDU filter interval, and - at higher return temperatures - on waste-heat recovery viability.

The SFN Failure Chain - What Metallic Pipe Actually Costs

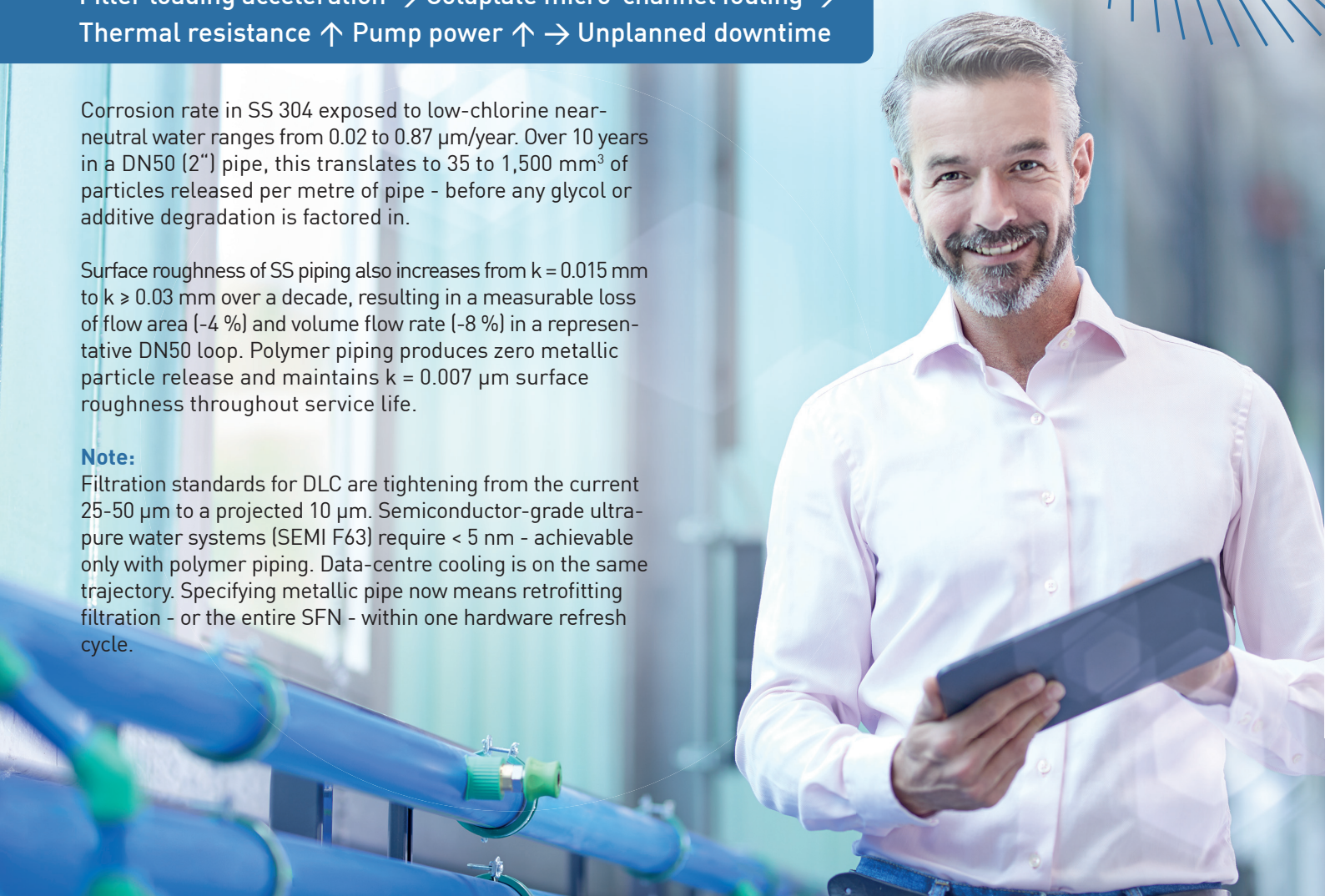
Stainless steel (SS 304/316) remains the default specification in many data-centre bids. The reason is trade familiarity, not engineering optimisation. In DLC loops, stainless steel introduces a failure chain that is rarely documented in tender documents but is consistently present in operational OPEX:

SS pipe corrosion → Metal-ion release into PG25/DI loop → Filter loading acceleration → Coldplate micro-channel fouling → Thermal resistance ↑ Pump power ↑ → Unplanned downtime

Corrosion rate in SS 304 exposed to low-chlorine near-neutral water ranges from 0.02 to 0.87 µm/year. Over 10 years in a DN50 (2") pipe, this translates to 35 to 1,500 mm^3 of particles released per metre of pipe - before any glycol or additive degradation is factored in.

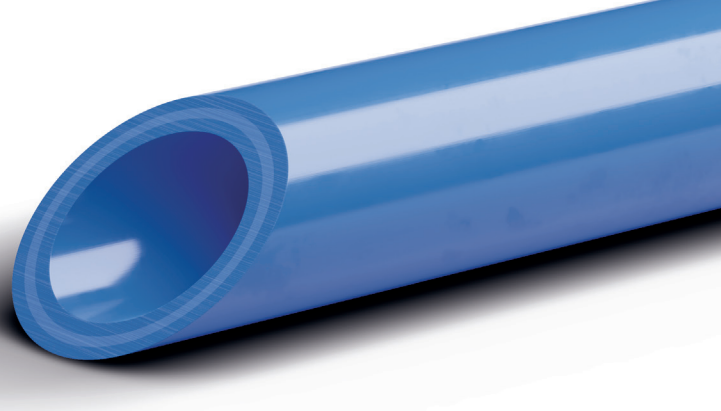
Surface roughness of SS piping also increases from k = 0.015 mm to k ⩾ 0.03 mm over a decade, resulting in a measurable loss of flow area (-4 %) and volume flow rate (-8 %) in a representative DN50 loop. Polymer piping produces zero metallic particle release and maintains k = 0.007 µm surface roughness throughout service life.

Note:
Filtration standards for DLC are tightening from the current 25-50 µm to a projected 10 µm. Semiconductor-grade ultrapure water systems (SEMI F63) require < 5 nm - achievable only with polymer piping. Data-centre cooling is on the same trajectory. Specifying metallic pipe now means retrofitting filtration - or the entire SFN - within one hardware refresh cycle.



PP-RCT vs Stainless Steel

Property	aquatherm blue (PP-RCT)	Stainless Steel SS 304 / 316
Metal-ion release into coolant	None	Confirmed, variable
Surface roughness (Ra)	0.007 µm - stable	0.1-15 µm, degrades
Galvanic / crevice corrosion risk	Zero	Present: requires inhibitors
Biofilm adhesion	Very low	High: promotes growth
Compatible with DI/ultrapure water	Yes: fully inert	No: DI water accel-erates corrosion
Passivation required precom-missioning	Not required	Mandatory (ASME B31.3 / ASTM A380)
Commissioning flush duration	Significantly reduced	Up to 8 weeks
Joining technology	Heat fusion (socket/ butt fusion) zero contamination	Orbital weld / press fit
Weld zone integrity	⩾ 96 % base material strength	Risk zone: HAZ degradation
Weight (relative, same DN)	~⅛ of steel	Heavy: structural load impact
Long-term hydro-static strength at ⩾ 40 °C	PP-RCT: superior vs PP-R at temp	N/A: metallic
EPD / EU sustain-ability reporting	Available - lower embodied carbon	Higher embodied energy (smelting)
Service life	50+ years	25-35 years (DLC conditions)



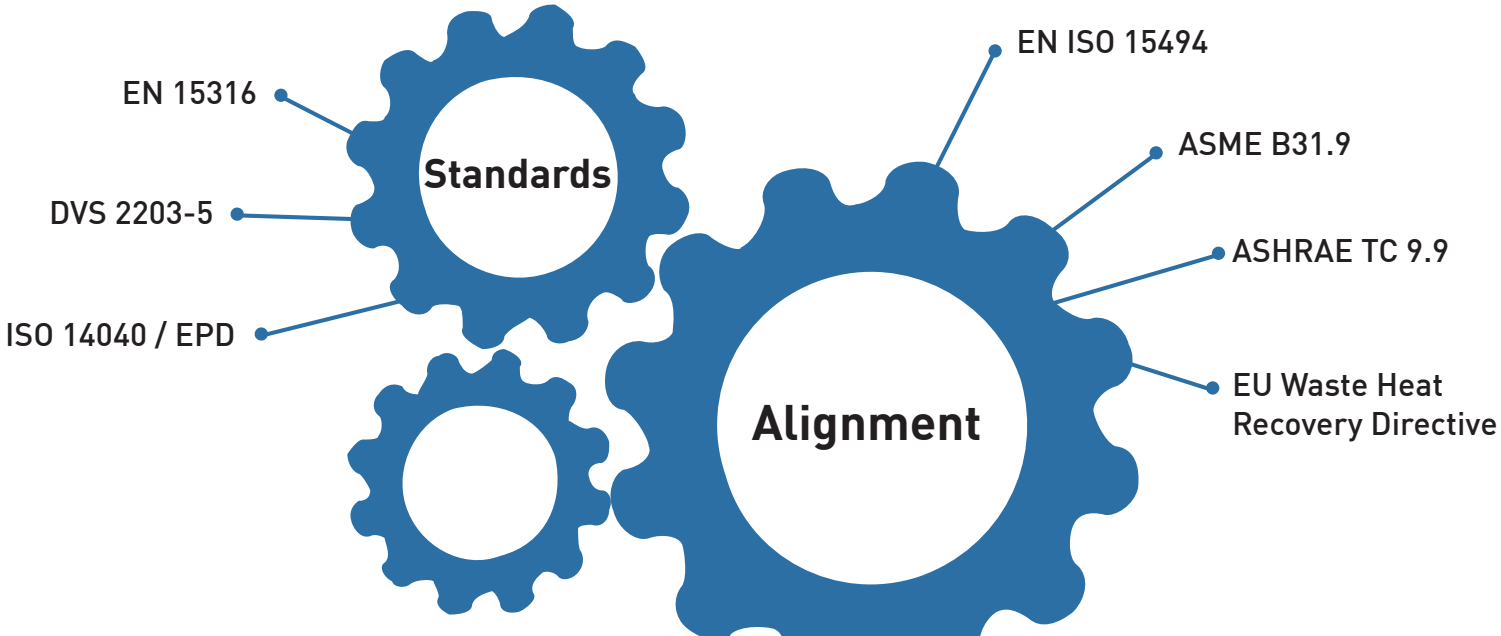
OPEX Model - 10-Year SFN Loop Cost

The following cost model covers a representative SFN loop of 3,785 litres – typical for a middensity DLC deployment. All figures reflect maintenance-only OPEX: coolant changes, filter changes, and chemical/labour testing. CapEx and energy costs are not included.

Cost Element	Stainless Steel (SS 304/316)	aqt. blue (PP-RCT)	10-Year Delta
Coolant changes	~ € 66,000	~ € 26,500	-60 %
Filter changes	~ € 17,500	~ € 1,800	-90 %
Maintenance & chemical tests	~ € 52,500	~ € 2,800	-95 %
Total 10-Year SFN OPEX	**~ € 136,000**	**~ € 31,000**	**- € 104,000**

Source: Operational cost model, aquatherm GmbH internal reference. Basis: 3,785 l closed SFN loop, PG25 coolant, ASHRAE TC 9.9 compliant DLC system, 10-year horizon.

Scale projection: At 10 MW IT load (approx. 100 x 100 kW racks), this translates to € 2.6-3.1 million in SFN OPEX savings over a single 10-year contract period – before accounting for reduced CDU filter downtime, fewer maintenance windows, and extended coolant media life. This figure is conservative; it does not include avoided unplanned outages from cold-plate fouling events.



Specification Parameters — How to Specify & Integrate

MATERIAL & PIPE

Parameter	Value	Note
Material designation	PP-RCT (beta-nucleated polypropylene random copolymer) - aqt. blue system	Confirmed, variable
Pipe series / SDR	SDR 11 (PN10-PN16 depending on temperature)	Confirm with operating temperature
Operating temp. range	-10 °C to + 70 °C continuous	PP-RCT maintains pressure rating at elevated temp. superior to PP-R
Max.operating pressure	Up to 16 bar at 20 °C (SDR 7.4)	Verify per SDR selected and fluid temperature

HYDRAULIC & THERMAL DESIGN PARAMETERS

Parameter	Value	Note
Design flow rate	1.5 - 2.0 l/min per kW IT load	Adjust for ΔT target; higher ΔT = lower flow = better WHR
Target ΔT (SFN)	10 - 15 °C	Higher ΔT reduces pump energy and enables waste-heat recovery
Supply/return temp. (SFN)	20-30 °C supply / 30-45 °C return	Return ≥ 35 °C enables direct district heat or absorption chiller input
Coolant compatibility	DI water, PG25, distilled water, low-additive blends	Fully inert – no inhibitor required to protect the pipe
Particle release	Zero metallic ions; inert polymer surface	Supports future tightening to < 10 µm filtration standard

JOINING

Parameter	Value	Note
Jointing method	Heat fusion (socket fusion / butt fusion) - no filler, no flux	Only approved method for SFN in DLC
Weld zone strength	≥ 96 % base material (DVS 2203-5 tensile test)	Minimum required: 60 % - aqt. exceeds by 36 pp
Weld traceability	Unique weld ID per joint, parameters logged	Enables NDT audit and QA documentation
Passivation required	None	No acid flush, no chromium oxide recovery protocol

INSTALLATION & COMMISSIONING

Parameter	Value	Note
Prefabrication option	Available - skid, manifold, rack-level assemblies	Reduces on-site labour and commissioning time
Commissioning flush	Significantly reduced vs SS (no passivation, no weld residue)	SS reference: up to 8 weeks (BSRIA guideline)
Structural load	~ ⅛ weight of equivalent SS pipe	Reduces ceiling load; enables longer bracketing spans

Specify PP-RCT (aquatherm blue)

- **SFN / TCS loops**
  CDU to rack cold-plate manifolds, all rack densities ≥ 30 kW
- **AI & HPC clusters**
  60-140 kW/rack where coolant purity is non-negotiable
- **DI water or low-additive coolant loops**
  only polymer piping is fully inert to ultrapure water
- **Waste-heat recovery return lines**
  30-45 °C return side; metallic contamination at these temperatures is unacceptable for district heating interfaces
- **Retrofit / brownfield DLC upgrades**
  lightweight, no weld passivation, fast commissioning
- **Prefabricated skid and rack-level assemblies**
  heat fusion enables off-site fabrication with full weld traceability

Lower priority / evaluate case-by-case

- **Pure FWS (facility side)**
  if no direct IT fluid contact and temperatures remain below 20 °C return; SS is established and adequate
- **Hybrid air/liquid transition zones**
  PP-RCT is still the forward-compatible choice but not operationally critical until rack density ≥ 30 kW
- **Extreme pressure applications (> 16 bar operating)**
  verify SDR against operating conditions; consult aquatherm engineering for non-standard configurations
- **Immersion cooling primary baths**
  dielectric fluid compatibility requires separate material qualification; aquatherm blue is not indicated here by default

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