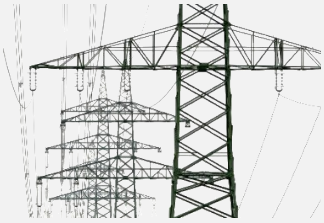
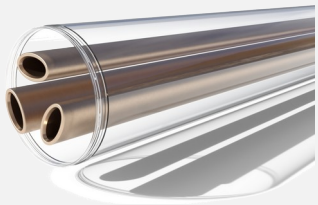
Technology comparison: pressurized air cable (PAC) vs. overhead line (OHL)

Pressurized air cable or overhead line? The following tables compare system parameters, economy, environment and society, and technical parameters[1]. All values are typical values for current products or projects and may vary depending on the application.

Comparison: system parameters

Topic	Overhead line 	Pressurized air cable (PAC) 
Main layout	Above ground along open corridors	Underground: microtunnel, pipe, or walkable tunnel.
Space requirement	Corridor 145 kV: 45–55 m Corridor 245 kV: 55–65 m Corridor 420 kV: 65–75 m	Pipe 145 kV: Ø 0.7 m Pipe 245 kV: Ø 1.0 m Pipe 420 kV: Ø 1.2 m
Construction along the line	Towers with foundation every ~300 m.	Pipe. Installation pit every ~300–500 m.
Line losses at I = 1000 A (scales with I^2)	145 kV: ~400 kW/km 245 kV: ~200 kW/km 420 kV: ~100 kW/km	145 kV: ~46 kW/km 245 kV: ~25 kW/km 420 kV: ~19 kW/km
Transmission power (typical values)	145 kV: ~500 MW 245 kV: ~1000 MW 420 kV: ~2000 MW	145 kV: ~800 MW 245 kV: ~1600 MW 420 kV: ~3600 MW
Large-scale use in the grid?	Yes. Current standard. New lines difficult to build.	Not yet. Complete replacement of the overhead line grid possible.
Operational experience	Extensive operational experience at all voltage levels	New technology. Experience similar to GIL or GIS.
Fault location	Distance protection, impedance method. Faults visible.	Integrated in pressure monitoring: indicates the gas compartment
Repair in case of fault	Simple repair. Faults visible. Standard spare parts.	Repair per busduct. Standard spare parts.
Repair duration	Several days	Several days
Parallel systems	Required for redundancy and high transmission power	Only for redundancy
Parallel systems (high currents)	Required for > 1500 A	Not required up to 4000 A

[1] Focus on voltage levels ≥ 145 kV. PAC can also be used at medium voltage.

Monitoring in operation	Additional monitoring systems, e.g. optical	Integrated pressure monitoring for all key parameters
Grounding	Ground wire along the line. Grounded at every tower.	Enclosure grounding at every available ground connection
Voltage upgrade 245 kV → 420 kV	Needed to reduce losses and increase transmission power	Optional to reduce losses and increase transmission power
Options for upgrade and grid enhancement	Thicker or more wires. A new line takes ~20 years.	Continuous expansion of the grid possible
Exposure (as critical infrastructure)	Exposed to weather, natural hazards, sabotage	Underground. Protected access. Rigid metallic enclosure.

Comparison: Economy

Topic	Overhead lines	Pressurized air cable (PAC)
Investment cost: Line plus installation (without approval costs)	145 kV: ~0.9 MCHF/km 245 kV: ~1.8 MCHF/km 420 kV: ~2.8 MCHF/km	145 kV: ~1.5 MCHF/km[2] 245 kV: ~2.9 MCHF/km 420 kV: ~4.3 MCHF/km
Cost of electrical losses over 40 years of operation at an average of 1000 A	145 kV: ~8.5 MCHF/km 245 kV: ~4.5 MCHF/km 420 kV: ~2.0 MCHF/km	145 kV: ~1.0 MCHF/km 245 kV: ~0.6 MCHF/km 420 kV: ~0.4 MCHF/km
Cost dependency on rated current	Strong dependency: higher current → higher cost	Low dependency: one base design for all currents
Economic limit to line length	Limited by the Ferranti effect to ~1000 km	No limit in modern grids with battery storage
Cost of reactive power compensation	Only in special cases.	None up to ~60 km length. Needed for > 60 km length.
Delivery time: Wires, towers, pipes	~Months	~Months
Cost for tower foundations / installation pits	~80 kCHF/foundation	~20 kCHF/pit
Operation and maintenance	High effort for inspection, tree cutting, animals, weather	Low effort. Integrated monitoring system.
Installation process	Build foundations & towers. String the conductors.	Lay pipe or drill microtunnel. Connect tubes and roll them in.
Public tendering	Standardized. Many established suppliers.	No product-specific tenders yet. Single supplier.
Expected lifetime	40 – 80 years	> 40 years (like GIS)

Comparison: Environment and society

Topic	Overhead lines	Pressurized air cable (PAC)
Approval process for line projects	Extensive and long (15–20 years). Highly project-specific.	Faster due to zero emissions. Existing corridors can be used.
Public acceptance	Poor for existing lines. None for	No reference yet. Expected to

[2] Typical values for long, mostly straight installations.

	new lines.	be better due to zero emissions.
External electric fields	Extensive electric fields	None: metallic enclosure.
External magnetic fields at 1000 A	< 100 µT in > 2.0 m distance < 1 µT in > 200 m distance	< 100 µT in > 0.3 m distance < 1 µT in > 3.0 m distance
Safety risks	Exposed high-voltage conductors	Large pressure vessel (~10 bar)
Exposure to vandalism, sabotage, terrorism	Countrywide exposure. Impossible to protect.	Minimal: underground, locked access, rigid enclosure
Emissions to environment	EM fields, noise, visual impact, heat	Minimal emissions.
Effects on neighborhood	High. Devaluation of nearby properties and landscapes.	Minimal effects.
Hazards to the environment	Birds, aircraft, paragliders, wildfires	None
Recycling at end of life	Metals (wires, towers) recyclable.	~99 % aluminum. Fully recyclable.

Comparison: Technical parameters

Topic	Overhead lines	Pressurized air cable (PAC)
Design and installation	Simple design. Installation at height.	Simple assembly. Installation in pits with special tools.
Insulation medium	Ambient air (~1 bar)	Pressurized air (~10 bar, dry)
Conductor material	Aluminum with steel core	Aluminum
Field stress on conductor during operation	~1.5–2.0 kV/mm	2–4 kV/mm
Shielding / enclosure	None	Thick aluminum enclosure
Fire protection	Metallic wires and towers: Non-flammable.	Metallic enclosure: Non-flammable.
Conductor cross section (Single wire or bundles)	240–1600 mm^2	Minimum: 2200 mm^2 Maximum: 5000 mm^2
AC resistance at operating temperature	145 kV: ~100 mΩ/km 245 kV: ~50 mΩ/km 420 kV: ~25 mΩ/km	145 kV: 12 mΩ/km 245 kV: 10 mΩ/km 420 kV: 8 mΩ/km
Capacitance per km	145 kV: ~11 nF/km 245 kV: ~10 nF/km 420 kV: ~14 nF/km	145 kV: ~50 nF/km 245 kV: ~50 nF/km 420 kV: ~50 nF/km
Charging current per km per phase at rated voltage	145 kV: ~0.28 A/km 245 kV: ~0.44 A/km 420 kV: ~1.07 A/km	145 kV: ~1.30 A/km 245 kV: ~2.22 A/km 420 kV: ~3.81 A/km
Reactive power, 3 phases	145 kV: ~0.07 MVAr/km 245 kV: ~0.19 MVAr/km 420 kV: ~0.78 MVAr/km	145 kV: ~0.33 MVAr/km 245 kV: ~0.94 MVAr/km 420 kV: ~2.80 MVAr/km

Reactive power compensation	Only in specific cases	Required for > 60 km length
Changing directions (lateral, vertical)	Straight wires between towers. ≤ 60° angles at towers.	Continuous bending or 90° angles if required
Internal arc fault withstand	Yes. But arcing, noise, and heat emission.	Yes. Arc remains inside; pressure stays below bursting pressure.
Temporary overloading	Very good. High-temperature conductors up to 350 °C, with high losses.	> 1 h at 1.5 × I_r. Good heat dissipation via metal enclosure.