Increasing Investments in District Energy Systems in Cities – a SE4All Energy Efficiency Accelerator – City of Belgrade

Final results of the interconnection study

Founded in ***2007***

Spinoff *of the Operations Research (OR) team of the University of Bologna*

We develop ***solutions and services*** *based on* ***analytics & optimization***

Young and highly skilled team: everyone holds a ***STEM Master Degree*** *or* ***PhD***

We are
Data scientists,
Business consultants,
Operations Research specialists,
SW application dev. professionals

We work for ***medium and large enterprises*** *in* ***several industries****: Energy, Waste, Logistics, Retail, etc.*

We participate in the ***scientific community*** *and active in fostering “****OR in Practice****”*

2 main Offices

Consultancy services and Commercial HQ in ***Bologna***

SW Factory in ***Cesena***

Proposition in DH

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GENERATION	DISTRIBUTION	DEMAND
DSS for Energy production optimisation	**DSS for network development optimization**	**Advanced analyctis methodologies**

DSS for Energy production optimisation

- H/P/C demand **forecast**
- Operational **scheduling** of production assets to **optimise operating margin**
- **Budgeting** and what-if yearly analyses
- System integration for **automatized process**

DSS for network development optimization

- **Investment (NPV)** optimisation analysis
- **Technical** and **economic** decision drivers integration
- Advanced built-in **thermal-hydraulic** model for feasibility check

Advanced analyctis methodologies

- Heat consumption **patterns and profiling**
- Identification and qualification of **user clusters**

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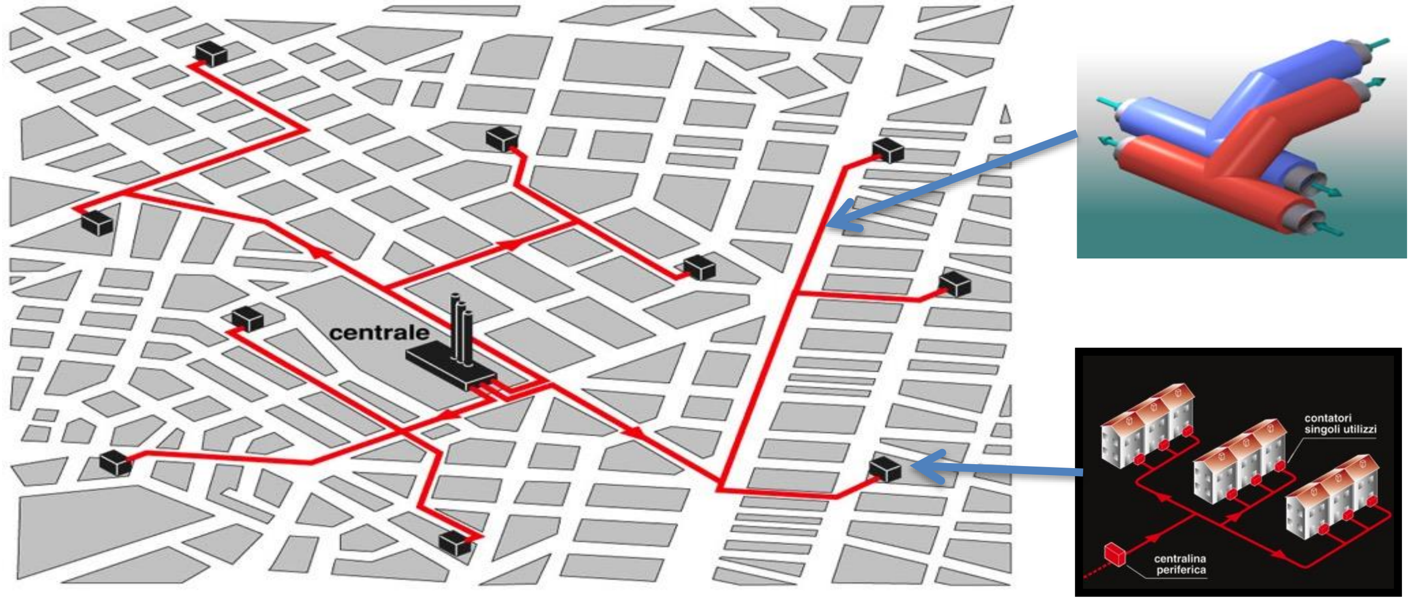
Network Optimisation

The Business Objective



How to plan Distric Heating (& Cooling) **Network Development** roadmaps that maximise the Return on Invested Capital (i.e. **Net Present Value**), amongst countless possible options?

Challenges for Decision Making

- **Geographic** dimension of the business issue (overcome Excel)
- Economic value assignments on **costs and revenues s**ides
- Several possible potential **scenarios** (what-if)
- **Thermal-hydraulic** feasibility analysis of proposed solutions

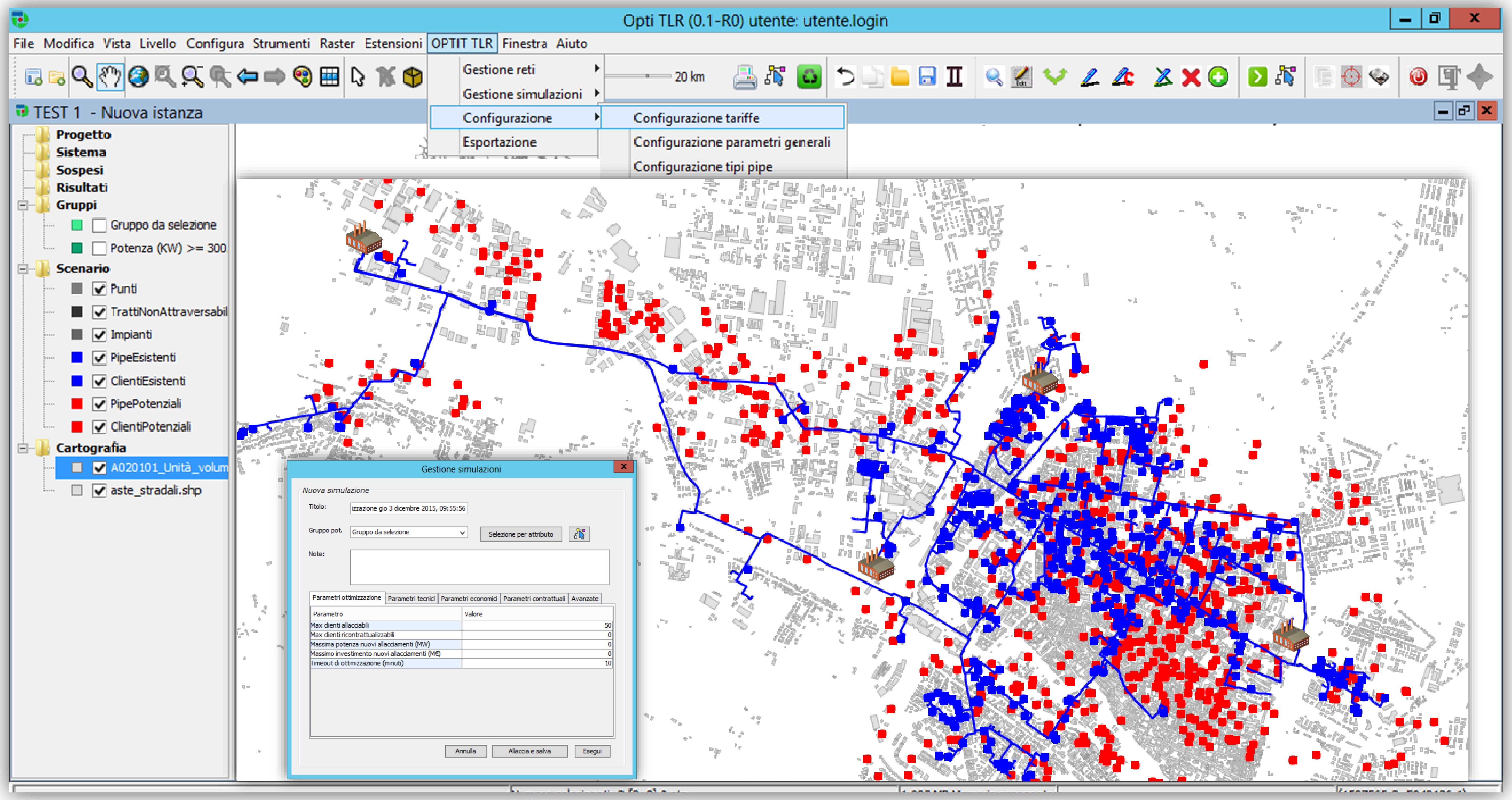
DHN: the solution

Existing & potential **pipings**

Existing & potential **users**

Existing & potential **plants**

Import + Puntual **editing** /drawing



Advanced **Scenario** Mgmt

€

Tariffs & **Capex/Opex**

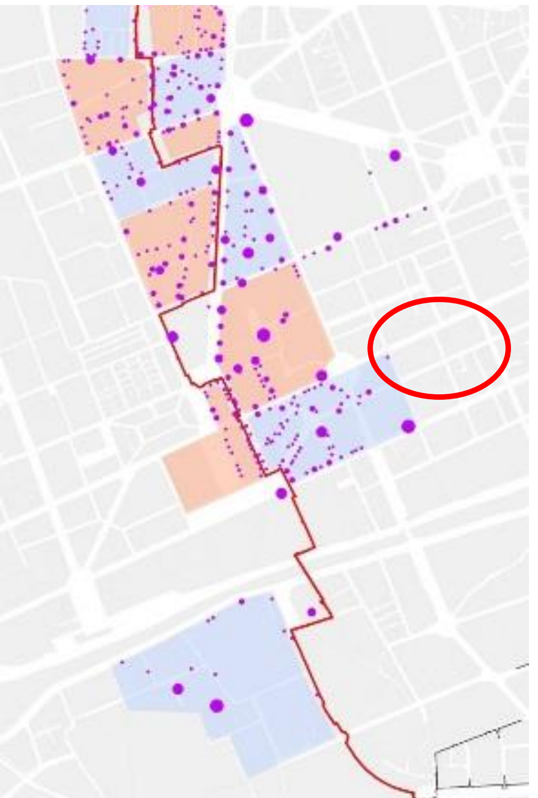
Technical constraints

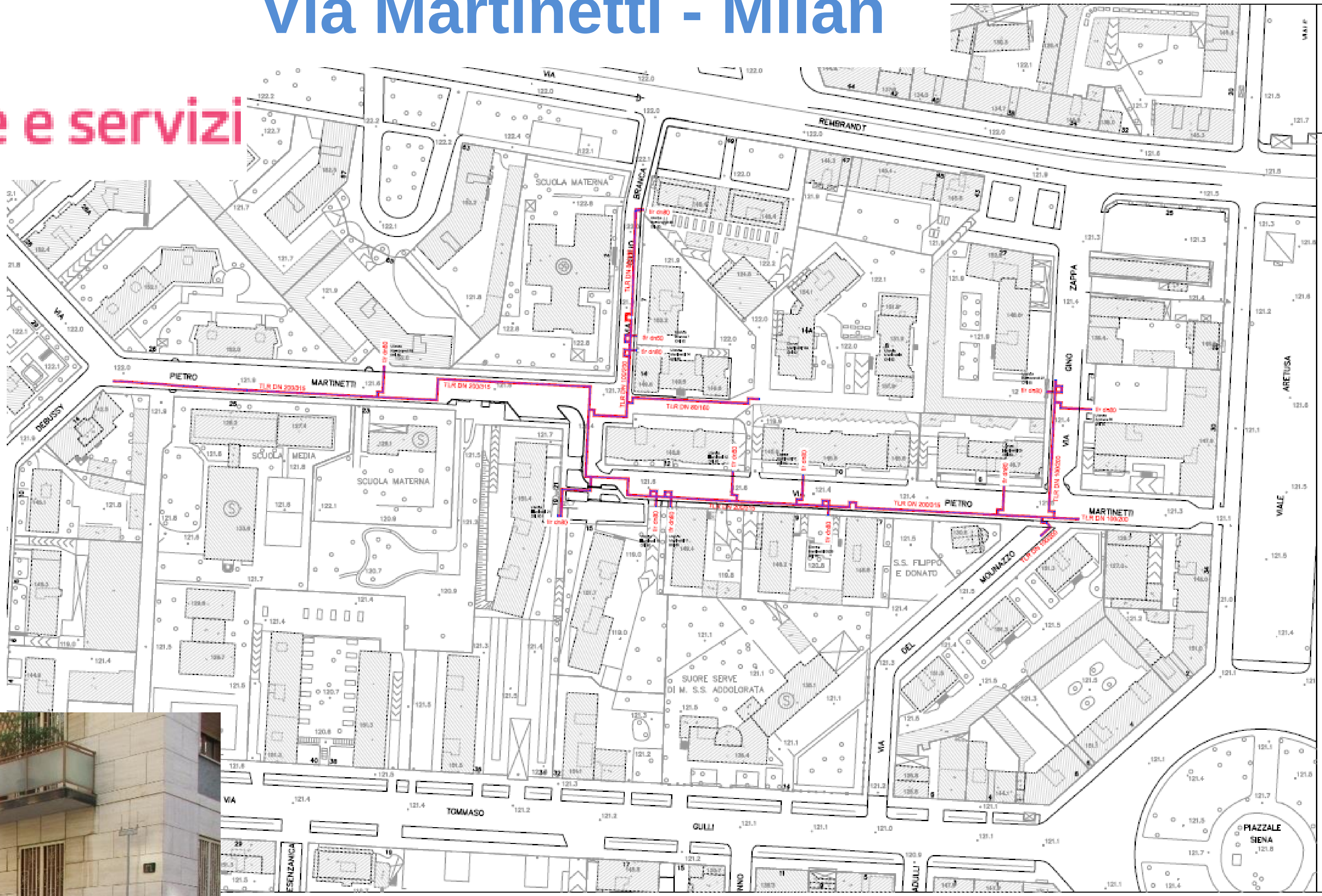
Financial parameters

Application Case

a2a calore e servizi

Via Martinetti - Milan





Decision Drivers Integration

The tool allows for a smooth transition of the feasibility and commercial analysis from Marketing & Sales to Engineering department

The Challenge in Beograd

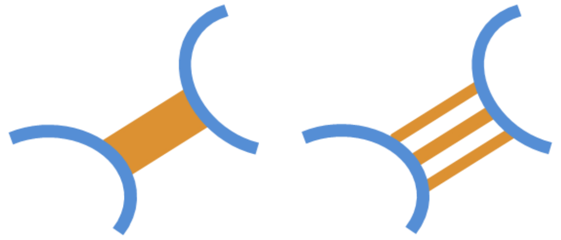
The key challenge: identify the optimal new network configuration

Analyze the technical and economic impacts of:

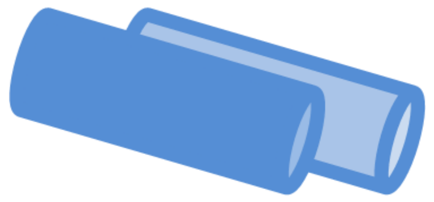
- Different interconnection scenarios
- Different piping sizing
- Integration of “carbon-friendly” energy sources

Goal: striking a balance between complex conflicting options

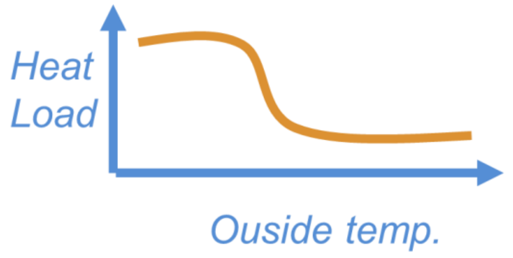
Technical and operational drivers → **One vs multi-connections**



Resource allocation → **Renovation vs New Piping**



Reference load to dimension → **Peak vs Low Load**



Project approach

Preliminary Activities → **Calibration** → **Scenarios Analyses** → **Delivery**

- **Preliminary Activities**: Data collection and integrity checks
- **Calibration**: Calibration and validation of Optit's hydraulic model
- **Scenarios Analyses**: Technical/economic analyses of identified investment scenarios
- **Delivery**: Shared assessment + Full report & Cartographic representation of the results

Reliable characterization of the current DH system

Benchmark 3 major sub-grids:
Optit's model vs **SCADA** vs **TERMIS**

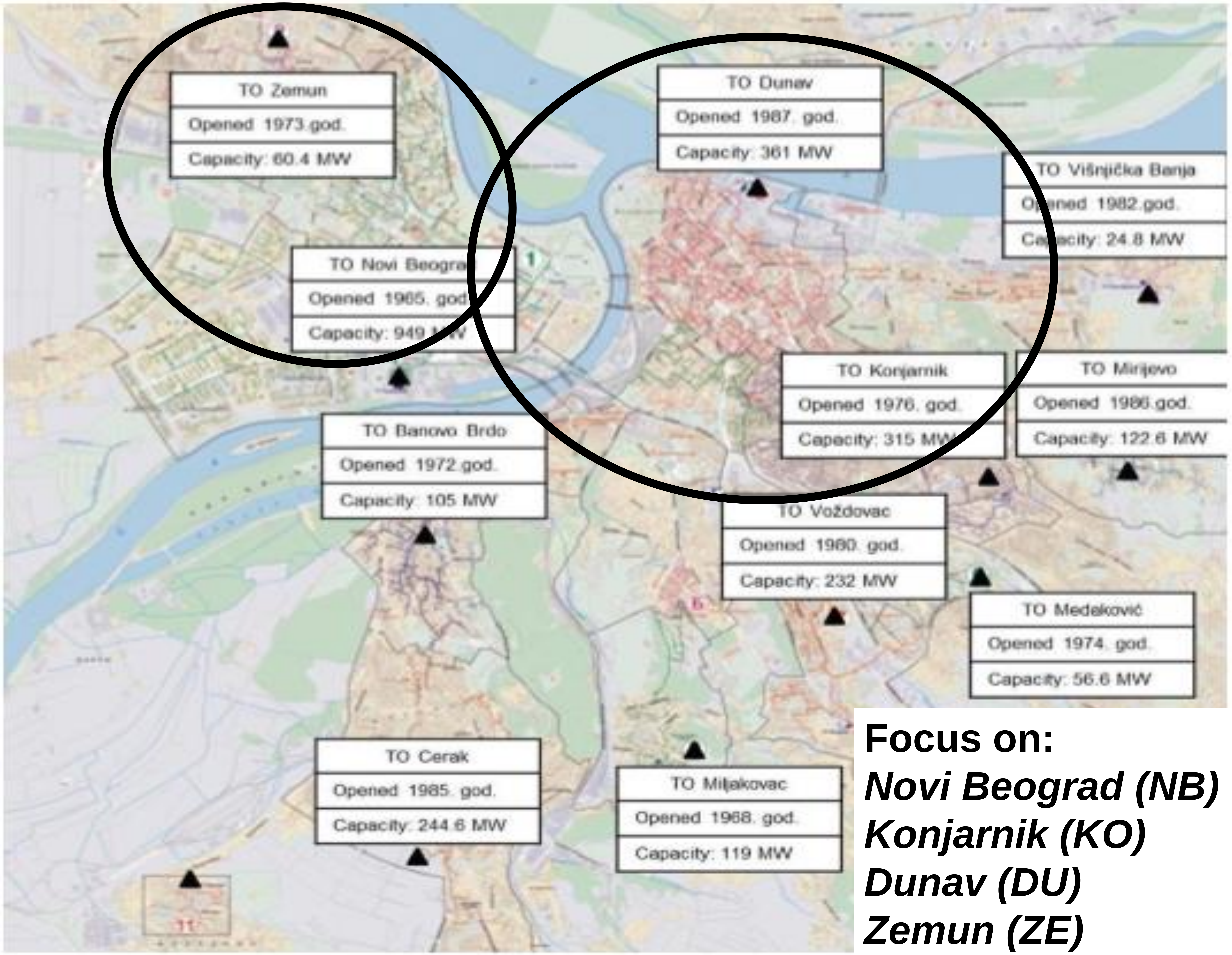
DEVIATION < 0.3 BAR FOR SUPPLY/RETURN PRESSURES & ΔP AT THE PLANT AND THE NETWORK'S CRITICAL POINTS

Pre-feasibility studies of investment scenarios

Produced, analyzed and discussed several (100+) **potential new network configurations**

TECHNICAL AND ECONOMIC INSIGHTS ON FUTURE INFRASTRUCTURE INVESTMENT AND ITS IMPACT ON OPERATIONS

Subject of the analyses



Focus on:
Novi Beograd (NB)
Konjarnik (KO)
Dunav (DU)
Zemun (ZE)

NEW CONFIGURATIONS

- **Perspective users** to be connected (**88 MW$_{th}$**)
- New (greener) sources: **Thermal Plant** (**600 MW$_{th}$**) + **WTE** (**56 MW$_{th}$**)
- **Planned construction** of new piping and **refurbishing of existing** piping

TWO SEPARATE HYDRAULIC SYSTEMS

- **Temperature-based regulation** (always nominal flows) in **Zemun-NB**
- **Flow-based regulation** (demand-dependent flows) in **Konjarnik-NB-Dunav**

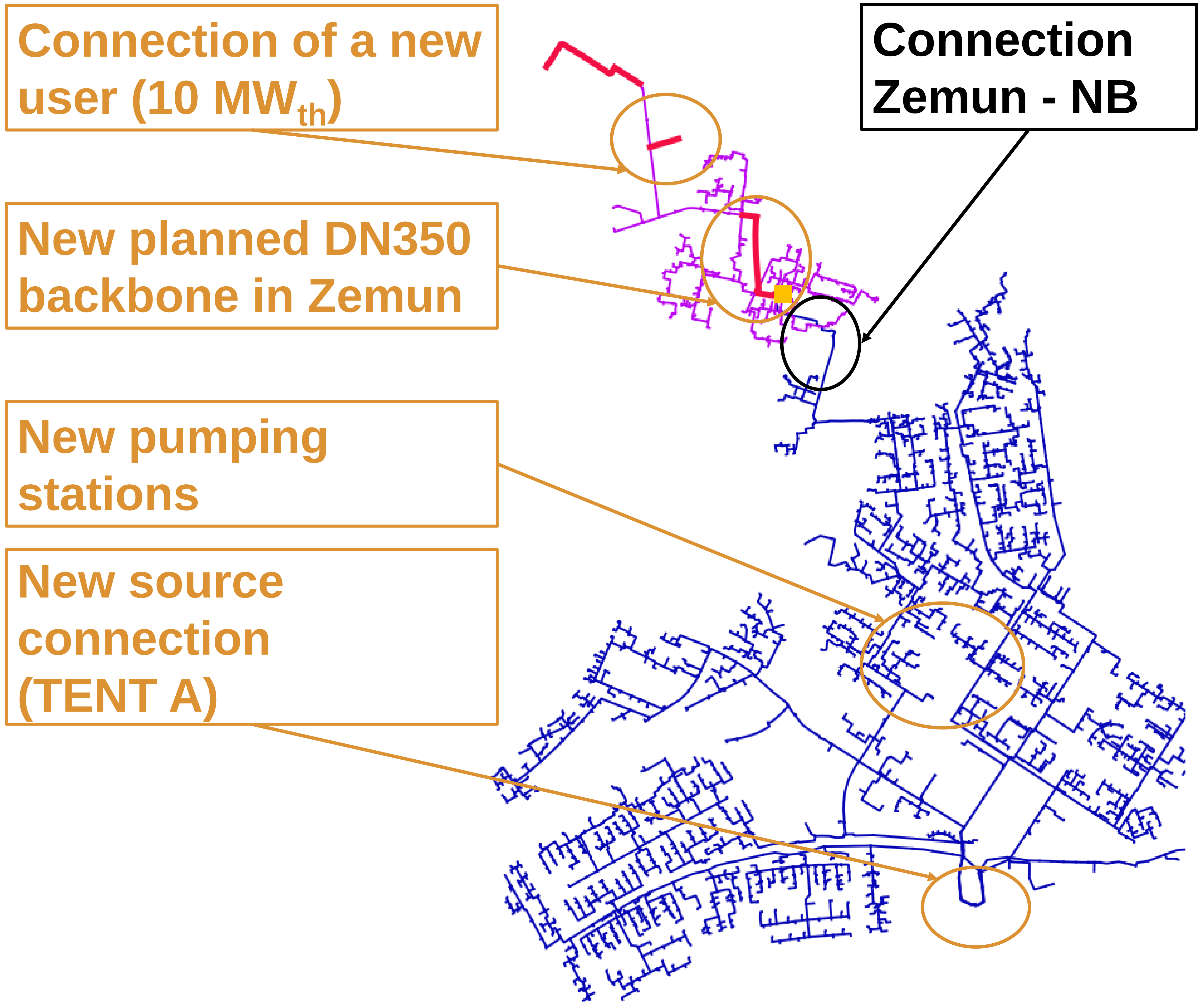
New Zemun-NB system

Work conditions

- The connection must **allow Zemun's current plant shut-down**
- NB backbones have **tight constraints** (supply and Δp at the plant)
- The new network configuration must follow the **current hydraulic regime** and temperature-based regulation
- Can leverage upon presence of **closed pipes** linking NB main backbones

Investigation Lines

- **Hydraulic balance** of new network configurations
- Impact of opening **different sets of closed pipes**
- Impact of the **new backbone construction**
- Characterization of the **pumping stations**



New Zemun-NB system

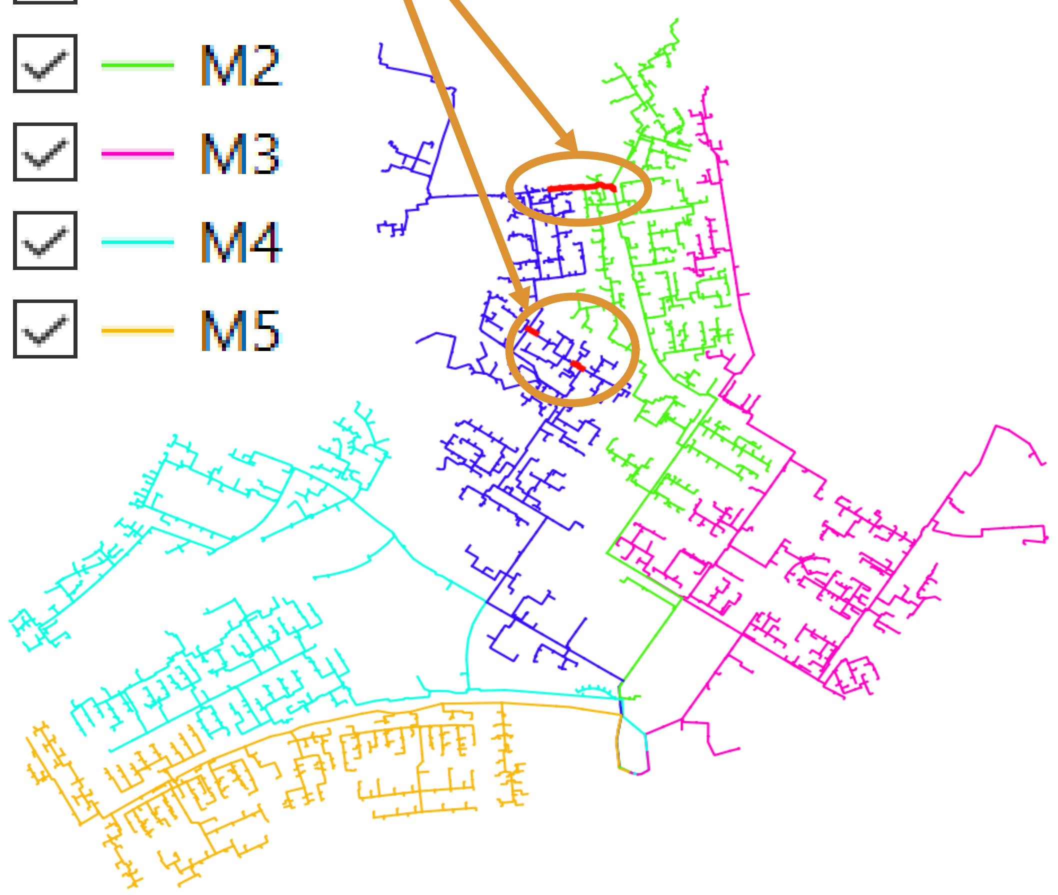
New network configuration

Δp distribution

- 1.0-1.5 bar
- 1.5-2.0 bar
- 2.0-3.0 bar
- > 3.0 bar

New opened pipes

- M1
- M2
- M3
- M4
- M5



Improved system resiliency

Zemun-NB connection

Hydraulic Benchmark

		Baseline	Simulated Scenario
Zemun	flow (kg/s)	246	0
Novi Beograd M1	flow (kg/s)	613	769
Novi Beograd M2	flow (kg/s)	643	800
Novi Beograd M3	flow (kg/s)	729	729
Novi Beograd M4	flow (kg/s)	638	638
Novi Beograd M5	flow (kg/s)	601	601
Novi Beograd M1-5	p supply (bar)	9.89	10.09
	p return (bar)	1.90	2.05
	Δp (bar)	7.99	8.04

NB-ZE CONNECTION

YEAR	NEW USERS SUPPLY (MWh)	NEW USERS REVENUE (RSD)	NEW USERS PRODUCTION COSTS (RSD)	PRODUCTION COSTS SAVINGS (RSD)	INVESTMENT COSTS (RSD)	AMORTIZATION (RSD)	GROSS FLUX (RSD)	TAXATION (RSD)	NET FLUX (RSD)	ACTUALIZATION COEFFICIENT (%)	ACTUALIZED VALUE (RSD)	CUMULATED ACTUALIZED VALUE (RSD)
0	11 000	137 177 400	-64 705 882	931 764 706	-126 908 705	-4 230 290	1 000 005 933	-150 000 890	727 326 629	100.0%	727 326 629	727 326 629
1	11 000	137 177 400	-64 705 882	931 764 706	0	-4 230 290	1 000 005 933	-150 000 890	854 235 334	98.0%	837 485 621	1 564 812 250
2	11 000	137 177 400	-64 705 882	931 764 706	0	-4 230 290	1 000 005 933	-150 000 890	854 235 334	96.1%	821 064 334	2 385 876 584
3	11 000	137 177 400	-64 705 882	931 764 706	0	-4 230 290	1 000 005 933	-150 000 890	854 235 334	94.2%	804 965 034	3 190 841 618
4	11 000	137 177 400	-64 705 882	931 764 706	0	-4 230 290	1 000 005 933	-150 000 890	854 235 334	92.4%	789 181 406	3 980 023 024
5	11 000	137 177 400	-64 705 882	931 764 706	0	-4 230 290	1 000 005 933	-150 000 890	854 235 334	90.6%	773 707 260	4 753 730 284
6	11 000	137 177 400	-64 705 882	931 764 706	0	-4 230 290	1 000 005 933	-150 000 890	854 235 334	88.8%	758 536 530	5 512 266 814
7	11 000	137 177 400	-64 705 882	931 764 706	0	-4 230 290	1 000 005 933	-150 000 890	854 235 334	87.1%	743 663 265	6 255 930 078
8	11 000	137 177 400	-64 705 882	931 764 706	0	-4 230 290	1 000 005 933	-150 000 890	854 235 334	85.3%	729 081 632	6 985 011 710
9	11 000	137 177 400	-64 705 882	931 764 706	0	-4 230 290	1 000 005 933	-150 000 890	854 235 334	83.7%	714 785 914	7 699 797 624
10	11 000	137 177 400	-64 705 882	931 764 706	0	-4 230 290	1 000 005 933	-150 000 890	854 235 334	82.0%	700 770 504	8 400 568 128
11	11 000	137 177 400	-64 705 882	931 764 706	0	-4 230 290	1 000 005 933	-150 000 890	854 235 334	80.4%	687 029 905	9 087 598 033
12	11 000	137 177 400	-64 705 882	931 764 706	0	-4 230 290	1 000 005 933	-150 000 890	854 235 334	78.8%	673 558 731	9 761 156 764
13	11 000	137 177 400	-64 705 882	931 764 706	0	-4 230 290	1 000 005 933	-150 000 890	854 235 334	77.3%	660 351 697	10 421 508 461
14	11 000	137 177 400	-64 705 882	931 764 706	0	-4 230 290	1 000 005 933	-150 000 890	854 235 334	75.8%	647 403 624	11 068 912 085
15	11 000	137 177 400	-64 705 882	931 764 706	0	-4 230 290	1 000 005 933	-150 000 890	854 235 334	74.3%	634 709 436	11 703 621 521
16	11 000	137 177 400	-64 705 882	931 764 706	0	-4 230 290	1 000 005 933	-150 000 890	854 235 334	72.8%	622 264 153	12 325 885 673
17	11 000	137 177 400	-64 705 882	931 764 706	0	-4 230 290	1 000 005 933	-150 000 890	854 235 334	71.4%	610 062 895	12 935 948 568
18	11 000	137 177 400	-64 705 882	931 764 706	0	-4 230 290	1 000 005 933	-150 000 890	854 235 334	70.0%	598 100 877	13 534 049 445
19	11 000	137 177 400	-64 705 882	931 764 706	0	-4 230 290	1 000 005 933	-150 000 890	854 235 334	68.6%	586 373 409	14 120 422 854

INDEX	VALUE
NPV (RSD)	€ 14 120 422 854

Conclusions

The hydraulic balance complies with the technical constraints provided and adheres to the current conditions

The load in Zemun is taken on by the expanded capacity in NB, allowing the current local boiler house to be dismissed

The interconnection investment itself (without the costs of integrating TENT A) has an immediate payback time (< 2 months)

New NB-DU-KO system

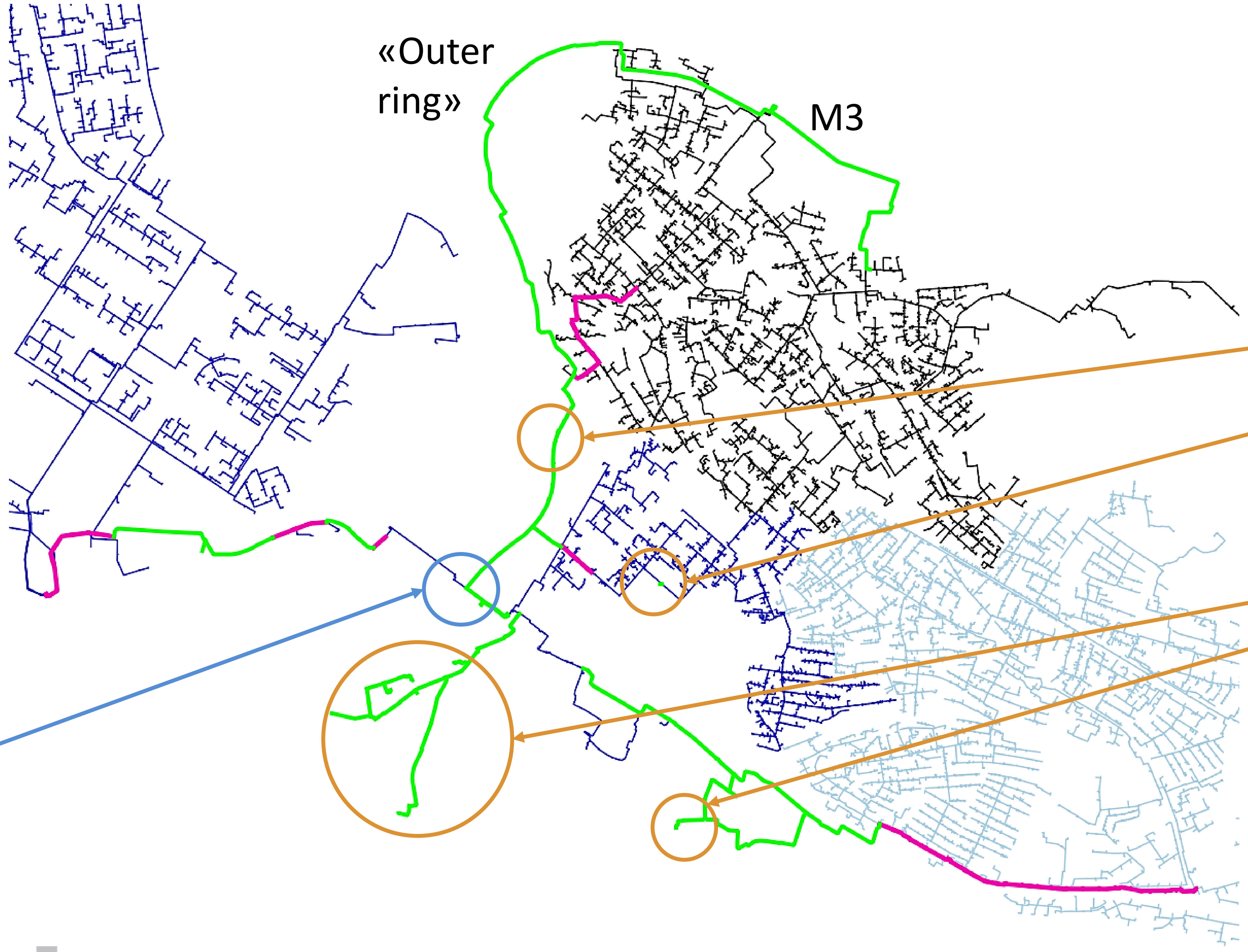
Initial Work Conditions

- The multi-network connection will **maximize the supply of new sources** (especially at lower loads)
- Significant **altitude differences** pose technical challenges to pressure management
- Presence of **closed pipes** linking the separated networks may be an opportunity

Potential new backbones (green lines)

Potential refurbishment of existing backbones (purple lines)

Planned new pumping station(s)



Connection of new users (63 MW_{th})

Existing Boiler stations (15 MW_{th}) to be shut down

New NB-DU-KO system

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Investigation Lines

Hydraulic balance of the new aggregated network	Minimize operating pressures
Planned new piping vs refurbishment of existing assets	Trade-off between costs/technical Benefit
How to operate in low-load conditions	Is it feasible to rely on new sources only?
Impact of opening closed-down pipes	Does it improve the hydraulic balance?
Design of the new pumping station(s)	What is the required minimum Δp?

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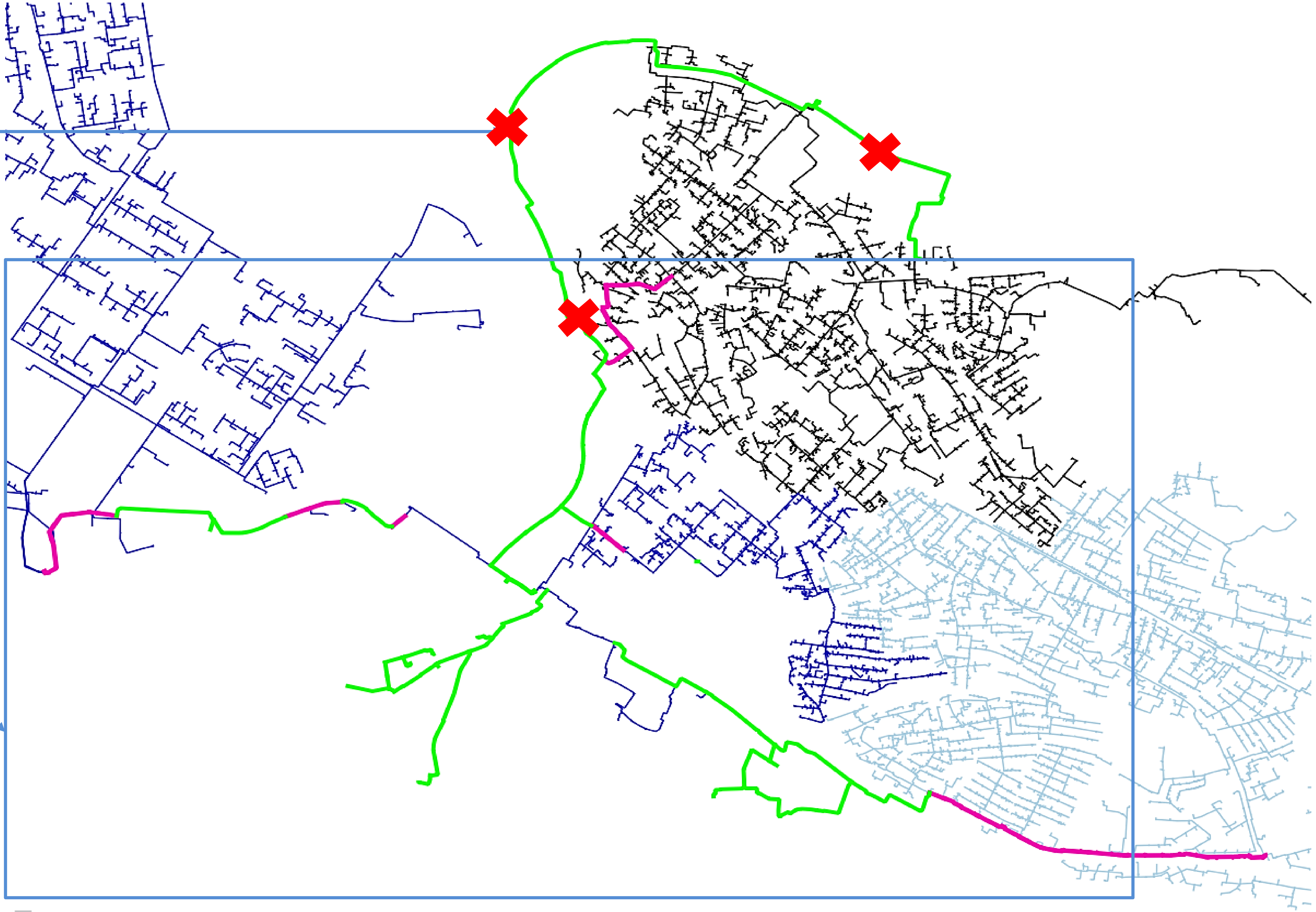
New NB-DU-KO system

Summary of results Work Conditions

The “outer ring” has been proved not to provide significant benefit

Planning guidelines have been confirmed and refined, integrating additional spot actions



NB-DU-KO connection

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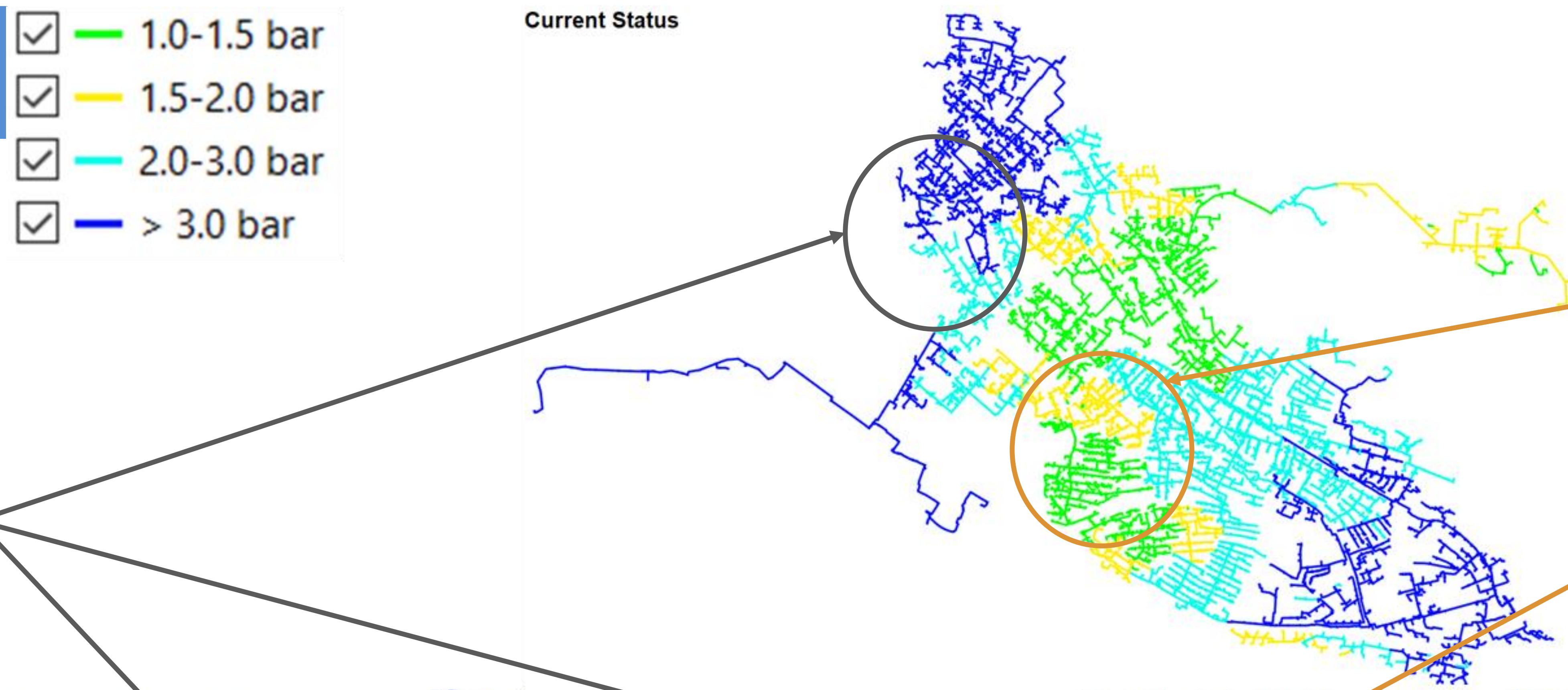
NEW NETWORK CONFIGURATION (100% FLOW)

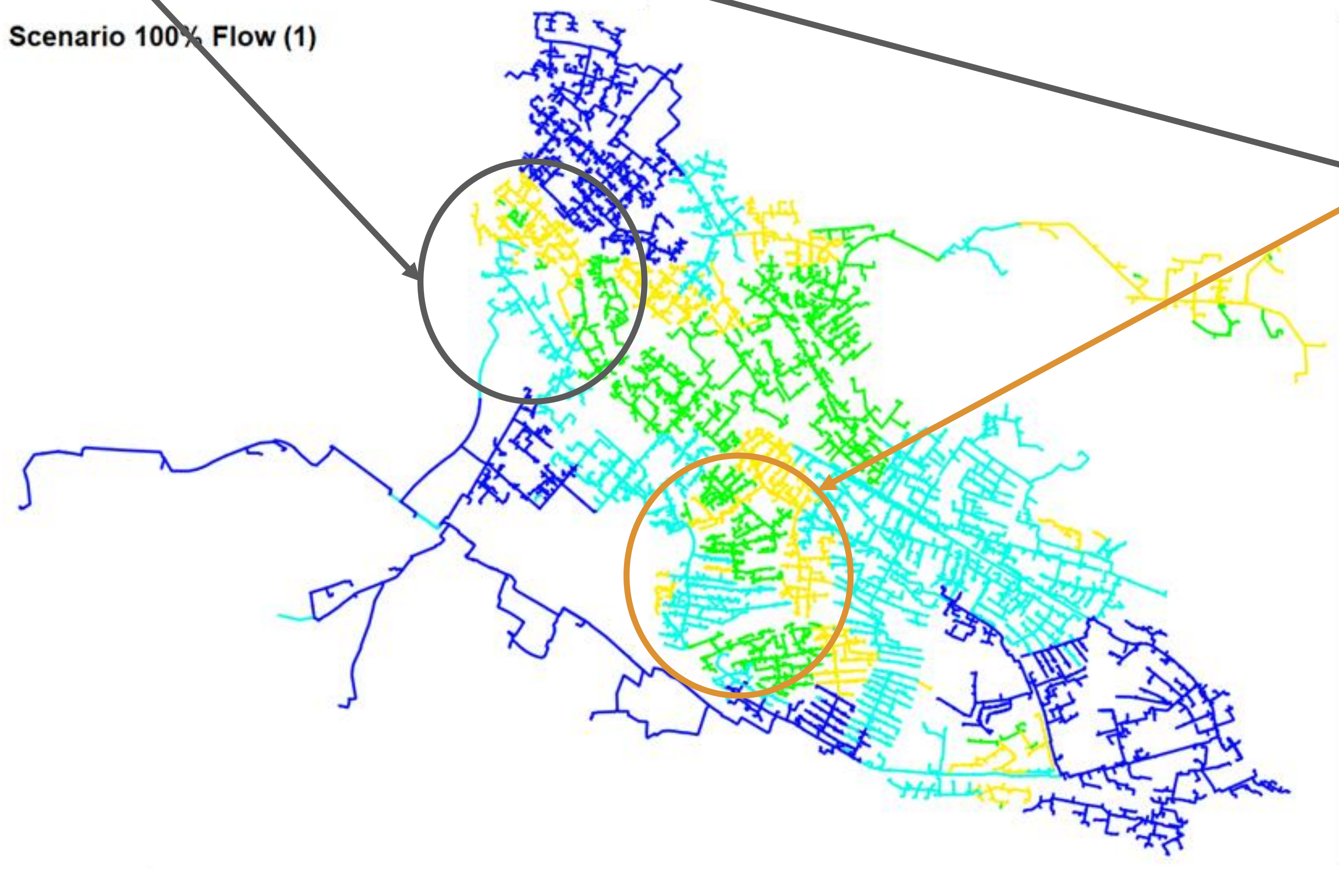
Δp distribution



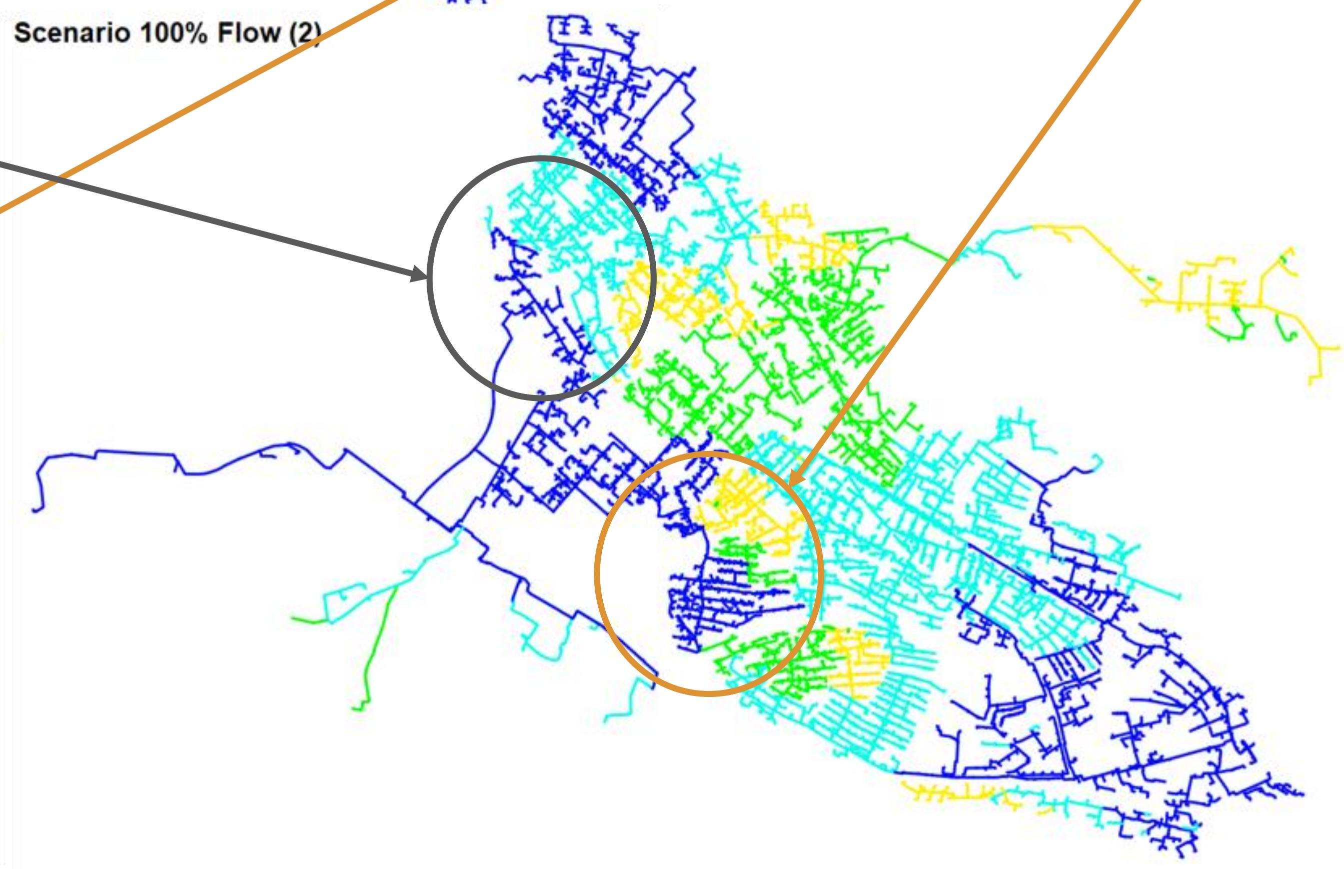
CURRENT STATUS

Shift in critical areas

Shift in critical areas



SCENARIO 1: NB-DU-KO CONNECTION (100% FLOW)



SCENARIO 2: NB-DU CONNECTION (100% FLOW)

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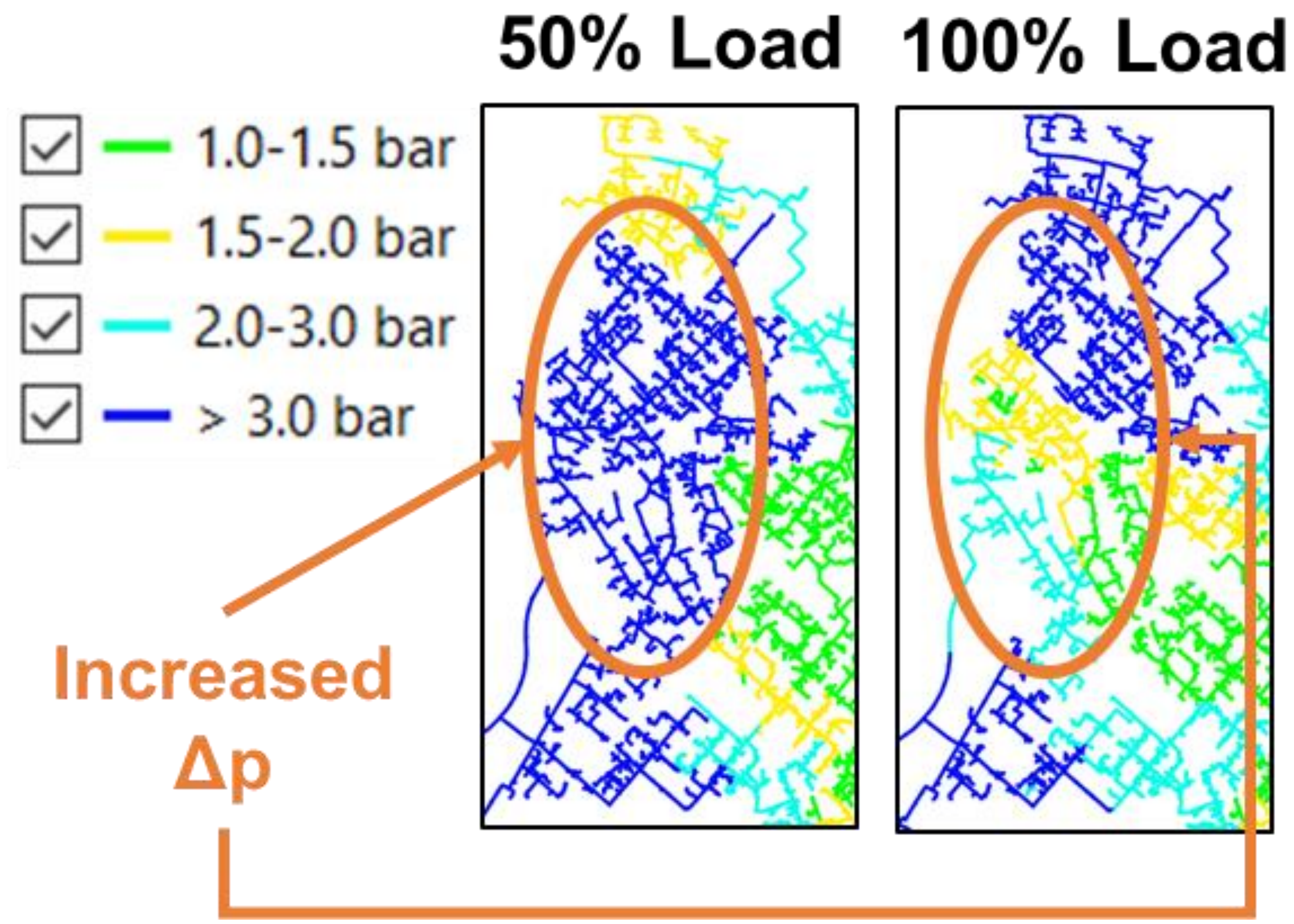
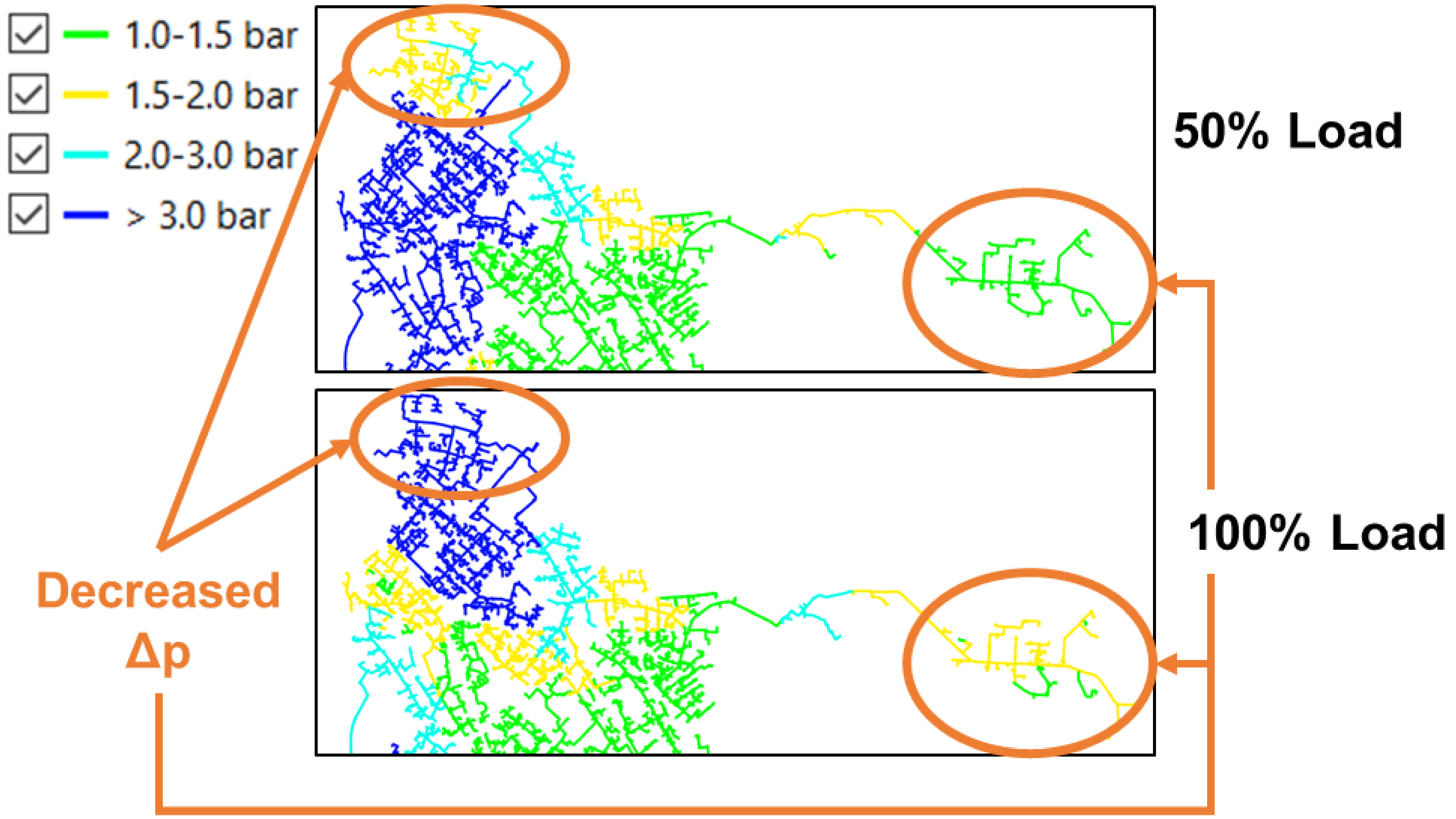
NB-DU-KO connection

Hydraulic regimes at low loads

Δp distribution





In low load scenarios the heat coming from TENT-A serves an even larger portion of Dunav's system, allowing a decrease in Δp at the plant, without reaching critical conditions at the peripheral sections of the network

NB-DU-KO connection

Hydraulic Benchmark

		Baseline	s 100% Flow (1)	s 100% Flow (2)	s 50% Flow
Dunav	**p supply (bar)**	12.00	12.00	12.00	8.82
	p return (bar)	7.12	7.12	7.12	6.30
	deltaP (bar)	4.88	4.88	4.88	2.52
Konjarnik	**p supply (bar)**	9.17	8.80	9.17	8.80
	p return (bar)	3.45	3.61	3.46	3.61
	deltaP (bar)	5.72	5.19	5.72	5.19
Novi Beograd M6	**p supply (bar)**	11.31	12.00	12.00	12.01
	p return (bar)	5.00	3.99	3.99	4.39
	deltaP (bar)	6.31	8.01	8.01	7.62

NB-DU-KO CONNECTION

YEAR	NEW USERS SUPPLY (MWh)	NEW USERS REVENUE (RSD)	NEW USERS PRODUCTION COSTS (RSD)	PRODUCTION COSTS SAVINGS (RSD)	INFRASTRUCTURAL INVESTMENT COSTS (RSD)	AMORTIZATION (RSD)	NET FLUX (RSD)	TAXATION (RSD)	NET FLUX (RSD)	ACTUALIZATION COEFFICIENT (%)	ACTUALIZED VALUE (RSD)	CUMULATED ACTUALIZED VALUE (RSD)
0	33 185	413 836 780	-88 729 412	971 105 882	-2 954 497 328	-98 483 244	1 197 730 007	-179 659 501	-1 837 943 578	100.0%	-1 837 943 578	-1 837 943 578
1	33 185	413 836 780	-88 729 412	971 105 882	0	-98 483 244	1 197 730 007	-179 659 501	1 116 553 750	98.0%	1 094 660 539	-743 283 038
2	33 185	413 836 780	-88 729 412	971 105 882	0	-98 483 244	1 197 730 007	-179 659 501	1 116 553 750	96.1%	1 073 196 607	329 913 569
3	33 185	413 836 780	-88 729 412	971 105 882	0	-98 483 244	1 197 730 007	-179 659 501	1 116 553 750	94.2%	1 052 153 536	1 382 067 105
4	33 185	413 836 780	-88 729 412	971 105 882	0	-98 483 244	1 197 730 007	-179 659 501	1 116 553 750	92.4%	1 031 523 075	2 413 590 180
5	33 185	413 836 780	-88 729 412	971 105 882	0	-98 483 244	1 197 730 007	-179 659 501	1 116 553 750	90.6%	1 011 297 132	3 424 887 312
6	33 185	413 836 780	-88 729 412	971 105 882	0	-98 483 244	1 197 730 007	-179 659 501	1 116 553 750	88.8%	991 467 777	4 416 355 088
7	33 185	413 836 780	-88 729 412	971 105 882	0	-98 483 244	1 197 730 007	-179 659 501	1 116 553 750	87.1%	972 027 232	5 388 382 320
8	33 185	413 836 780	-88 729 412	971 105 882	0	-98 483 244	1 197 730 007	-179 659 501	1 116 553 750	85.3%	952 967 874	6 341 350 195
9	33 185	413 836 780	-88 729 412	971 105 882	0	-98 483 244	1 197 730 007	-179 659 501	1 116 553 750	83.7%	934 282 230	7 275 632 425
10	33 185	413 836 780	-88 729 412	971 105 882	0	-98 483 244	1 197 730 007	-179 659 501	1 116 553 750	82.0%	915 962 970	8 191 595 395
11	33 185	413 836 780	-88 729 412	971 105 882	0	-98 483 244	1 197 730 007	-179 659 501	1 116 553 750	80.4%	898 002 912	9 089 598 307
12	33 185	413 836 780	-88 729 412	971 105 882	0	-98 483 244	1 197 730 007	-179 659 501	1 116 553 750	78.8%	880 395 012	9 969 993 319
13	33 185	413 836 780	-88 729 412	971 105 882	0	-98 483 244	1 197 730 007	-179 659 501	1 116 553 750	77.3%	863 132 365	10 833 125 684
14	33 185	413 836 780	-88 729 412	971 105 882	0	-98 483 244	1 197 730 007	-179 659 501	1 116 553 750	75.8%	846 208 201	11 679 333 885
15	33 185	413 836 780	-88 729 412	971 105 882	0	-98 483 244	1 197 730 007	-179 659 501	1 116 553 750	74.3%	829 615 883	12 508 949 768
16	33 185	413 836 780	-88 729 412	971 105 882	0	-98 483 244	1 197 730 007	-179 659 501	1 116 553 750	72.8%	813 348 905	13 322 298 672
17	33 185	413 836 780	-88 729 412	971 105 882	0	-98 483 244	1 197 730 007	-179 659 501	1 116 553 750	71.4%	797 400 887	14 119 699 560
18	33 185	413 836 780	-88 729 412	971 105 882	0	-98 483 244	1 197 730 007	-179 659 501	1 116 553 750	70.0%	781 765 576	14 901 465 135
19	33 185	413 836 780	-88 729 412	971 105 882	0	-98 483 244	1 197 730 007	-179 659 501	1 116 553 750	68.6%	766 436 839	15 667 901 974

INDEX	VALUE
NPV (RSD)	€ 15 667 901 974

Conclusions

The interconnection plan is feasible and may be achieved in different manners (S1 & S2), allowing for operational flexibility in case of boundary conditions variations (

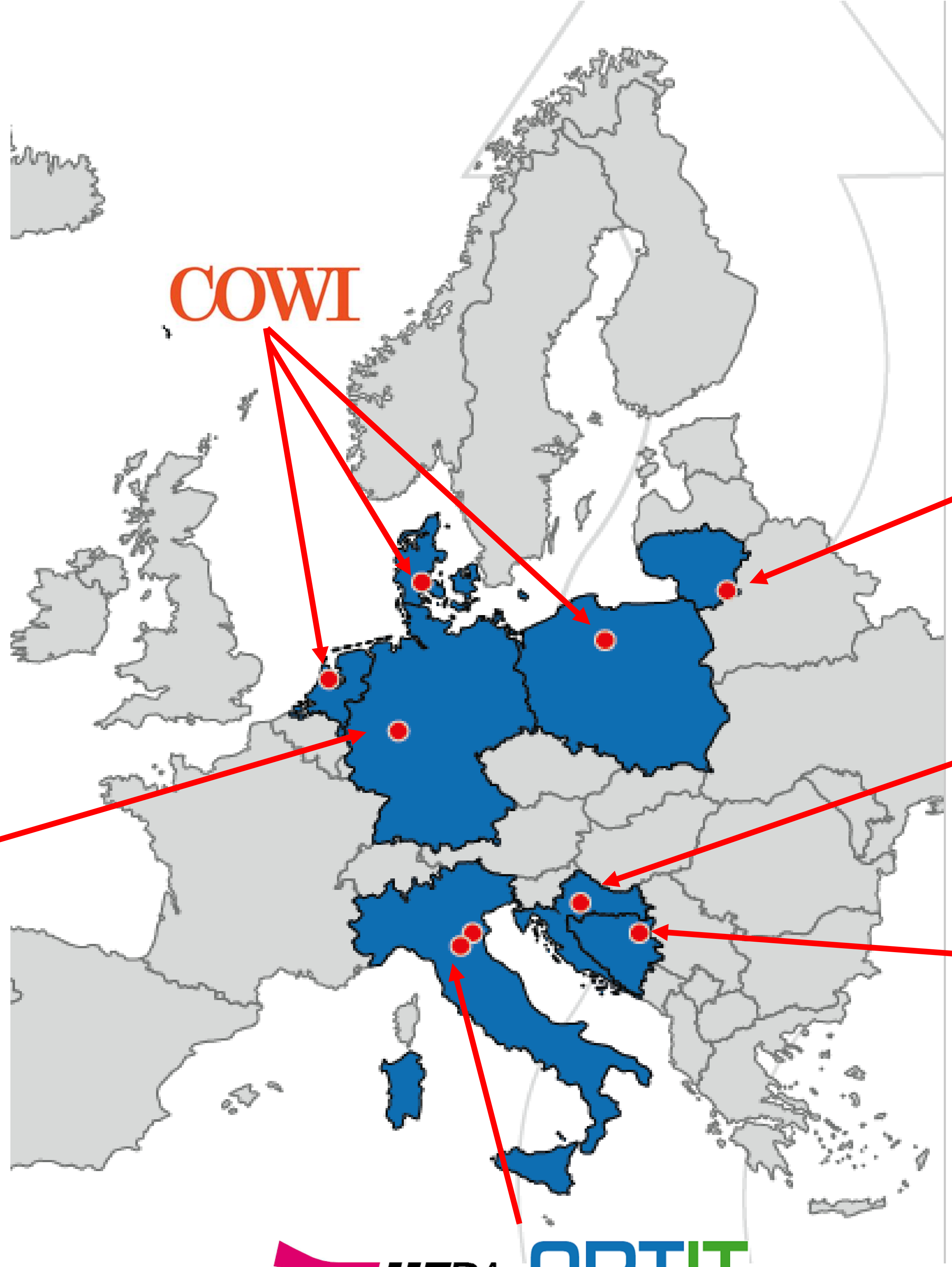
Refurbishment of long segments of existing pipeline is necessary in order to comply with the technical constraints and avoid bottlenecks (yet, the outer ring has been seen to be superfluous)

In low-load conditions the new sources may be saturated within the technical constraints and many areas in Dunav and Konjarnik may be then served by TENT-A, decreasing the ∆p required at the former plants.

The interconnection investment itself (without the costs of integrating TENT A) has an payback time of less than 3 years

Conclusions

- The current networks have been configured into Optit's tool, with a successful validation against both SCADA data and TERMIS simulations
- Lots of (+100) potential investment scenarios have been considered and analyzed, determining the best trade-off between investment costs and technical benefits
- Interconnection scenarios are feasible and show increased operating flexibility in different load conditions, that can be exploited in light of future further network expansion
- The finalized scenarios have been provided through cartographic data, KPI assessment and investment cash flow analysis



Improving existing DH networks in Europe:

- Initiate the DH **upgrading process** for 8 systems up to the investment stage (Generation, Distribution, Use)
- Produce **Best Practices and Tools** Handbooks
- Develop regional / national action plans for DHN **retrofitting**
- **Replicate** the proposed solutions across Europe

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Thank you for your attention!