ENERGY.
ENGINEERING.
EXCELLENCE.

WATER CONSERVATION WITH WET-TO-HYBRID COOLING CONVERSION

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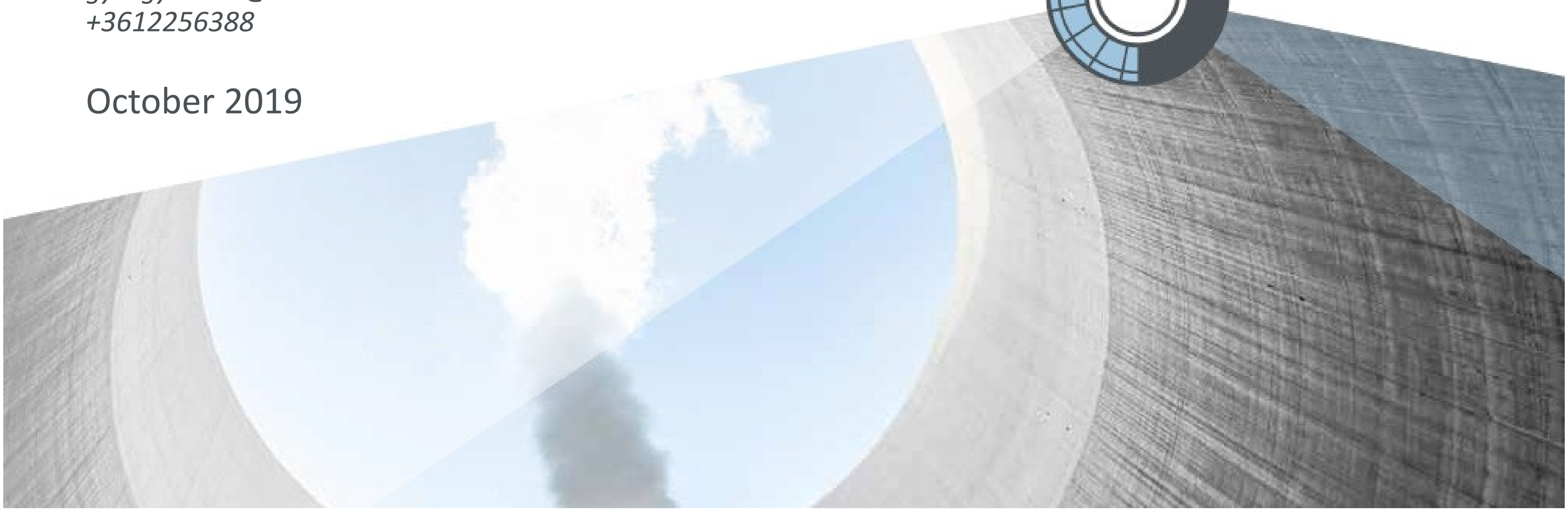
October 2019



TOPICS

1. **Company introduction**
2. Vulnerability of Power Plants to Water Availability
3. System configuration
4. Dry cooling tower components
5. Summary & select references
6. Questions & discussion

ENEXIO

TECHNOLOGY LEADER WITH GERMAN & HUNGARIAN ENGINEERING HERITAGE

Organization

1920: Foundation of GEA by Otto Happel Sr.

GEA

First presence in the United States in the state of Delaware

1948: Foundation of EGI in Budapest by Prof. Dr. László Heller

1992: GEA acquires shares of EGI

GEA-EGI

Building up of Heat Exchanger Production sites in Langfang and Wuqing

Reorganization of GEA Group: Part of GEA Heat Exchangers Segment

GEA

Acquisition by Triton-Partners

Triton

Brand change to ENEXIO and establishment of a standalone presence

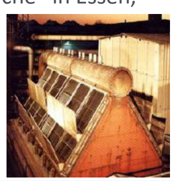
ENEXIO

1920 1935 1939 1948 1954 1983 1986 1992 1999 2005/06 2010 2014 2015 2019

Technology

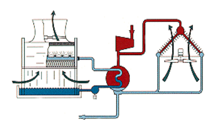
Development of ACC for stationary steam turbines

Start-up of first ACC at “Prosper Zeche” in Essen, Germany

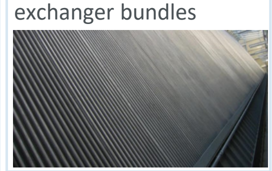


First Heller system, Hungary

First PAC-System (Hybrid cooling)



Introduction of self-supporting heat exchanger bundles

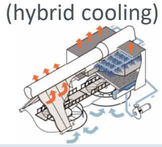


Market introduction of InAIR®

9 operational plants

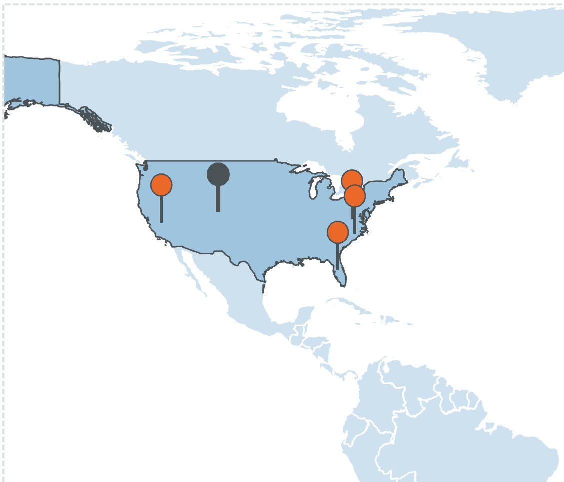
InAIR

Market introduction of Deluge ACC (hybrid cooling)



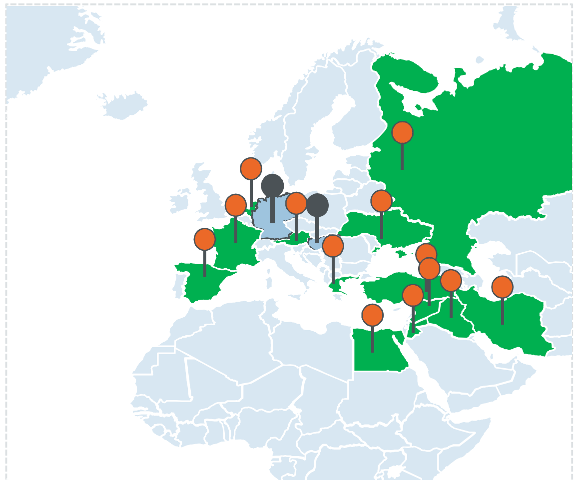
GLOBAL CUSTOMER BASE WITH A GLOBAL FOOTPRINT

United States



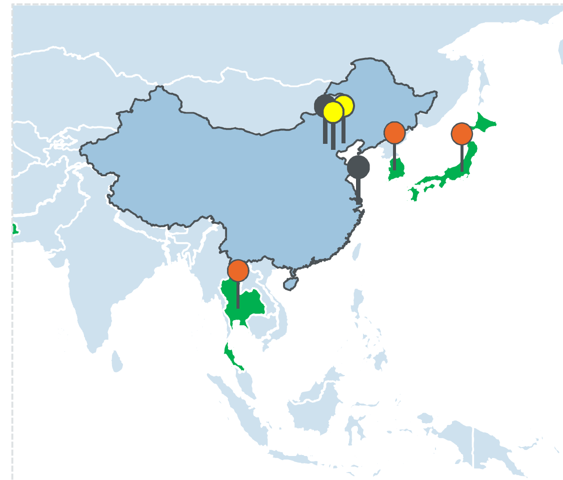
- Project support office in Lakewood, Colorado
- Sales representatives throughout the USA
- 2 FTE

Europe



- Offices in Herne, Germany and Budapest, Hungary
- Technology, engineering and sales hub
- 102 FTE

China/Asia



- Business unit office in Beijing, branch in Shanghai
- Production hub with two manufacturing sites in Langfang and Wuqing
- 153 FTE

Office *Production* *Sales Agent / Representative*

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THE FULL RANGE OF INDUSTRIAL DRY COOLING SYSTEMS

<table>
<tr><th>Technology</th><th>Air Cooled Condenser InAIR®</th><th>Air Cooled Condenser A-Frame</th><th>Indirect Dry Cooling Tower Heller</th><th>Hybrid Cooling Solutions</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Applications</td><td colspan="2">Conventional thermal power plants, combined cycle power plants, combined heat and power plants, CSPs, biomass & waste-to-energy plants</td><td colspan="2">Conventional thermal power plants, combined cycle power plants, nuclear power plants, combined heat and power plants, CSPs, biomass & waste-to-energy plants</td></tr>
<tr><td>Key features</td><td>▪ Differentiated by self-supporting bundles
▪ Lowest CAPEX
▪ Optimized steel structure
▪ Significant erection advantages
▪ Minimized fan stresses
▪ High level of standardization</td><td>▪ Established Industry standard
▪ Honed to perfection through 80 years of continuous development</td><td>▪ Differentiated by jet condenser and stainless steel tubes;
▪ Natural draft: lowest OPEX due to minimized power consumption and maintenance;
▪ Mechanical draft: best for extreme cold climates and/or plot constraints
▪ Fast start-up</td><td>▪ Hybrid (wet/dry) cooling system: limited use of water
▪ Full range of technical solutions to design for exact pre-defined water use
▪ Applicable for wet-to-dry conversion: conversion of existing wet cooling systems</td></tr>
<tr><td></td><td colspan="4">Services available for all Dry Cooling technologies, e.g. rebundling, refurbishment, etc.</td></tr>
</table>

ENEXIO'S EXPERIENCE (FORMER GEA & EGI)

- ENEXIO invented both the Direct (ACC) & Indirect (HELLER) dry cooling technologies
- The first ACC was installed in 1939
- The first indirect (HELLER) dry cooling system was installed in 1954
- There are more than 120 indirect & more than 1000 direct dry cooling references worldwide
- Largest fleet of references for round shaped natural draft cooling towers (DRY & WET)
- Largest fleet of references of mechanical draft indirect (HELLER) systems
- References for fan assisted natural draft towers
- Invented and patented dry / wet systems such as:

  ENEXIO's PAC® system

  ENEXIO's HELLER based derivatives

  ENEXIO's Deluge ACC

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VULNERABILITY OF POWER PLANTS TO WATER AVAILABILITY

Evaporative/wet cooling systems are the biggest water consumers in a thermal power plant:

- Each 1MWh electricity produced in a fossil power plant requires 2300-2500 liters (600-660 gal) of make-up water to replace wet cooling tower losses (by evaporation, blow-down and drift)
- Nuclear plants consume 25-35% more than fossil plants, http://www.world-nuclear.org/information-library/current-and-future-generation/cooling-power-plants.aspx
- Example: the daily make-up water consumption of the wet cooling tower of a 500MW steam turbine – catering for 600 000 public electricity consumers – equals the public water consumption of 150 000 people (EU average 5-700 W/person & 200 liter/day/person) https://en.wikipedia.org/wiki/List_of_countries_by_electricity_consumption

Water resources are getting scarce, while need for water grows further:

Water demand side growth (population, industrialization, agriculture, etc.) and **supply side depletion** triggered e.g. by climatic changes make thermal **power plants vulnerable to water shortages**

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VULNERABILITY… - STUDIES, STATISTICS, SOLUTIONS

Global recognition of water imbalance triggered an abundance of studies on **power generation vulnerabilities to water scarcity** around the world**.** Examples include:

- **USA, Department of Energy**: „Water Vulnerabilities for Existing Coal-fired Power Plants" (http://www.ipd.anl.gov/anlpubs/2010/08/67687.pdf)
  - The 2010 study found more than 340 coal firing power plants across the US with various vulnerabilities to water shortages then and in future
  - Excluding coal plant retirements since 2010 (https://www.sourcewatch.org/index.php/Coal_plant_retirements), the 2018 screening of the 2010 database shows nearly **60 coal firing plants**, equipped with wet cooling towers, and not subject to retirement in the next 10 years, in medium to high vulnerability situation
  - A **large number of US thermal power plants** other than coal firing, like gas firing CCPP-s, are also assumed to face high vulnerabilities
- **EU**: „Climate change and the vulnerability of electricity generation to water stress in the European Union" (https://www.nature.com/articles/nenergy2017114)
  - The 2017 study found **more than 400 EU-based thermal power plants** located in water basins that are and will be subject to water shortages and making these plants vulnerable to water
- Many of the studies conclude, that while some plants at fortunate locations may resort to alternate water sources (brown/brackish water, aquifers, seawater, etc.), the **sustainable solution** to vulnerabilities is „low-water cooling technology retrofits at power plants" i.e. **conversion to all-dry or hybrid cooling technologies** (https://www.researchgate.net/publication/277530487_Novel_methodology_for_evaluating_economic_feasibility_of_low-water_cooling_technology_retrofits_at_power_plants)

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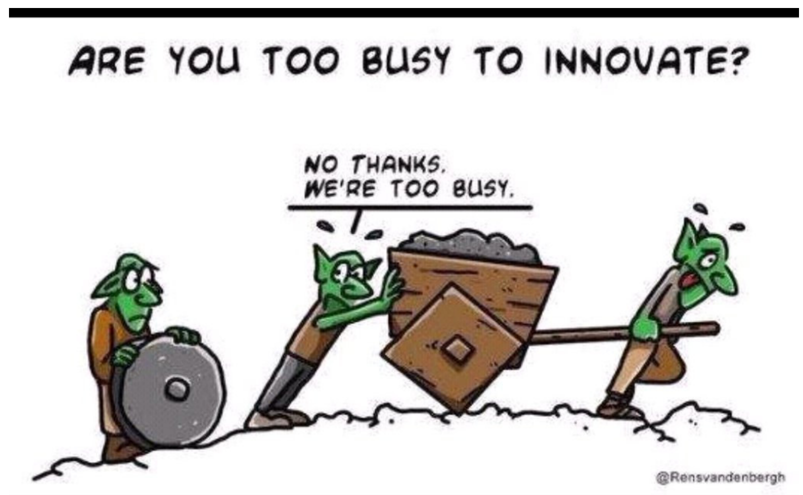

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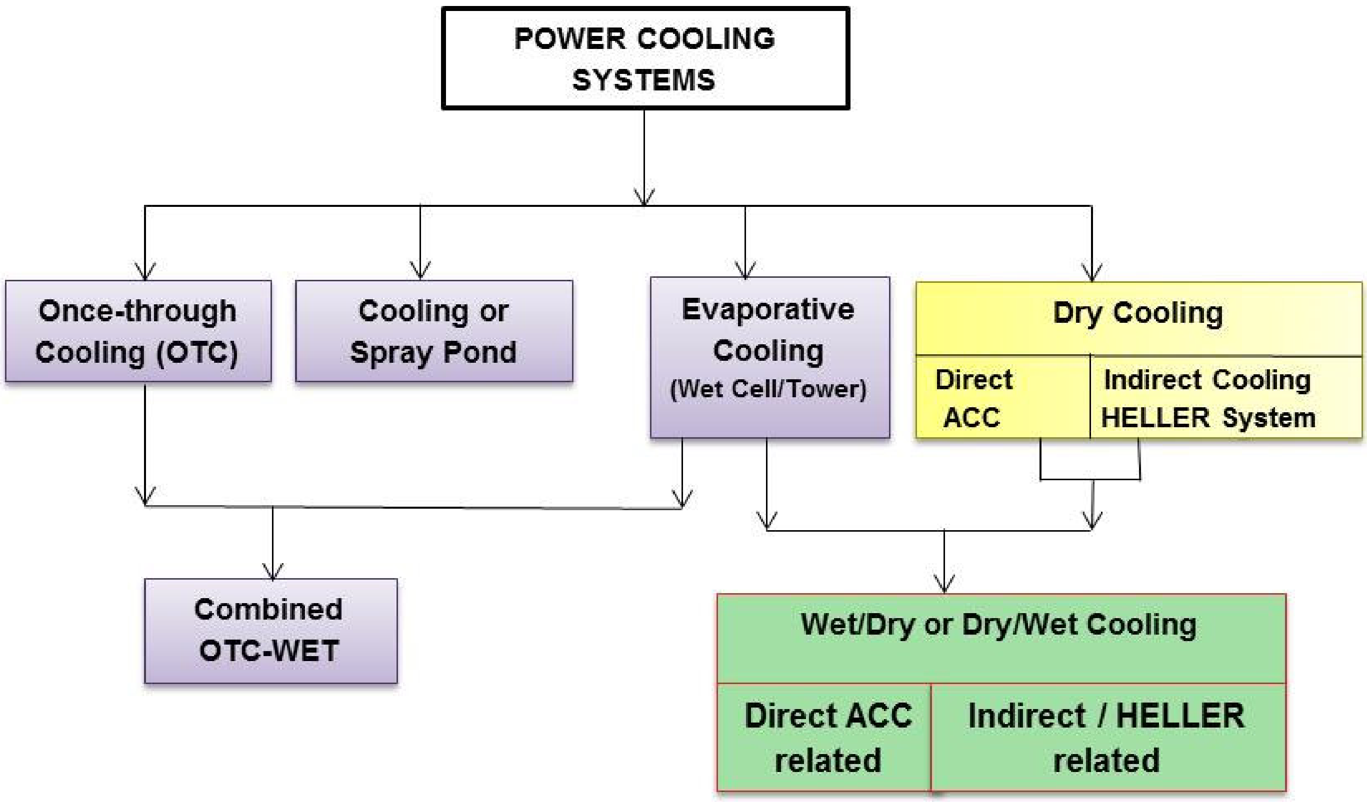
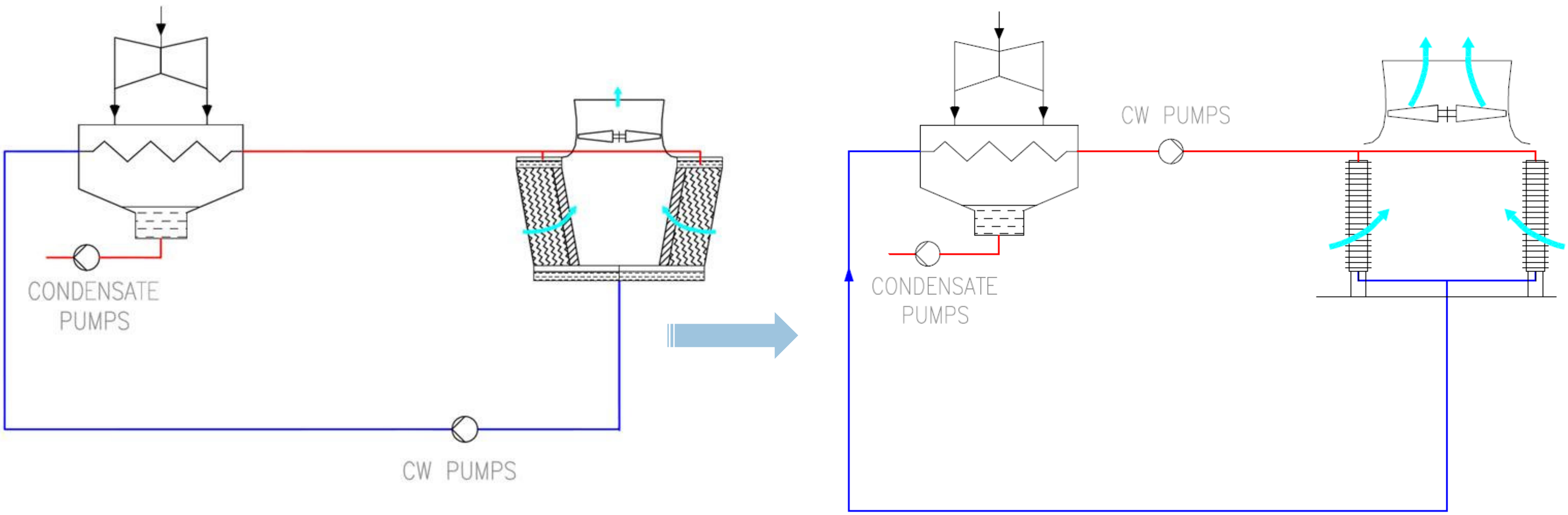
CLASSIFICATION OF COOLING SYSTEMS



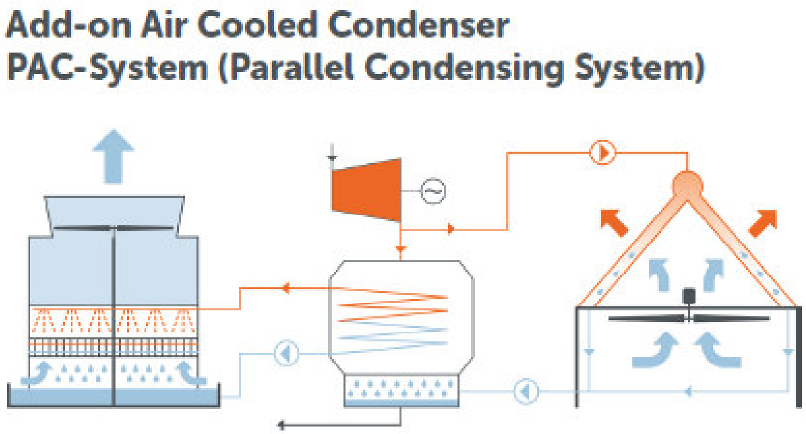
COOLING SYSTEM CONVERSION – WET TO DRY CONVERSION



Indirect dry cooling features:

- CW pumps in the WARM line
- Totally closed circuit, system is pressurized
- Head tank is needed
- Possibility to use Aluminum HEX
- One-time water fill of the system, water quality remains constant
- Can utilize existing surface condenser

COOLING SYSTEM CONVERSION – TECHNICAL OPTIONS



PAC: space next to T/G hall available

Tap part of the exhaust steam from surface condenser neck for dry-cooling by an add-on Air Cooled Condenser

Ideal for small to medium size conversions, where the layout of the existing facility allows for the placement of an add-on ACC right next to the Turbine Hall, to ensure minimal steam-side pressure drop

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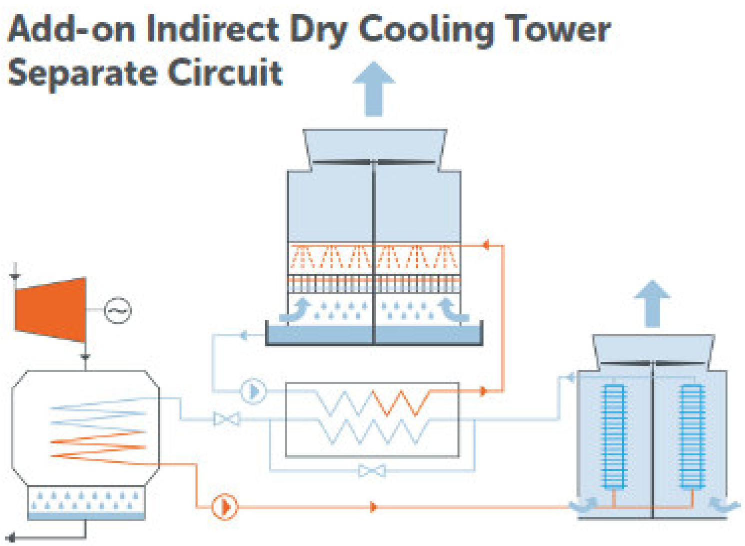


Indirect dry add-on: flexible layout

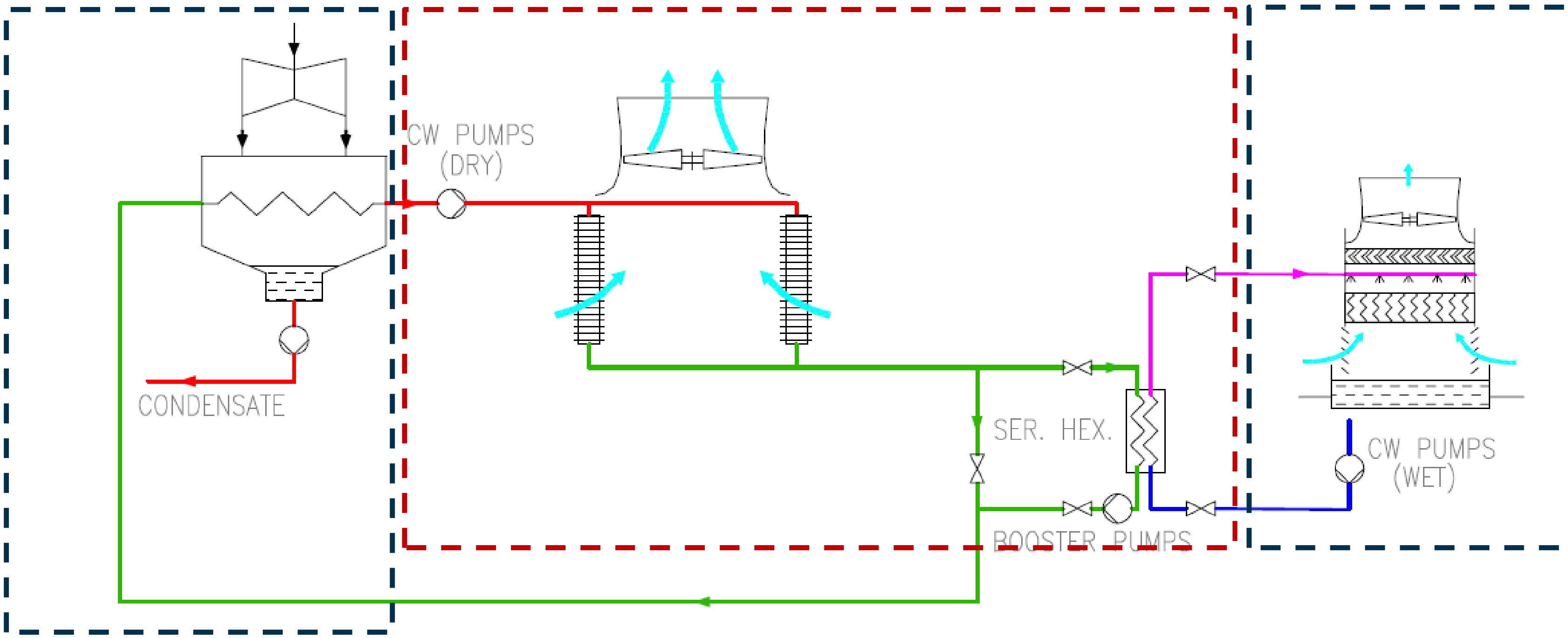
Connect a dry tower (mechanical or natural draft) with the surface condenser, and enhance dry cooling in hot summer hours with the existing wet cooling tower.

Fits all small to large conversion sizes;

Can be built any distance from the Turbine Hall, thus with no restriction by existing plant layout

Flexibly adapts to any existing plant layout, plant down-time for conversion is minimal

COOLING SYSTEM CONVERSION – ADD-ON INDIRECT DRY COOLING TOWER – SEPARATE CIRCUIT CONFIGURATION



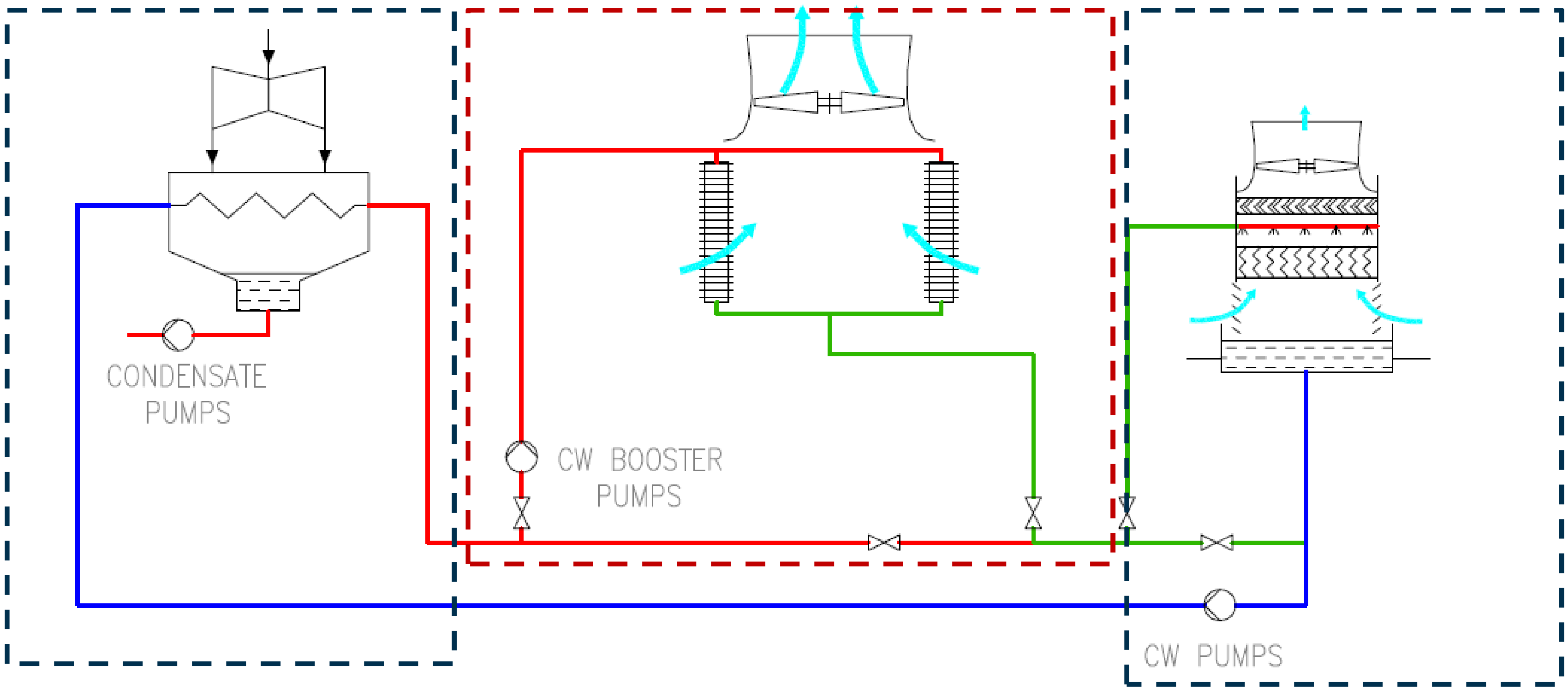
EXISTING SURFACE CONDENSER

ADDITIONAL DRY COOLING TOWER, CW MAIN PUMPS, PIPING, VALVES, PHEs

EXISTING WET TOWER WITH PUMPS

ENEXIO

COOLING SYSTEM CONVERSION – ADD-ON INDIRECT DRY COOLING TOWER – SINGLE CIRCUIT CONFIGURATION



EXISTING SURFACE CONDENSER

ADDITIONAL DRY COOLING TOWER, BOOSTER PUMPS, PIPING, VALVES, etc.

EXISTING WET TOWER WITH PUMPS

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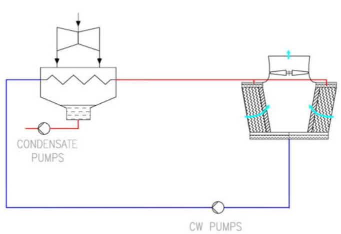
COOLING SYSTEM CONVERSION – THE OPTIMUM SOLUTION

Conversion solutions are **combinations of wet and dry cooling technologies**, selected to meet the following requirements (in random order):

- Maximum reduction of water consumption with minimal impact on efficiency of power generation
- Taylor-made solutions to meet targeted water savings
- Proven components used
- Matching the site layout without compromising on power generation efficiency
- Short turbine down-time for interconnection between existing and new cooling circuits
- Affordable budget
- Optimum conversion scheme definition and customization in collaboration with plant owner/operator (circuits and components shown below are for demonstration only):



Existing wet cooling system

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Plant data collection by ENEXIO

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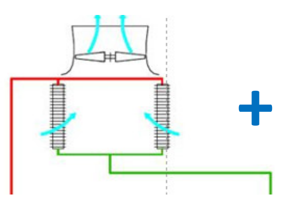

Investigation of all applicable Enexio dry cooling add-on solutions

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Year-round impact simulation, optimum solution selection with customer based on life-cycle cost comparison

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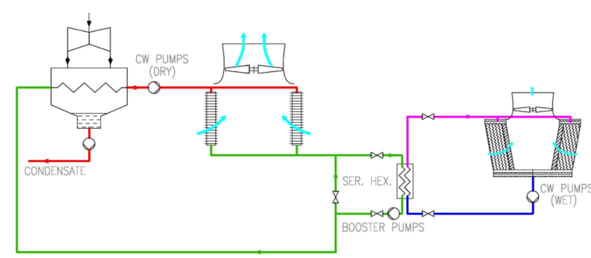

ENEXIO wet/dry conversion solution

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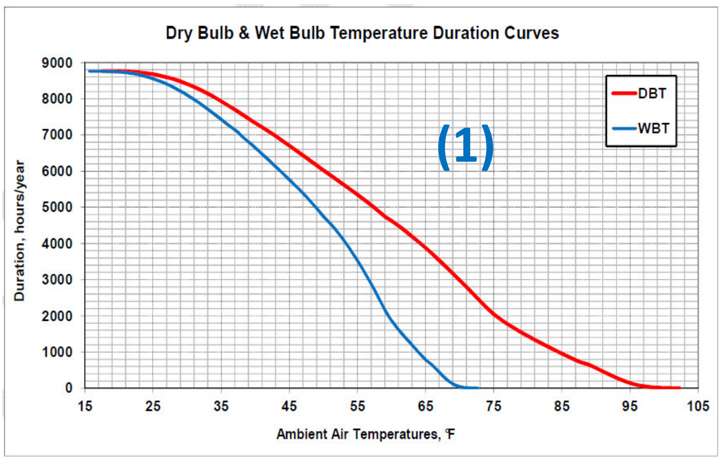
COOLING SYSTEM CONVERSION – YEAR-ROUND IMPACT SIMULATION

ENEXIO provides our customers up-front with a transparent, **year-round impact simulatio**n of multiple conversion options, by combining plant **environmental data** (**1**) with **steam turbine** (**2**) and multiple **conversion system** (**3.1…3.n**) back-pressure **characteristics**, to obtain annual **power output** (**4.1…4.n**) and **water consumption** (**5.1…5.n**) estimates for each conversion option: (charts prepared for a 500MW conversion case study in Texas)



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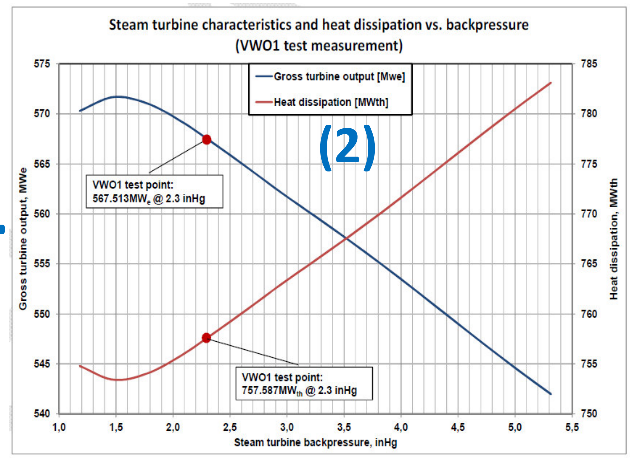

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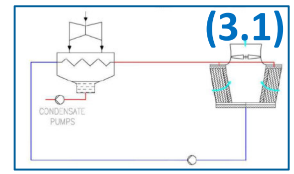

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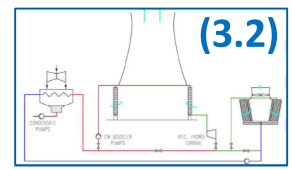

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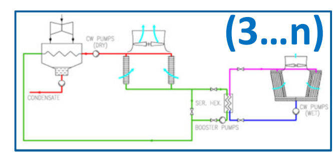

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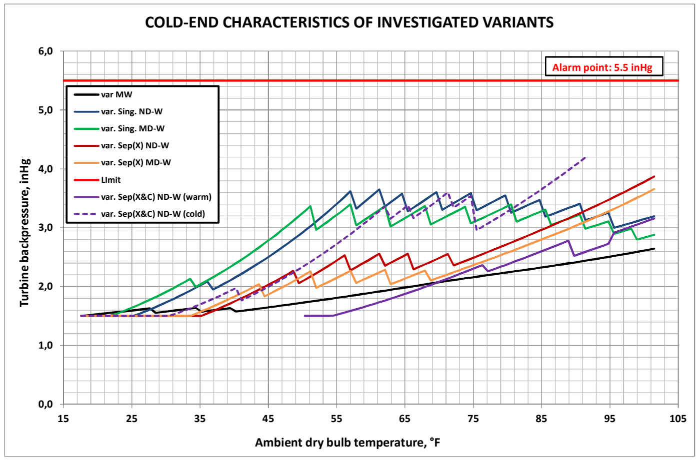

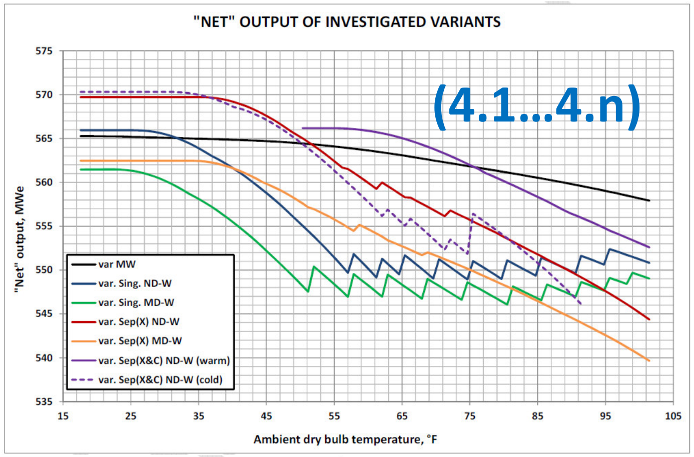

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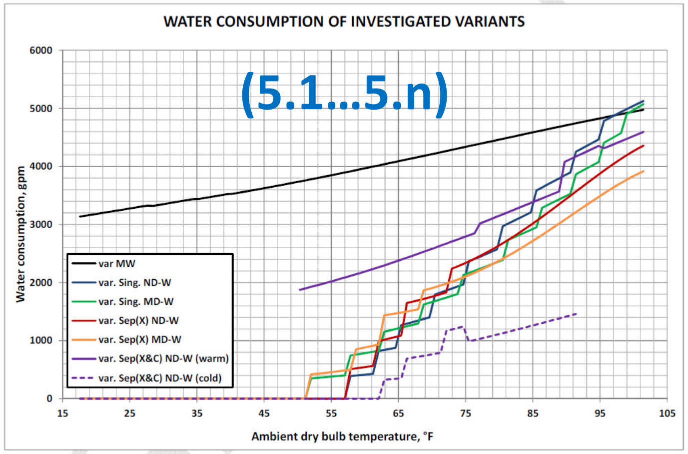

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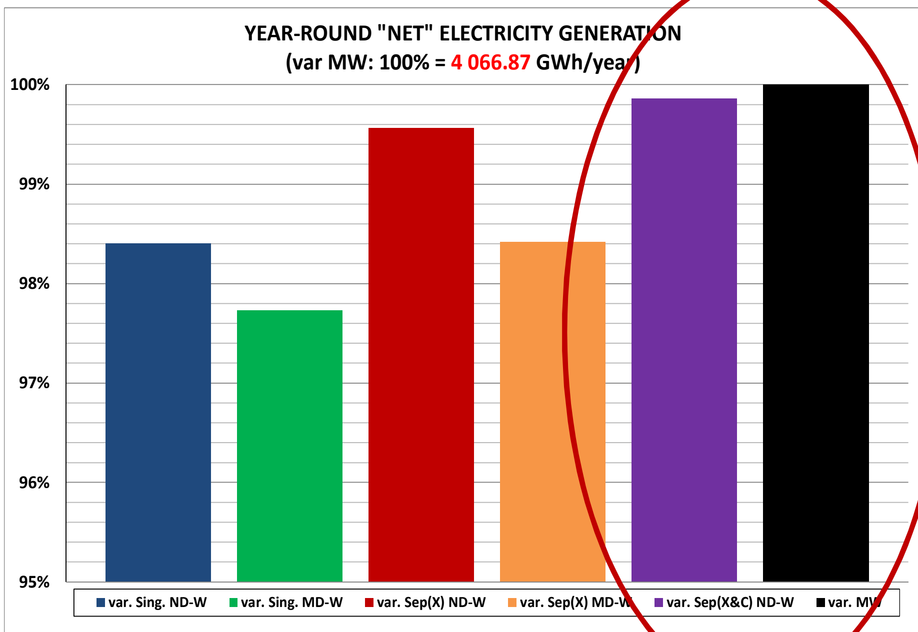
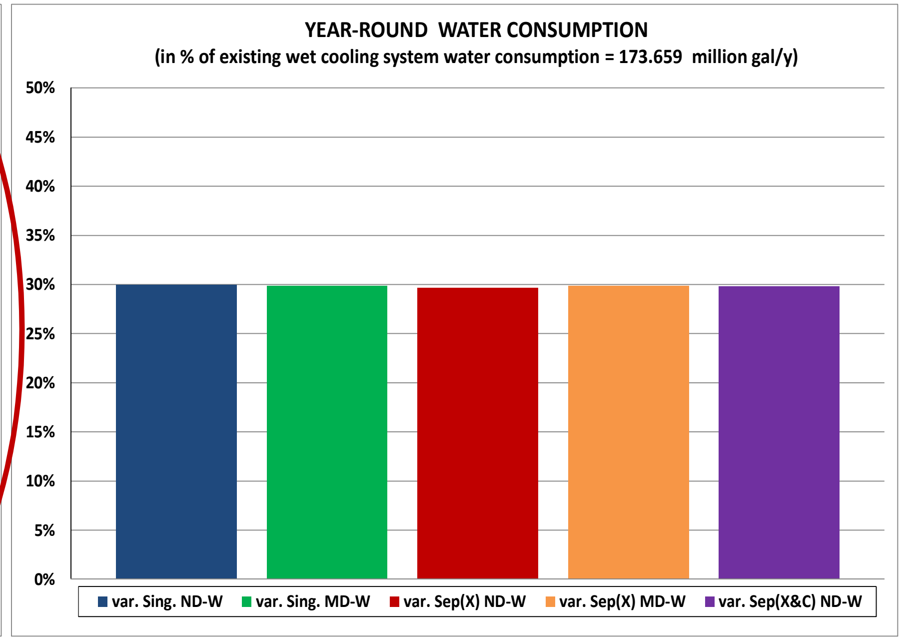
COOLING SYSTEM CONVERSION – NET PRESENT VALUE

Based on the net output curves, the water consumption curves and the temperature duration curves a complete year-round system simulation is prepared for all investigated variants *(e.g. single circuit dry add-on, separate circuit dry add-on, natural draft dry add-on, mechanical draft dry add-on, different size dry add-ons, etc.)*. As a result, the annual net electricity generation and annual water consumption figures are calculated for all investigated variants. After collection of economical data *(planned plant lifetime, currency interest rate, electricity price, water cost)*, ENEXIO will provide the customer with the **Net Present Value of cost savings** for customers.





ENEXIO wet-to-dry/wet conversions allow uncompromised annual power generation (close to 100%) at 70% annual water saving

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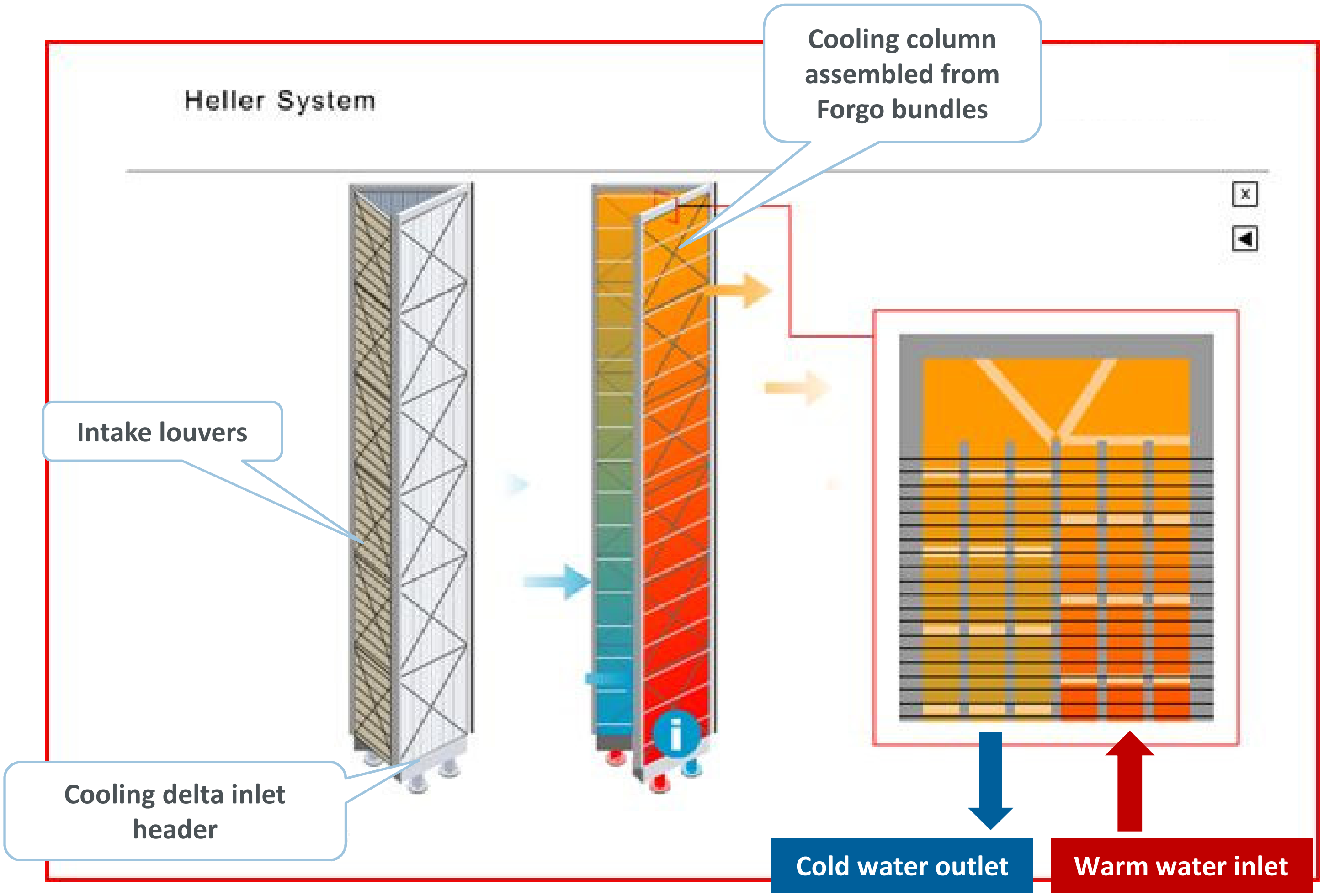
MAIN COMPONENTS
FORGO BUNDLE

- Single metal, aluminum
- Possibility of using CS and SS for tubes, tubesheets, headers in case of special requirements
- Integrated plate fins unite an array (usually 60pcs) of tubes
- Spring-type contact between hard plate-fin collars and softer tubes
- Easy to clean due to continuous fin surface
- Environment-friendly air-side oxide layer enhancement (ENVIROX)
- Site assembly without site welds
- No air-side corrosion, service life is equal to that of power plant
- No deterioration of air-side performance during lifetime
- Protective double iron-oxide (magnetite and hematite) layer formation on water side during operation
- Delivered in horizontal position with headers mounted

MAIN COMPONENTS
COOLING DELTA



MAIN COMPONENTS
COOLING DELTA

Cooling delta steel structures assembled

Cooling deltas assembled

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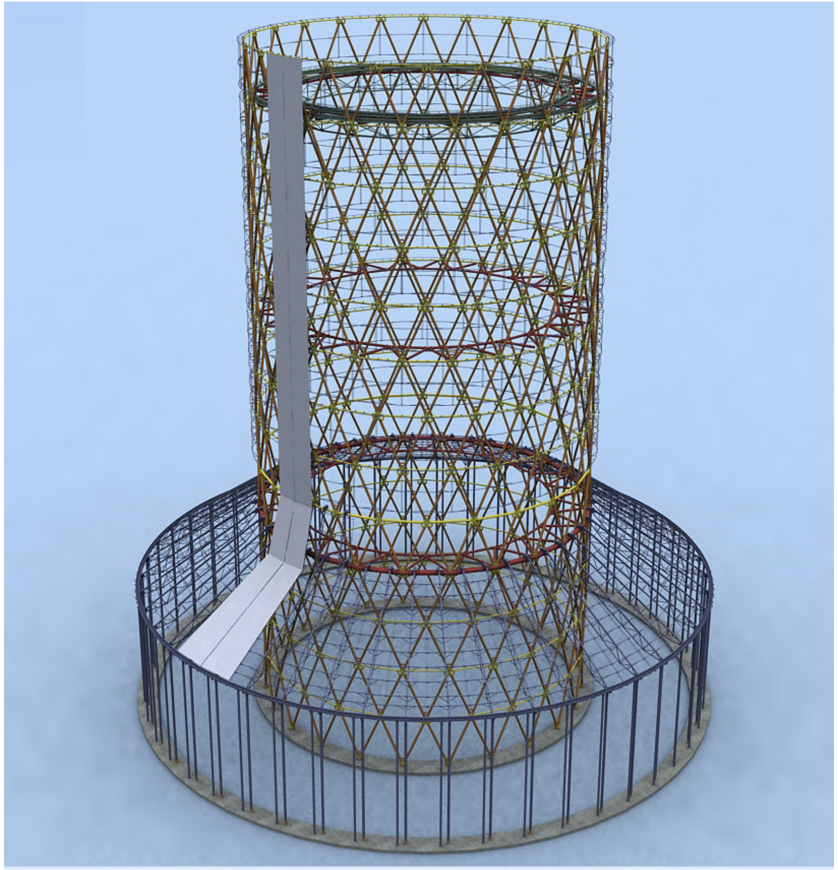
MAIN COMPONENTS
NATURAL DRAFT TOWER

Cylindrical steel shell

Concrete hyperbolic shell

ENEXIO

MAIN COMPONENTS
NATURAL DRAFT STEEL STRUCTURE TOWER



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MAIN COMPONENTS
MECHANICAL DRAFT TOWER

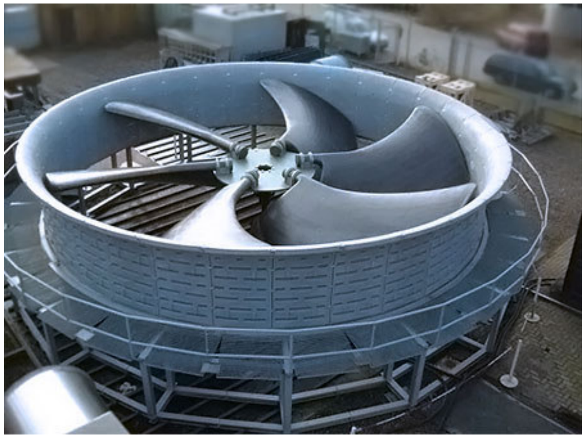
Round shaped

Rectangular shaped

MAIN COMPONENTS
MECHANICAL DRAFT TOWER

Steel structure of mechanical draft rectangular shaped tower

MAIN COMPONENTS
FAN UNIT



Key features:

- Low speed applied
- Motor and gearbox placed at ground level
- Easy maintenance of motor & gearbox

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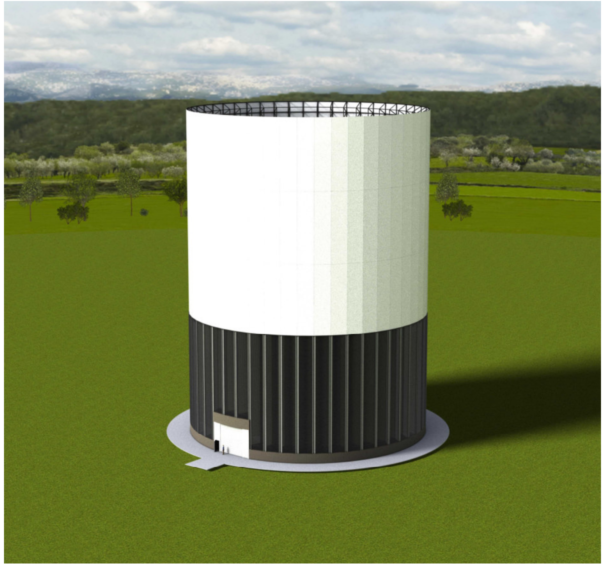
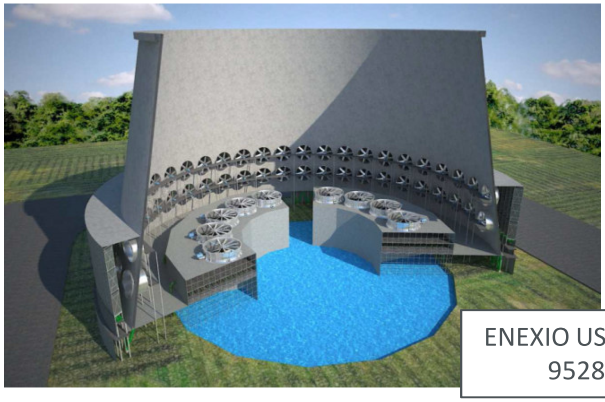
MAIN COMPONENTS
FAN ASSISTED NATURAL DRAFT TOWER



Steel structure



Reinforced concrete structure

ENEXIO US Patent No.: 9528767B2

MAIN COMPONENTS
HEAT EXCHANGER CLEANING SYSTEM

- Semi-automatic delta cleaning system. The delta cleaning system works independently from the cooling tower. Use this equipment once a year (in spring), or twice if heat exchangers become dirty.

- The washing equipment and the washing car move on properly constructed rails on a linear route, as controlled by the operator. On the washing car, a set of vertically installed nozzles are moved rotationally within the preset angle range by an electric motor.

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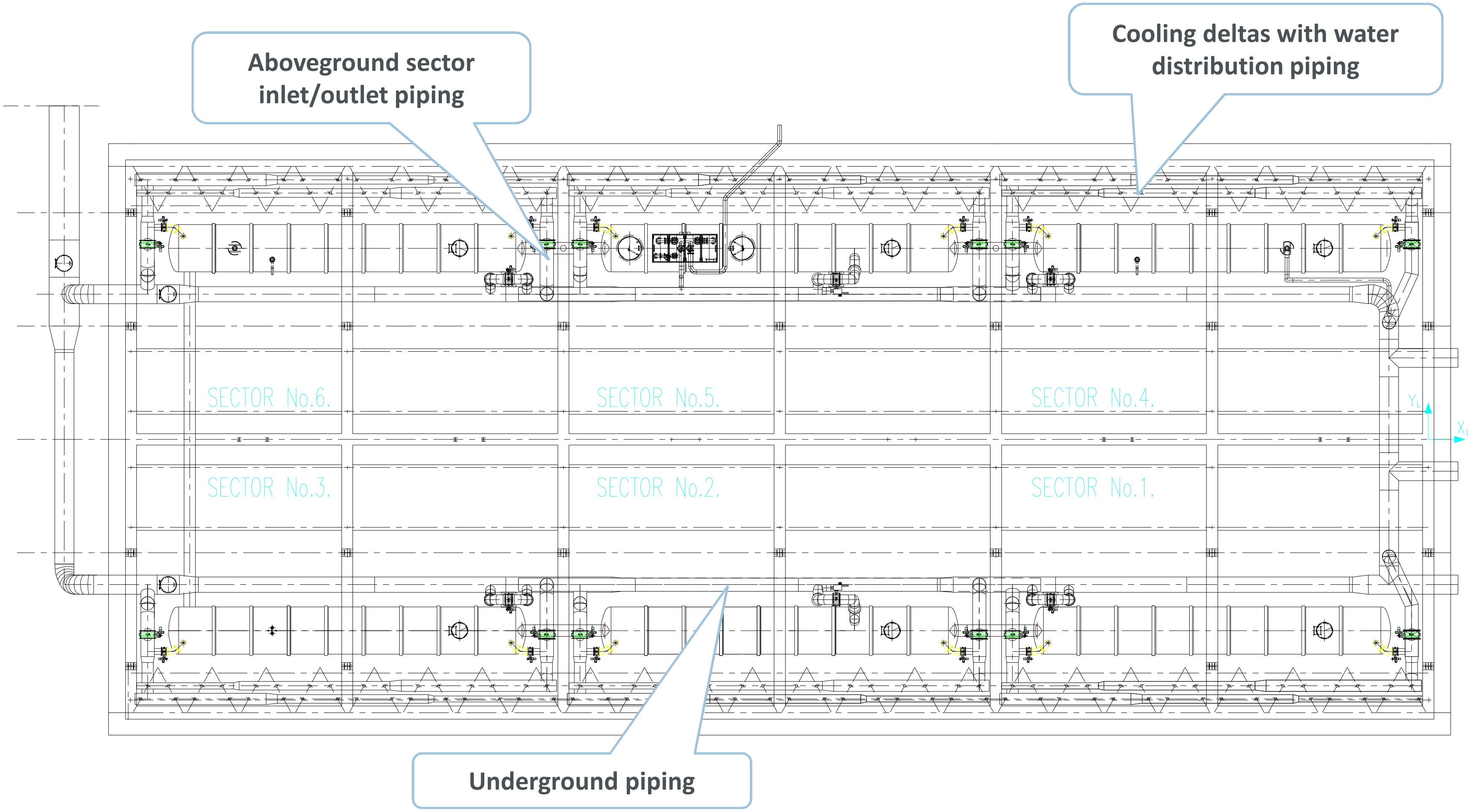
MAIN COMPONENTS
PIPING AND TANKS



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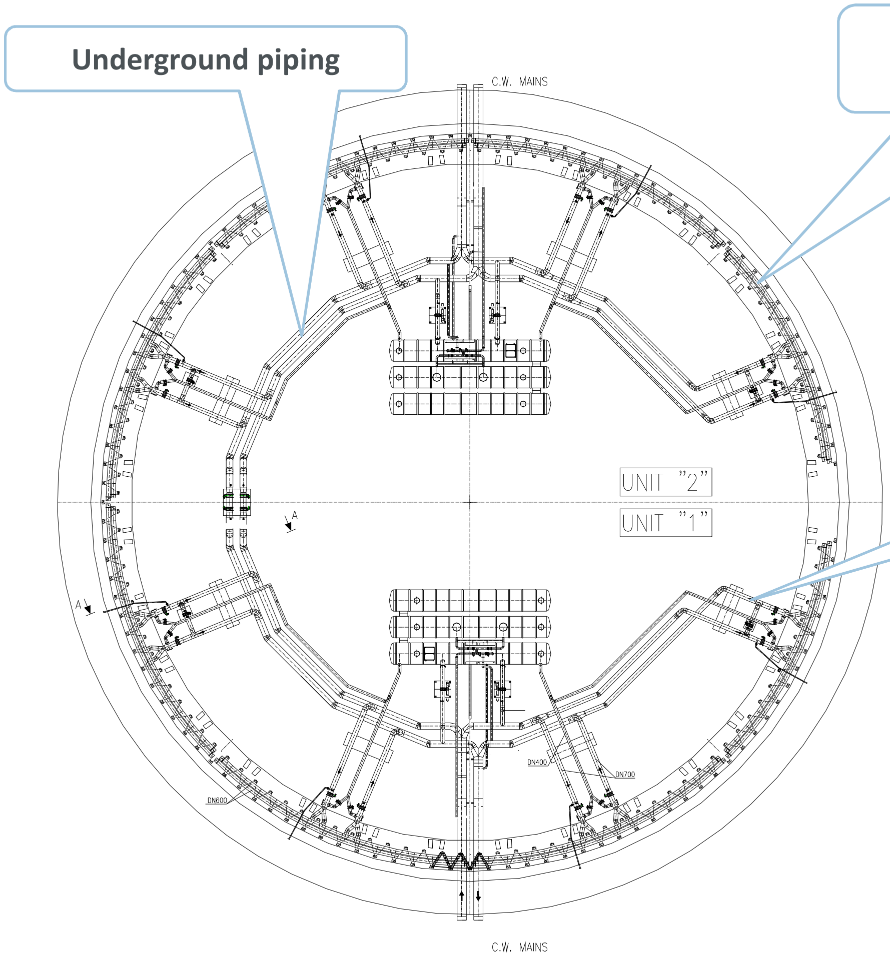

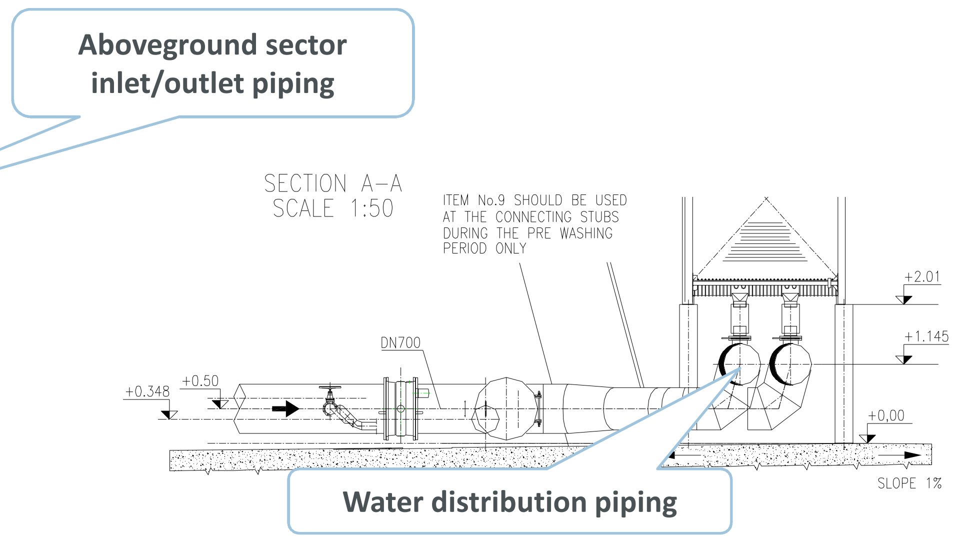

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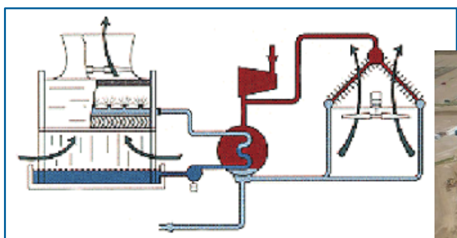
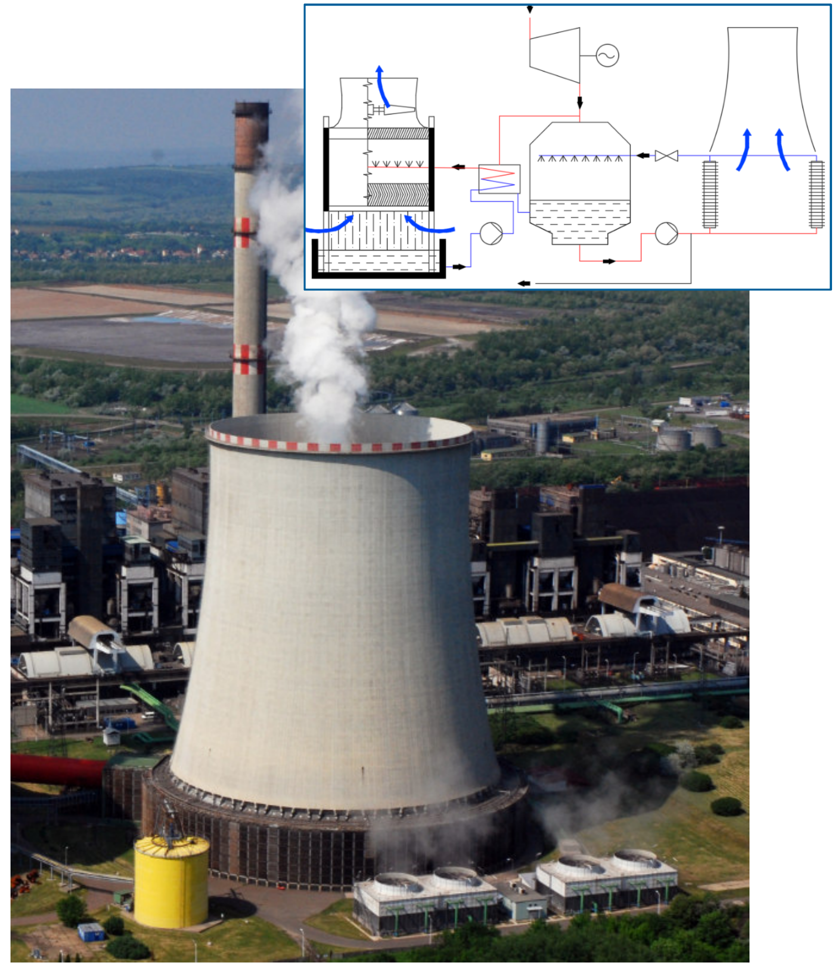
SUMMARY

A seasonal or persistent lack of water today may curtail your plant's output and availability tomorrow.

Reduce your plant's water dependency, protect your asset against droughts, increasing water costs and regulations to your water supply.



ENEXIO reference plant with Air Cooled Condenser and Wet Cooling Tower in a PAC combination (Comanche PP, Pueblo, Co.)



ENEXIO reference plant with an Indirect Dry Cooling (Heller) system and Wet Cooling Tower in parallel connection (Mátra PP, Hungary) (Plume from Heller dry tower originates from a wet scrubber placed inside)

SELECT REFERENCES

180 MWe Adler CCPP, Sochi, Russia (2012)
Ten twin main cooler cells with louvers

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Ten twin main cooler cells with louvers

SELECT REFERENCES

120 MWe Tereshkovo CCGT, Moscow, Russia (2011)
Six twin main cooler cells with louvers and heaters

ENEXIO

SELECT REFERENCES

800 MWe Modugno CCPP, Modugno, Italy (2009), near sea shore;

- 24 main cooler cells without louvers
- Cooling tower arrangement adapted to plot area constraints

TOPICS

1. Company introduction
2. Vulnerability of Power Plants to Water Availability
3. System configuration
4. Dry cooling tower components
5. Summary & select references
6. Questions & discussion