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The Advanced HELLER System

Technical Features & Characteristics

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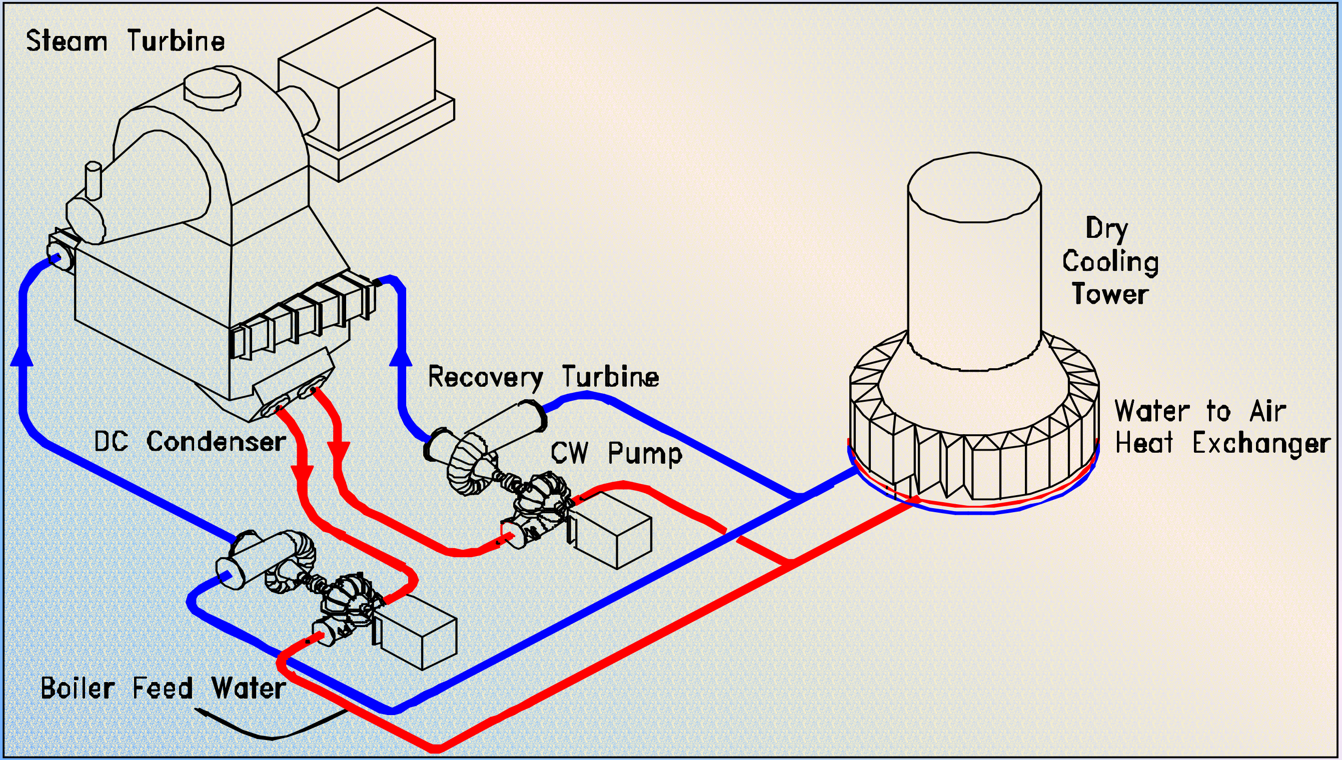
Contents

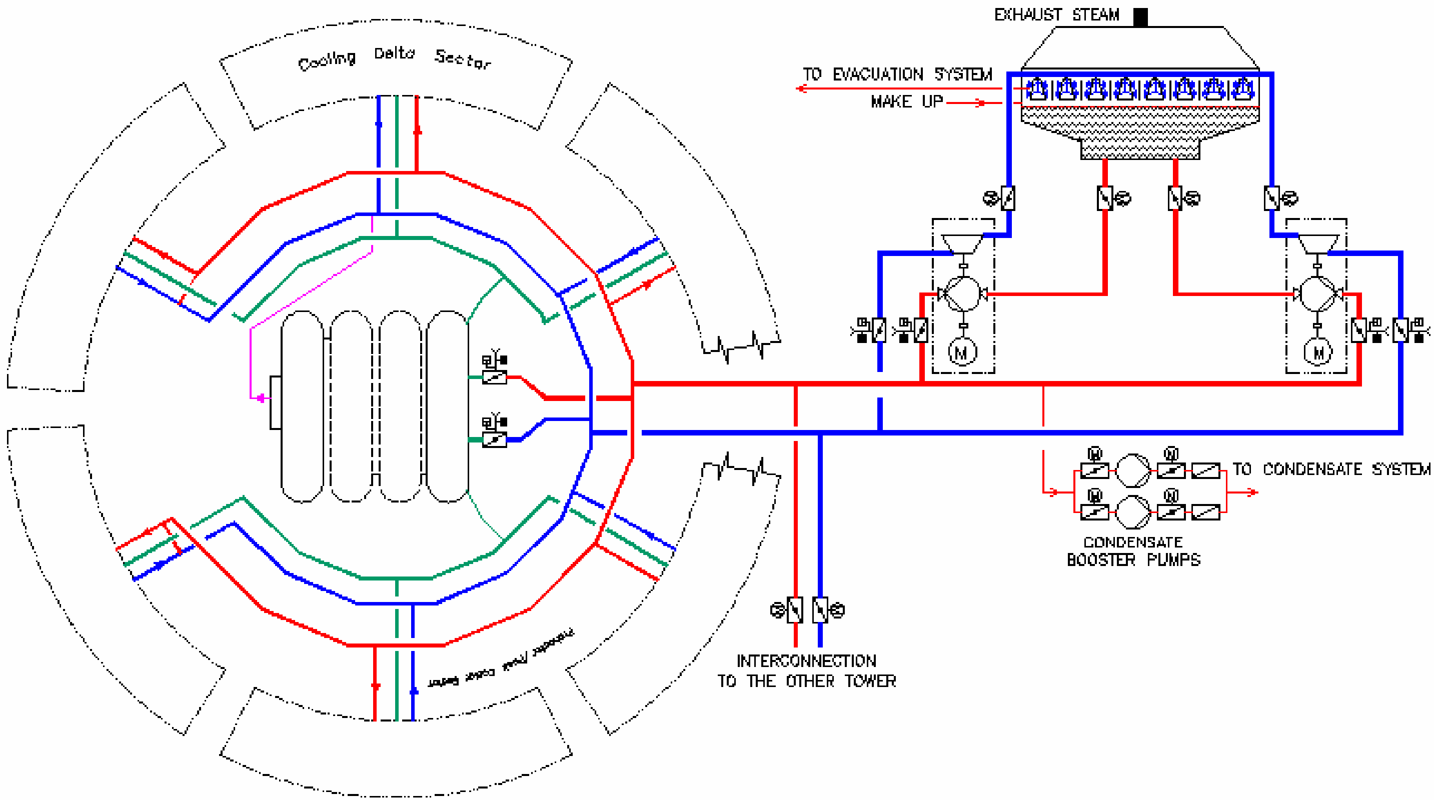
1. HELLER System: Circuitry, Technical Solutions

1.1 HELLER System Circuitry:

HELLER System is an indirect dry cooling plant. The power plant waste heat is initially exchanged in a condenser (preferably a direct contact one) to a closed cooling water circuit. The heat absorbed by the water is rejected to ambient air in fin tube type heat exchangers. [3]



1.1 HELLER System Circuitry – cont.



1.2 Technical Solutions - Condenser Options

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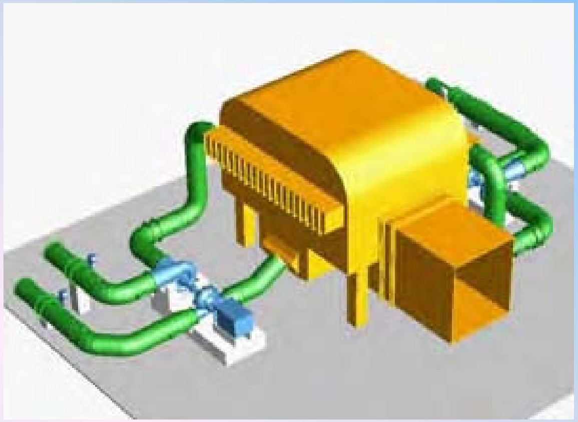
- Conventional Surface Condenser TTD ~ 3-4°C (5.4-7.2°F)

- Direct Contact (DC) Jet Condenser TTD ~ 0.3°C (0.6°F)

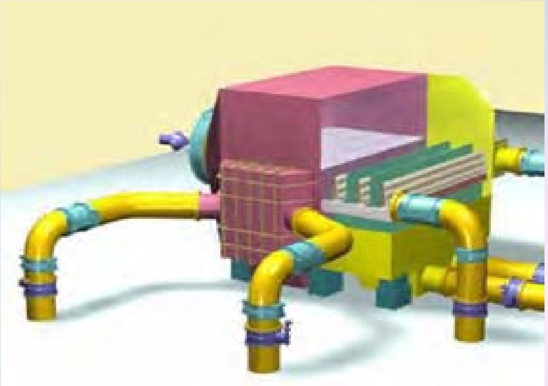
for top entry

for lateral exhaust

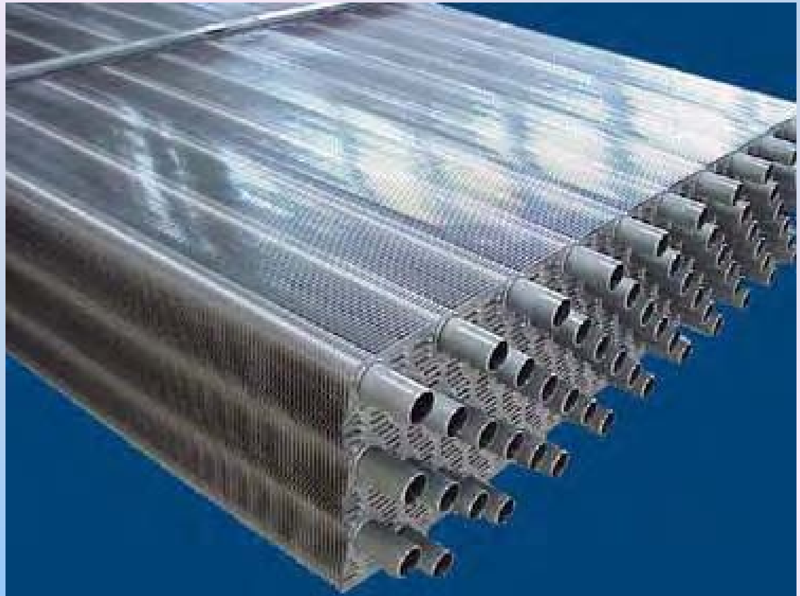


- Combined DC & Surface Condenser

  for one of EGI's novel dry/wet cooling systems



1.2 Technical Solutions – Water-to-Air Heat Exchangers



- The 5th generation FORGÓ Air Cooler, developed for power applications, is a mono-metal all aluminum heat exchanger with protective surface treatment.
- The hard plate Al-fin and normal Al-tube bond provides enduring metallic contact due to “spring effect”.
- Minimum deposition and easy cleaning (cleaning once or twice a year).

- Cooling delta washing equipment enables efficient online cleaning.

1.2 Technical Solutions – Air Moving Equipment (Draft Options)

➢ Mechanical Draft:

– lowest investment cost among dry cooling plants

– relatively high auxiliary power consumption and noise emission

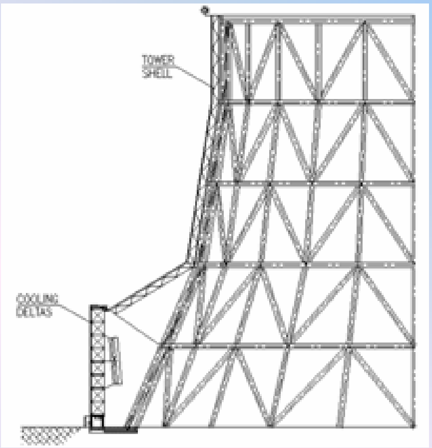
– the circular arrangement reduces noises & warm air re-circulation

➢ Fan Assisted Natural Draft

– fairly competitive for areas with limited restriction on superstructure height (allowing 50-70 m); a low noise solution

– if height limitation is very strict (< 40m), has no distinctive advantage over mechanical draft

– if height is > 60m, part of the air coolers can be without fans



1.2 Technical Solutions – Air Moving Equipment (Draft Options) – cont.

- **Natural Draft:**

– outstanding competitiveness, if the evaluation is based on economic life-cycle present value (extends the economic feasibility of dry cooling against wet cooling)

– improves power plant efficiency by ~2% (compared to fan draft dry cooling)

– zero noise emission

– increased availability & reliability

– low maintenance due to avoiding fan

– opportunity to exhaust flue gases via tower shell, resulting in low ground level concentration of pollutants

– the most environmental friendly solution, but its visual impact is high

2. HELLER System References

- **More than 50 years of experience**
- **A total of 17,000 MW_e power plant capacity in service with the HELLER System**
- **EGI has reference plants in 17 countries including:**

  - units operating under extreme ambient conditions (as cold as - 62°C, or some at + 50°C)
  - the largest dry cooled Combined Cycle Plant in the world
  - the only dry-cooled nuclear power plant in the world
  - natural draft dry cooling towers through which flue gases are exhausted

2. HELLER System References – cont.

Natural Draft Cooling Towers at the Shahid Rajai TPP (4 x 250 MW_e Iran)
Turbine cycle: by MHI; Boiler: by IHI

2. HELLER System References – cont.

In the background the cooling towers of the 4 x 200 MW_e „old” Razdan PS (Armenia)
In the foreground the cooling tower to serve the 2 x 310 MW_e Razdan Extention
(a single tower shell incorporates the air coolers of two units)

2. HELLER System References – cont.

Al Zara 3 x 220 MW_e T.P.P., Syria (commissioned in 2001)
Turn-key contractor: MHI

2. HELLER System References – cont.

GEBZE & ADAPAZARI 3 x 777 MW_e CCPP commissioned in 2002 (Turkey)
EPC-Contractor: BECHTEL-ENKA JV, End-user: INTERGEN
The world's largest dry cooled combined cycle power plant

2. HELLER System References – cont.

3 × 777 MW_e Gebze-Adapazari CCPP
In the foreground: open-air hydraulic machines of the HELLER System
In the background: vertically arranged air coolers

2. HELLER System References – cont.

Dry/deluged Mechanical Draft HELLER System for the 150 MW$_e$ Újpest Combined Cycle co-generation plant, Budapest, Hungary

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2. HELLER System References – cont.

Kaneka Chemical Works (Japan)

Mechanical Draft HELLER Systems with optional spraying at

Sochi Cogeneration Combined Cycle (Russia)

Advanced HELLER System - Technical

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3. Cooling System Characteristics

- **Cooling systems are integral parts of power plants – therefore their characteristics shall also be investigated how they influence the power plant as a whole.**

- **Capability of cooling systems (especially that of the non-water solutions) heavily depend on ambient conditions. Thus it is important to determine their impact on the power output variation as well as the year-round electricity production in function of ambient temperatures. It needs to combine the cooling system and the turbine characteristic curve with the ambient temperature duration diagrams (dry bulb for dry cooling and wet bulb for evaporative one).**

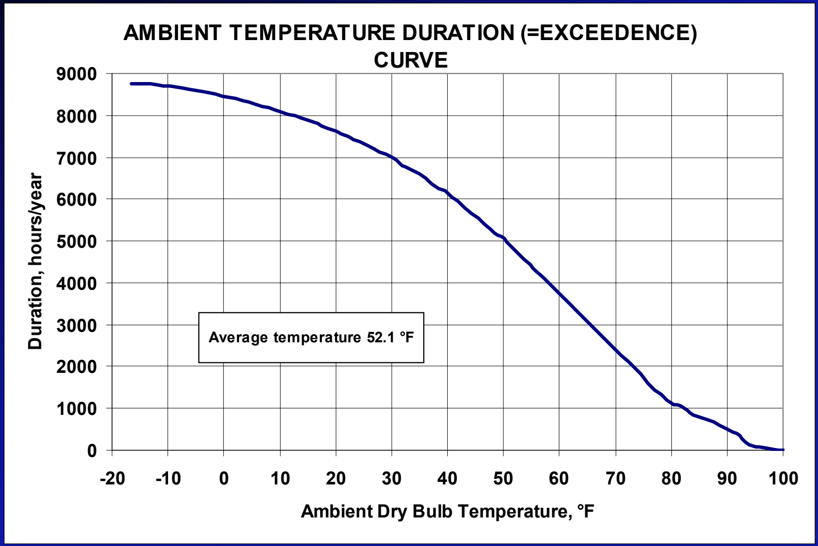
- **Such evaluation process is introduced via the investigation of two power cycles:**

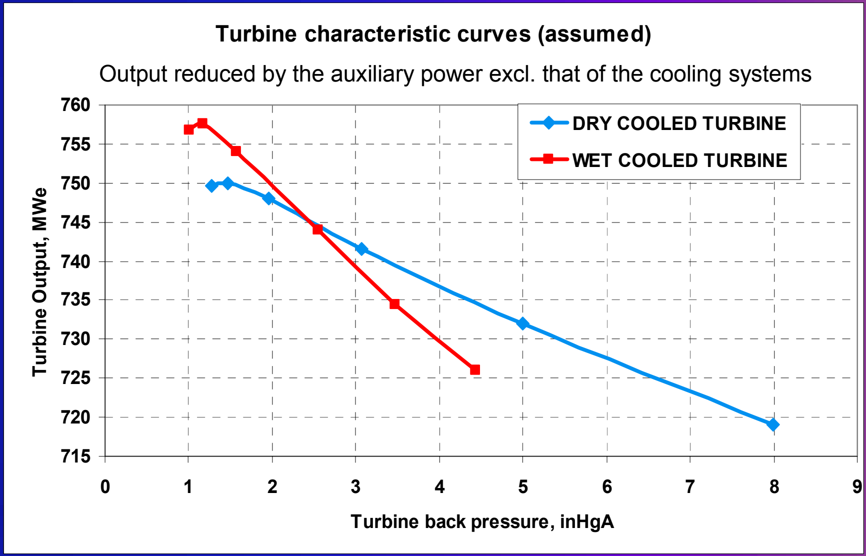
  - an 800 MW_e coal fired supercritical power plant

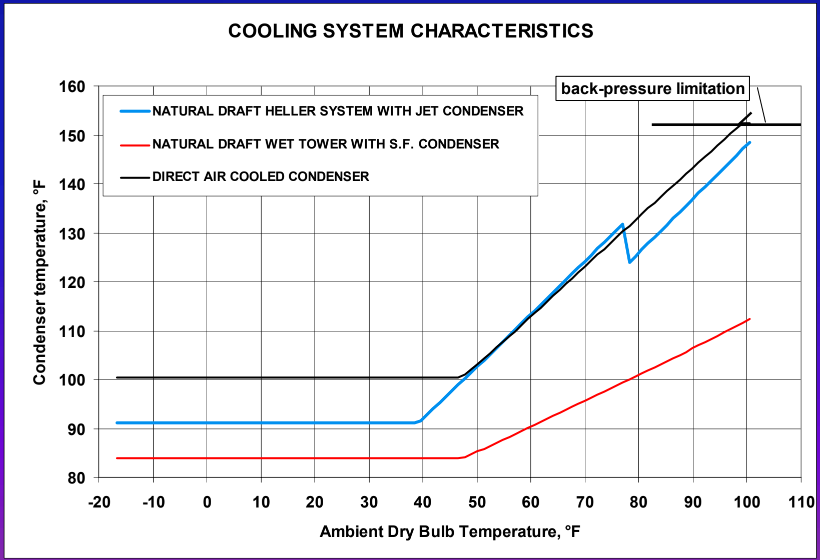
  - a 500 MW_e combined cycle power plant (CCPP)

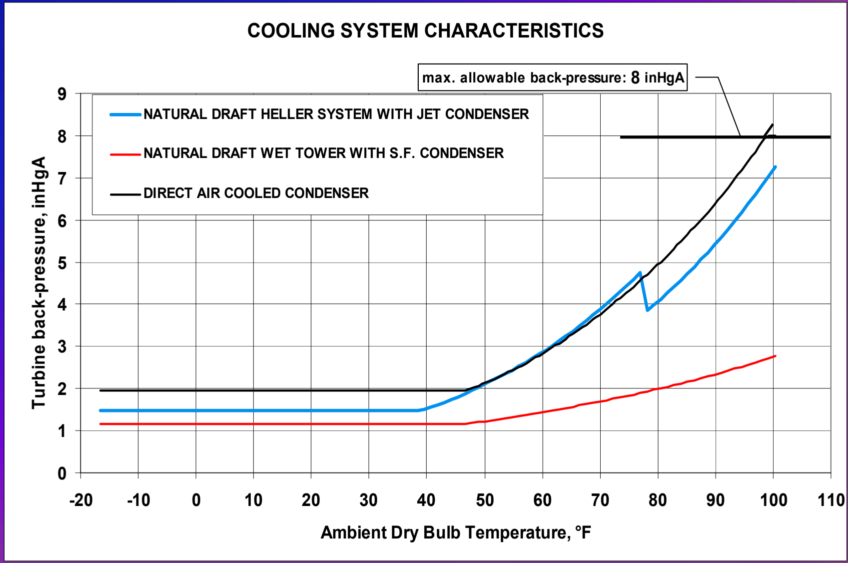
3.1 Characteristics of Cooling Options for an 800 MW_e Supercritical Cycle

Advanced HELLER System - Technical

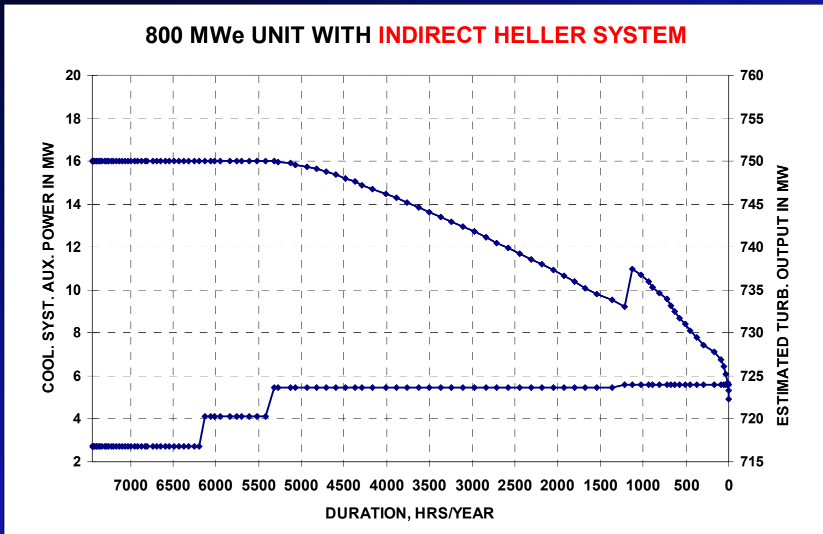


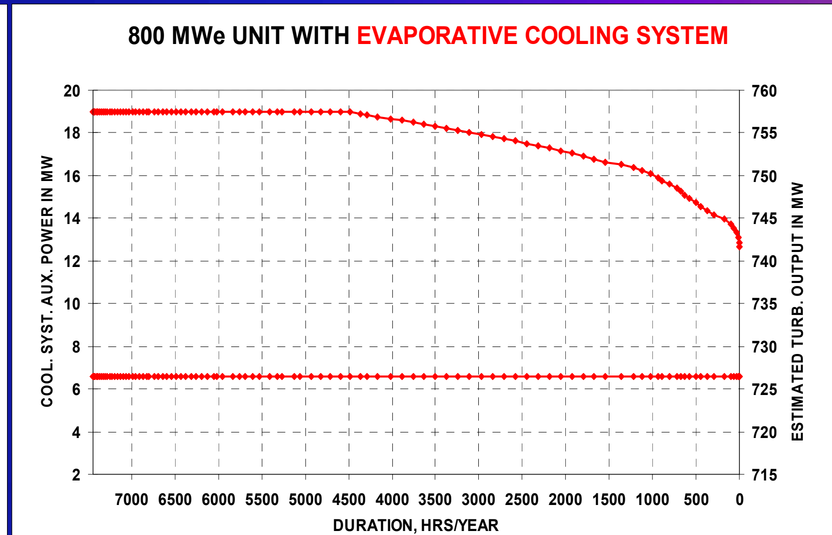




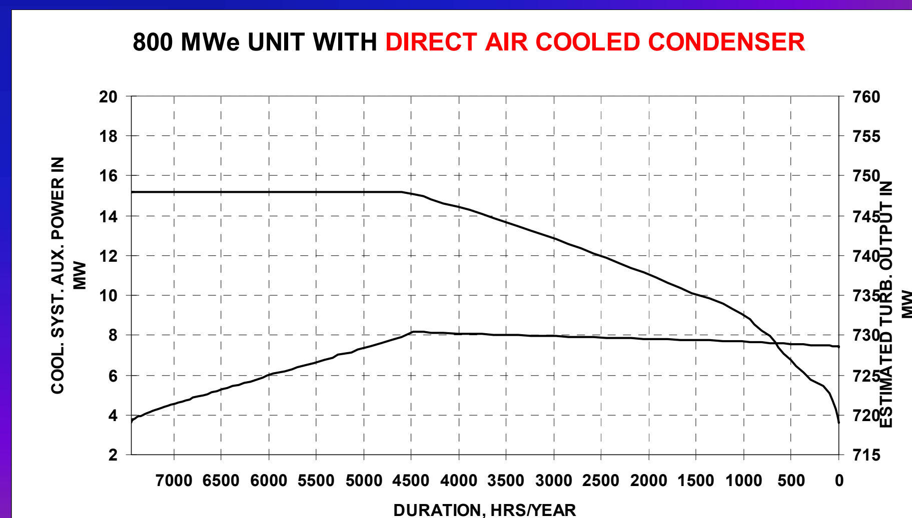


3.1 Characteristics… for an 800 MW_e Supercritical Cycle – cont.

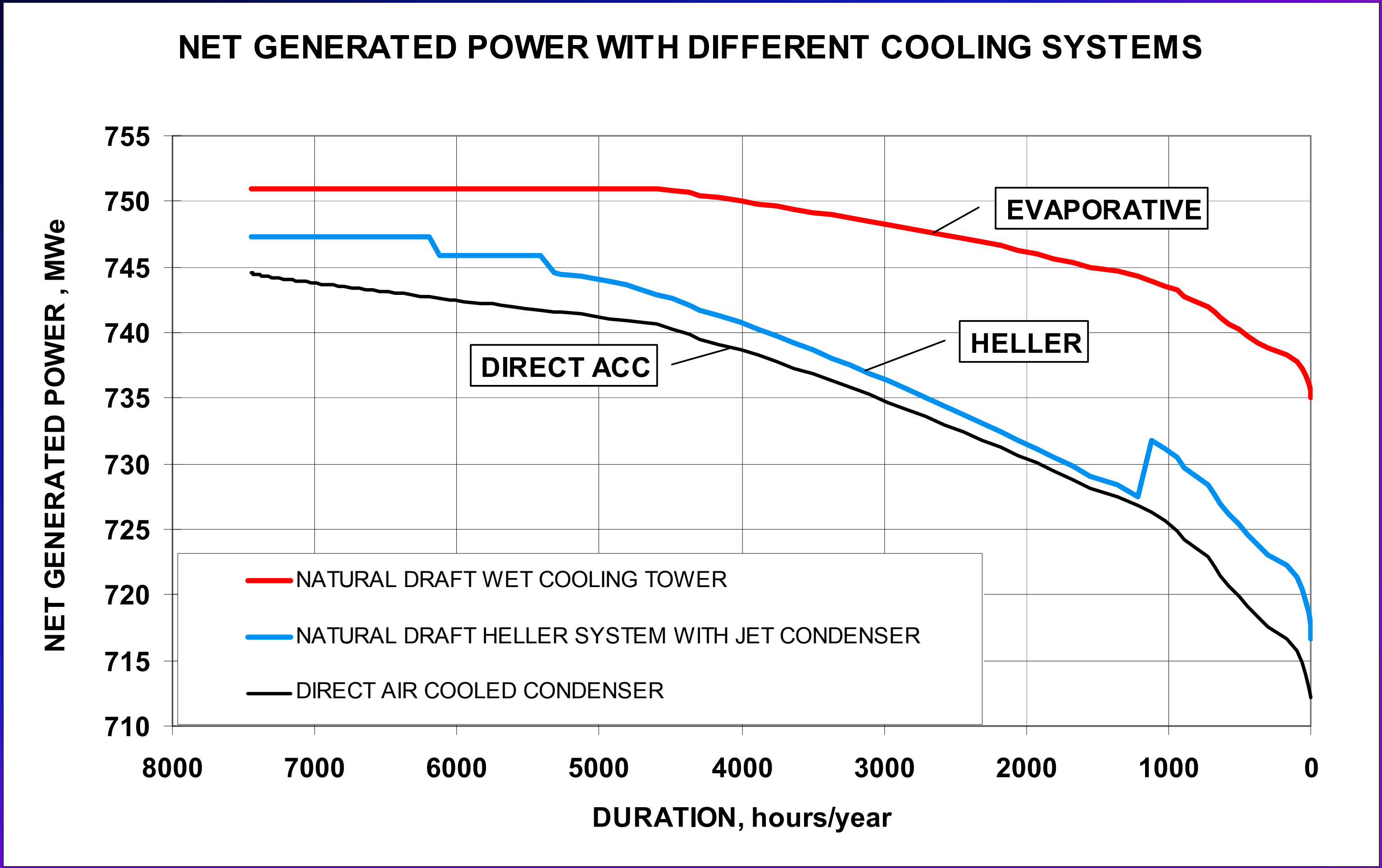




Yearly variation of steam turbine output and auxiliary power consumption versus duration in case of different cooling systems



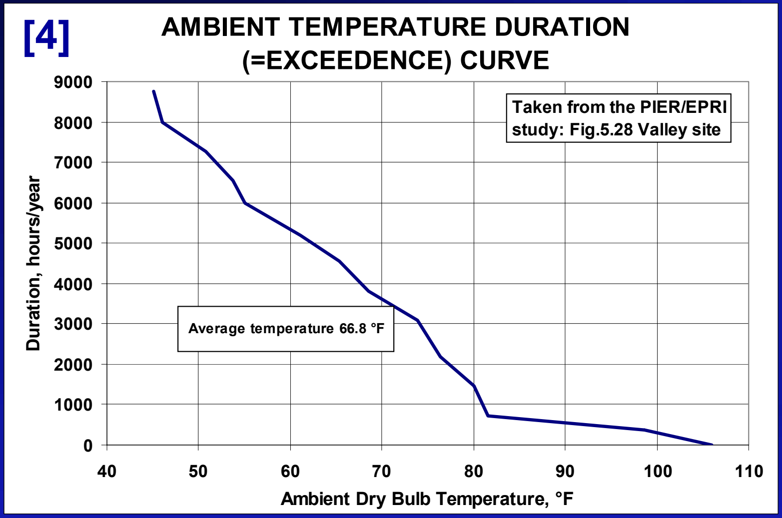
3.1 Characteristics… for an 800 MW_e Supercritical Cycle – cont.

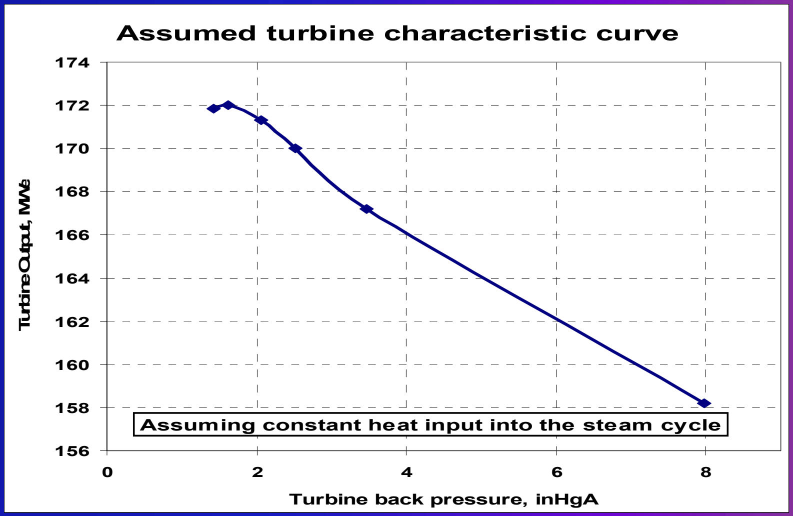


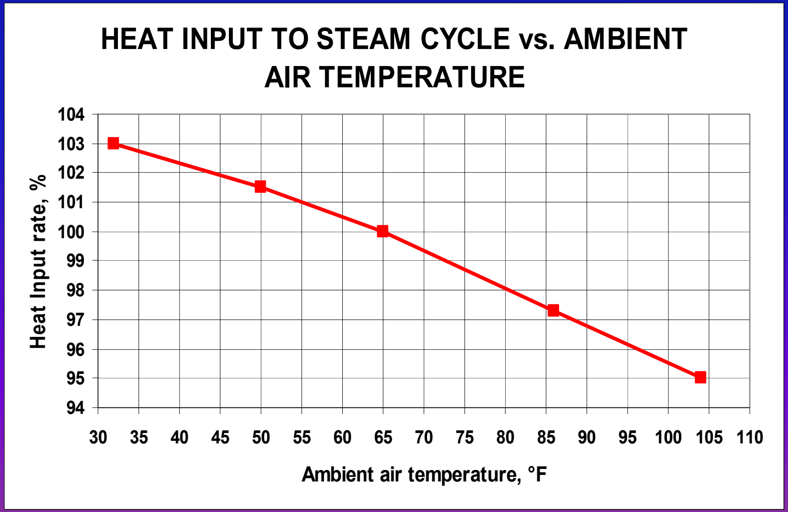
Advanced HELLER System - Technical

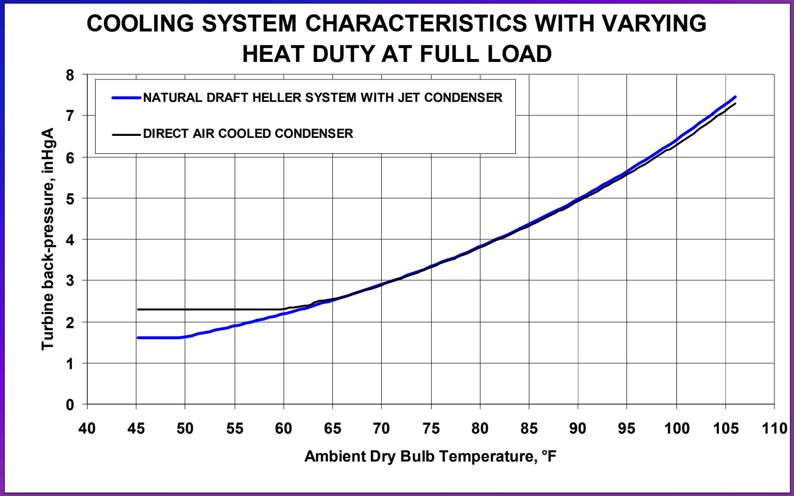
3.2 Characteristics of Dry Cooling Options for an 500 MW_e CCPP

The difference relative to conventional steam cycles is that CCPP steam cycles have a varying heat input in fuction of ambient air temperature

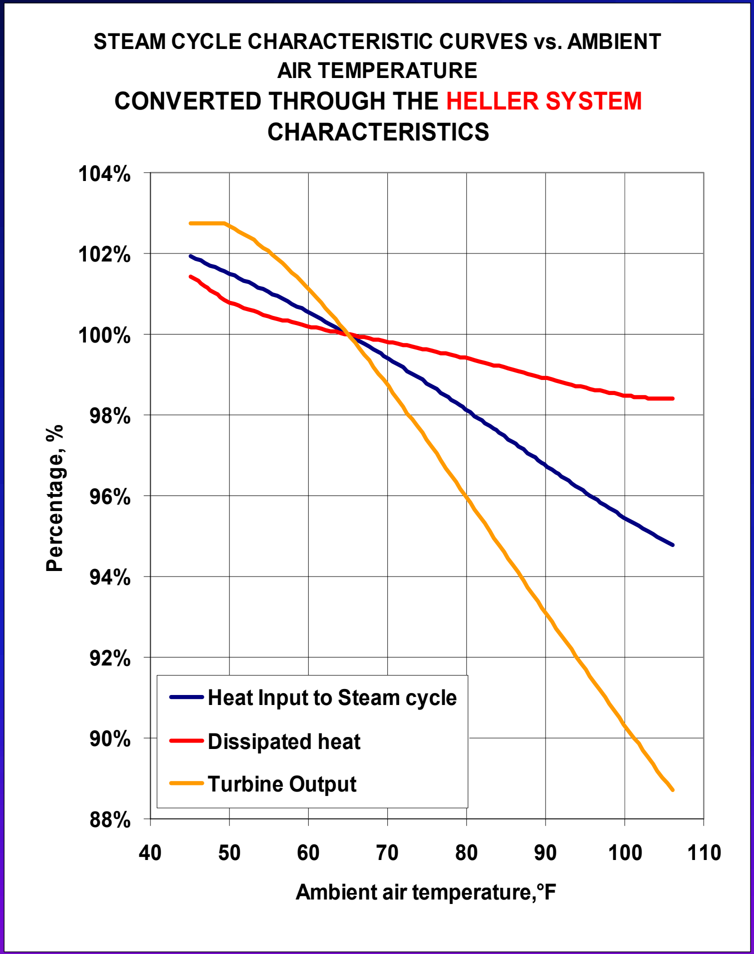


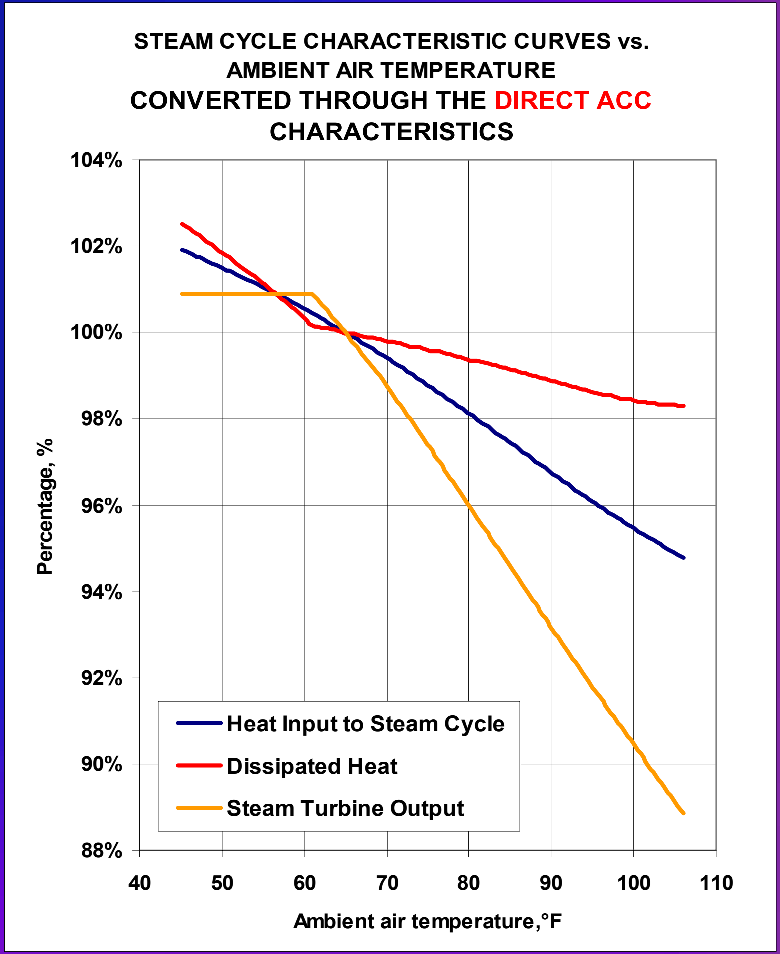




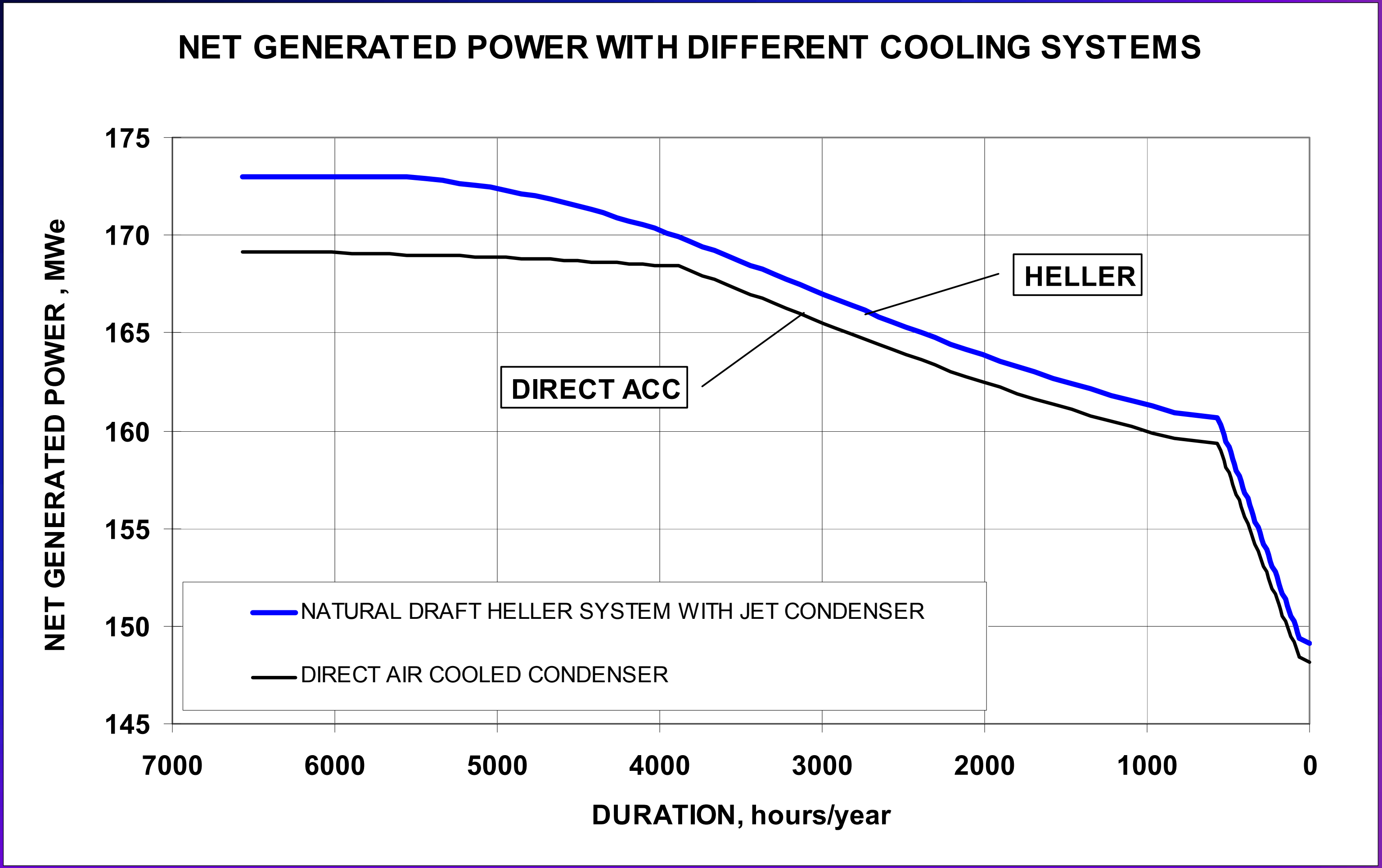


3.2 Characteristics… for an 500 MW_e CCPP - cont.





3.2 Characteristics… for an 500 MW_e CCPP - cont.



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4. HELLER System Availability & Maintenance Considerations

System design concepts and equipment selection have all been refined with a view to providing HELLER System with the maximum possible availability and minimum maintenance:

- **Cooling Water Quality and CW Circuit:** The closed cooling water circuit has condensate quality water, thus precludes any deposition and fouling throughout the whole circuit (incl. the condenser) – by this eliminating the need for cleaning and excluding any external contamination to feed water cycle.
- **Condenser:** The direct contact (DC) jet condenser is a simple, maintenance-free equipment (no tubing), representing 100% availability. Vacuum – similarly to surface condensers is restricted to this space only.
- **Common Feed Water & CW Circuit:** The large condensate quality cooling water volume provides adequate buffering
  - for the power cycle water chemistry regime even in case of temporary malfunctions of water treatment plant (WTP) or condensate polishing plant (CPP),
  - and for smoothing wind gusts induced fluctuation of CW temperature, thus that of the turbine back pressure, too.

4. HELLER System Availability & Maintenance – cont.

• **Impact on Power Unit Water Chemistry, CPP, Boiler:** HELLER System - based on the above features – relative to any other cooling systems provides ideal conditions to applying the most efficient oxygenated water treatments (CWT & NWT) and easing the sensitivity of supercritical cycles to water chemistry, resulting in

- better efficiency and reliability and less maintenance of the CPP ion exchangers (extended periods between regenerations and thus increased resin life-span);

- reduced carry-over of corrosion products to the boiler, thus maintaining the original efficiency for a longer period and requiring less major boiler cleaning.

• **Air Moving Equipment:** The natural draft tower shell represents 100% availability. There is an extreme dry air flow inside, thus no need for maintenance even if flue gases exhausted via the tower shell (no need for any painting or re-painting throughout the whole lifetime of the project).

• **Air Cooler:** The treated all aluminum matrix-type air cooler has a life-span in line with that of the power unit without performance deterioration. Air side surface can effectively be kept clean by washing once or twice a year during operation with an equipment being part of the supply. Sectionalized air cooler arrangement (e.g. 10 sectors) ensures 93% heat dissipation capacity at unchanged back-pressure even if one of the sections is disconnected, or 100% heat dissipation at a 1.7°C higher condenser temperature.

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4. HELLER System Availability & Maintenance – cont.

• **Hydraulic Machinery:** The only continuously moving components of the system requiring brief maintenance during scheduled plant shut-down. If one set of hydraulic machines is out of operation, in case of the 800 MW_e supercritical cycle 92% of the original heat dissipation can be maintained at unchanged vacuum, or the heat dissipation remains 100% at 1.9 ºC higher condenser temperature. Whereas in case of the investigated 500 MW_e CCPP these figures are 81% and 4.5°C.

• **Independence from Water Availability:** Even those HELLER Systems which are equipped with supplementary spraying for enhancing heat dissipation capacity in summer peak periods, can be operated in all-dry mode, i.e. without any water, thus it is not affected by water availability.

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5. Environmental Impacts

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5.1 Comparison of Effects by Dry Cooling Systems on the Environmental Impacts of a 800 MW_e CCPP

Two proven dry cooling systems (a natural draft HELLER System and a mechanical draft ACC) are compared by their influence on the environmental impact of a 800 MW_e Combined Cycle Power Plant (CCPP). First, some performance, operational and layout features are specified:

	HELLER System natural draft	Direct ACC mechanical draft
Operational & Layout Features		
Steam Turbine gross output at design point	270.1	270.1
Yearly average of steam turbine gross output	267.7 MW_e	266.3 MW_e
Cooling System Auxiliary Power Consumption - at design point - yearly average	 2400 kW 2340 kW	 4600 kW 4190 kW
Yearly average of steam turbine net output	265.34 MW_e	262.11 MW_e
Water consumption	nil	nil
Availability / Reliability	excellent	good/fair
Maintenance	low	medium
Air cooler life-span	> 30 years	> 30 years
Flexibility in site arrangement	good	fair
Plot area	∅ 121 m	70 m × 80 m
Primary wind effect	medium	medium
Warm air re-circulation	no	yes
Warm air trans-circulation	no	yes

5.1 Comparison… Environmental Impacts of an 800 MW_e CCPP – cont.

The main qualitative and quantitative environmental impacts are summarized in the following table:

	HELLER System natural draft	**Direct ACC mechanical draft**
Environmental Impacts & Features		
Water need and polluted water discharge	nil	nil
Effect on power cycle ground level NO_x concentration by cooling system	opportunity to reduce NO_x to 10 %	no effect
CO_2 emission - extra CO_2 emission at same electric generation	base	+ 21 million kg CO_2 per year
- or surplus electricity production at same CO_2 emission	+ 19,4 million kWh per year	base
Noise emission by cooling system	no	medium/high
Area around the 800 MW_e CCPP "occupied" by noise over 45 dB(A)	54 ha	90 ha
Visual impact	high	low

5.1 Comparison… Environmental Impacts of an 800 MW_e CCPP – cont.

➢ Noise Emission Impacts

Some more details are given of the noise impacts by the mentioned 800 MW_e CCPP, equipped with either a natural draft HELLER System or by a mechanical draft ACC.

- Noise impacts are best assessed in terms of the area affected by certain noise levels. In mixed industrial-residential districts the German TA-Lärm Standard specifies the allowable noise level (sound pressure) as 60 dB(A) in daytime and 45 dB(A) at night. The corresponding figures for residential-only districts are 50 dB(A) and 35 dB(A), respectively.

- The following slide shows how smaller area is affected by noise emission with the natural draft HELLER System version:

  - Note the area affected by noise levels higher than 45 dB (A): 54 hectares for the HELLER System variant and 90 hectares for the ACC variant.

  - Note also how the natural draft HELLER tower reduces the power plant noise level in certain directions.

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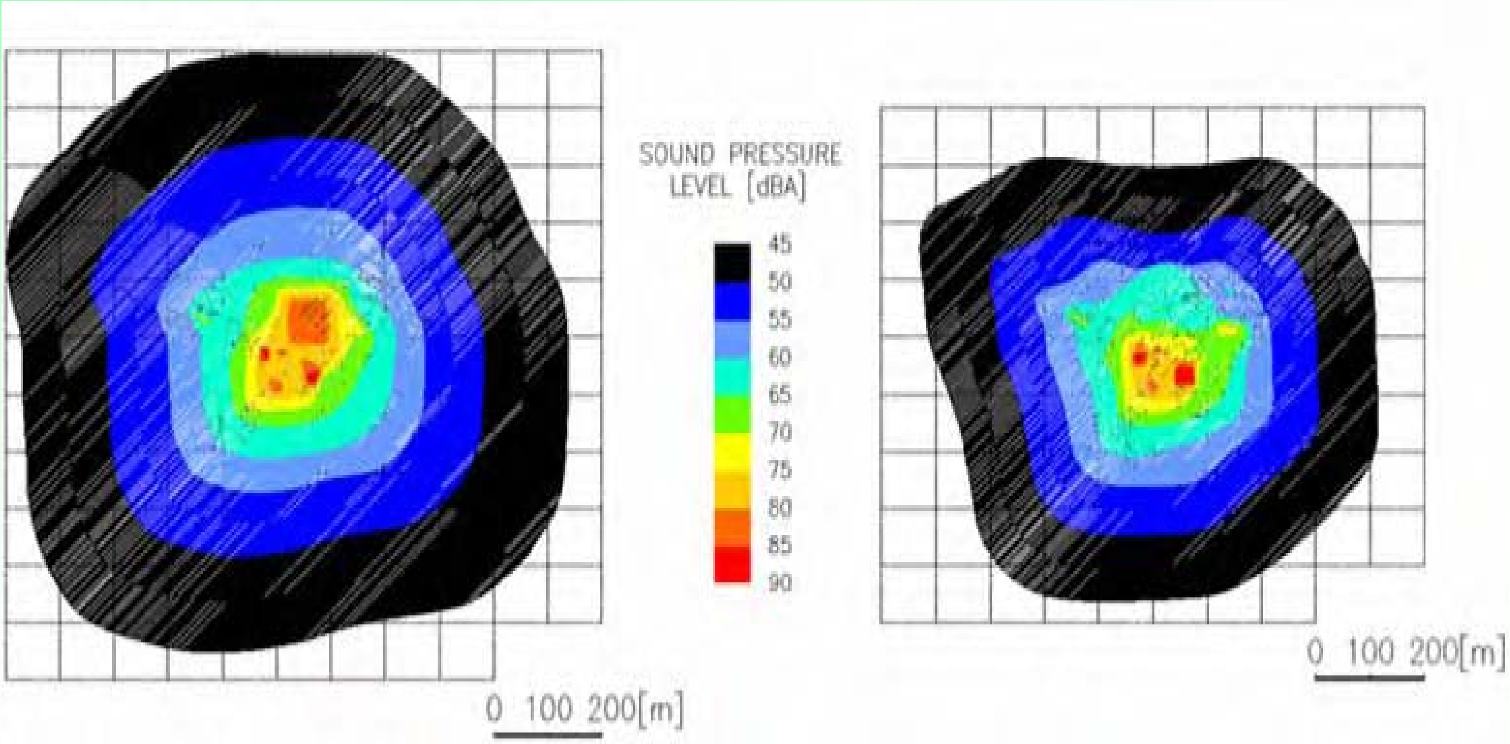
5.1 Comparison… Environmental Impacts of an 800 MW_e CCPP – cont.

Sound pressure levels for an 800 MW_e combined cycle power plant equipped with functionally equivalent dry cooling systems of natural draft HELLER System and mechanical draft direct ACC:



5.1 Comparison… Environmental Impacts of an 800 MW_e CCPP – cont.

- **Visual Impacts**

- For an 800 MW_e CCGT power station, The mechanical draft direct ACC has a plot area of 70 m × 80 m and its height is about 40 m. Due to its limited height from a distance of several hundred meters it has a relatively low-key appearance and small impact on sight.

- The natural draft HELLER System needs a plot area characterized by a base diameter of 120 m, its exit diameter is about 67 m and its height is 135 m.

➢ Summary Conclusions Regarding Environmental Impacts

- In terms of noise emission, CO_2 emissions, opportunity to reduce ground level concentration of pollutants, the HELLER System is superior to the ACC.
- The visual impact of the natural draft HELLER System is greater, though as experiences suggest, it can be integrated to a CCPP site without being too obtrusive. Particularly since there would never be any vapour plume above it.

✓ *In addition, it is remarkable that for the specific application the investment cost of a state-of-the art natural draft HELLER Dry Cooling System is approximately the same as that of the mechanical draft direct ACC, however its total life-cycle cost on a present value basis is significantly lower. The difference in favor of the HELLER System is about 50 % of the investment cost.*

5.2 HELLER System to Reduce Ground Level Concentration of Pollutants

- **The stack-in-tower concept: a greener & cheaper alternative for flue gas exhausting [6] [7]**

  • Natural draft towers (dry and wet towers alike) allow themselves to apply the stack-in-tower arrangement to substitute a high separate chimney with a 40-50 m high stack located inside the tower.

  • The natural draft HELLER System offers significantly more favorable conditions for the stack-in-tower concept than an evaporative cooling tower. The warmed-up (15-25°C increase to the ambient temperature) extremely dry cooling air-flow has a mass flow rate of about 50 times larger than that of the flue gas (in case of conventional steam cycles) – thus represents a tremendous up-lift momentum.

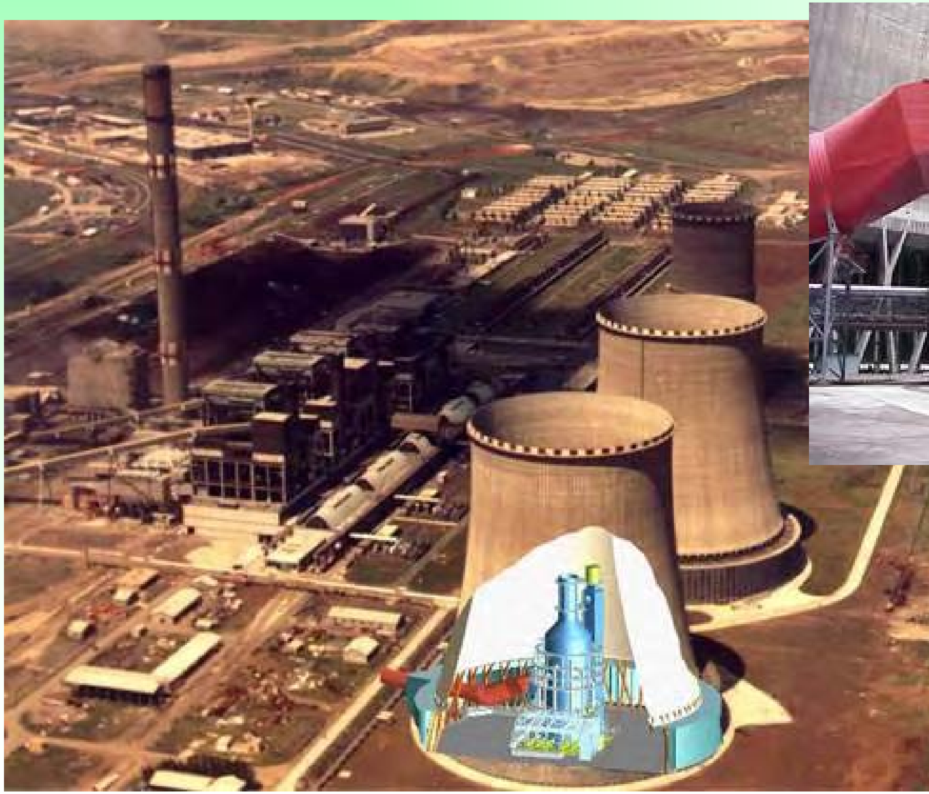
  • This solution not only reduces dramatically the ground level concentrations of pollutants and saves most of the separate high chimney’s investment cost, but also eliminates the necessity of flue gas re-warming recuperator in case of wet scrubbers (FGD).

5.2 HELLER System to Reduce… Pollutants – cont.

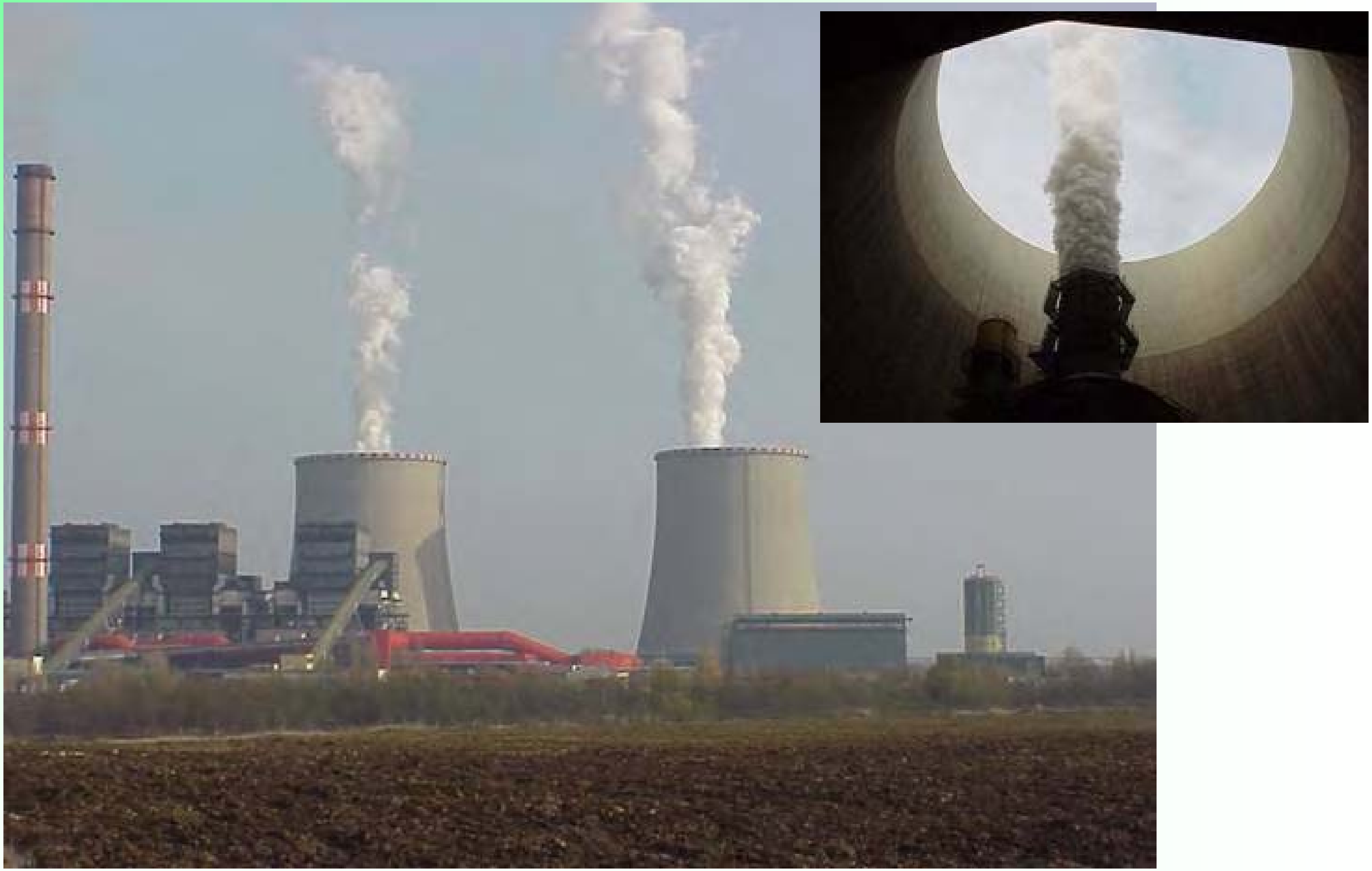
- **EGI's references with HELLER System stack-in-tower concept**

  - **The 800 MW_e lignite fired MATRA PS (Hungary) – an RWE power plant**

    As part of the full scale retrofitting of the power station, FGD plants were implemented into the existing dry HELLER towers.



5.2 HELLER System to Reduce… Pollutants – cont.



MATRA PS

The complete FGD plants are located inside the HELLER type dry cooling towers

5.2 HELLER System to Reduce… Pollutants – cont.

• **The 2 x 160 MW_e CFB boiler based CAN TPP (EÜAS, Turkey) – EPC contractor: ALSTOM**

Flue gases are exhausted through a single tower shell of the HELLER System, serving both CFB boiler based steam cycles.

5.2 HELLER System to Reduce… Pollutants – cont.

Flue gas ducts conducted to the HELLER type dry cooling tower at CAN TPP.

5.2 HELLER System to Reduce… Pollutants – cont.

➢ **Evaluation of the effects on the imission of a 800 MW_e coal fired supercritical steam cycle served by different cooling system alternatives (see also Section 3.1)**

- Natural Draft HELLER System: a 165 m high cooling tower with a 50 m stack inside
- Natural Draft Evaporative Cooling System: a 157 m high cooling tower with a 50 m stack inside
- Mechanical Draft ACC: a 250 m high separate chimney

The results of the dispersion modeling based on the VDI S/P method are given in the attachment for all 3 variants considering yearly average, daily average and hourly maximum ground level concentration values in a 16x16 km area.

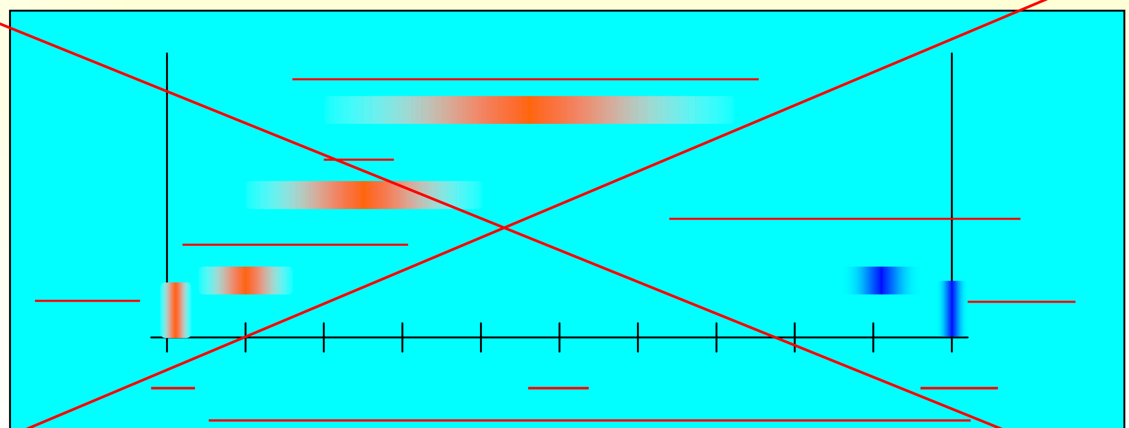
The power unit with all three cooling system variants meet the allowable limit values for the ground level concentrations. The HELLER System stack-in-tower scores the best - resulting in 60% lower yearly average and 40% lower hourly maximum values than the Evaporative CS stack-in-tower. The results of Evaporative CS stack-in-tower are somewhat better than those of direct ACC with a separate chimney.

Application of dry/wet combination are to be considered if

- the available water is less than needed for an all-wet system
- the make-up water price high enough but still does not justify an all-dry system
- there is an emphasis on reducing environmental impact

EGI has developed several dry/wet combinations derived from HELLER System [1] [5] aiming at

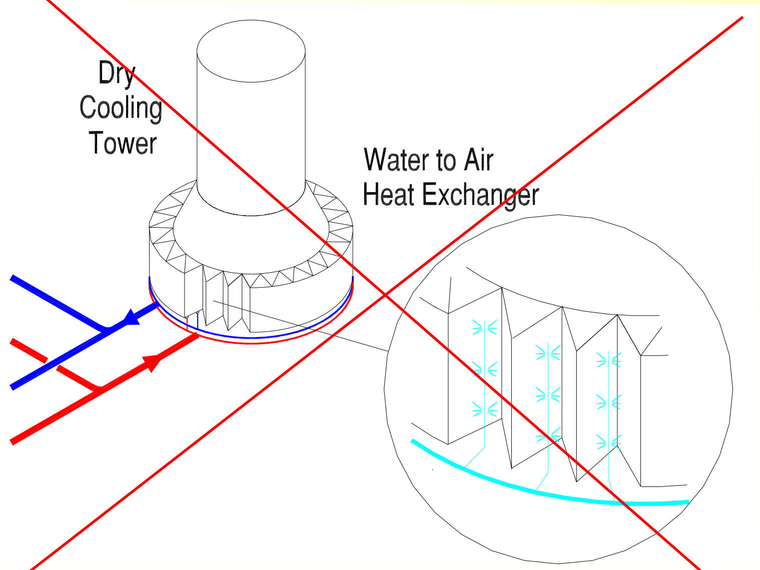
- improving environmental compatibility and water conservation feature relative to wet cooling
- improving summertime turbine output and reducing investment costs relative to dry cooling



6. Dry/Wet Combinations Derived from HELLER System – cont.

- **Dry System with Water Spraying (2-10%)**

All dry HELLER Systems equipped with optional water spraying opportunities to be used for peak-shaving in the hottest summer days. Low additional investment, minimal & limited water-use (2-10%).



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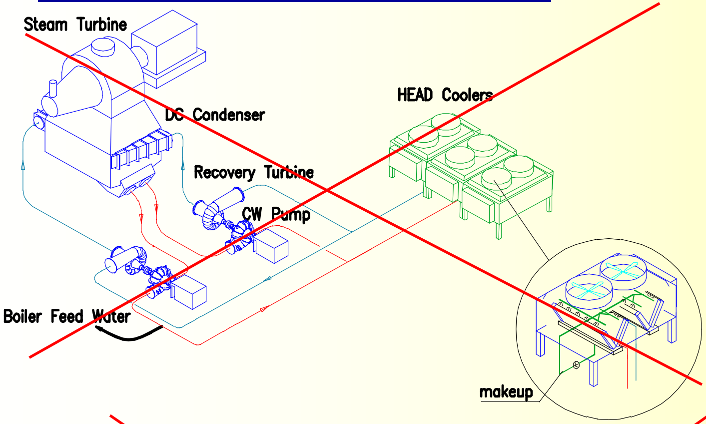
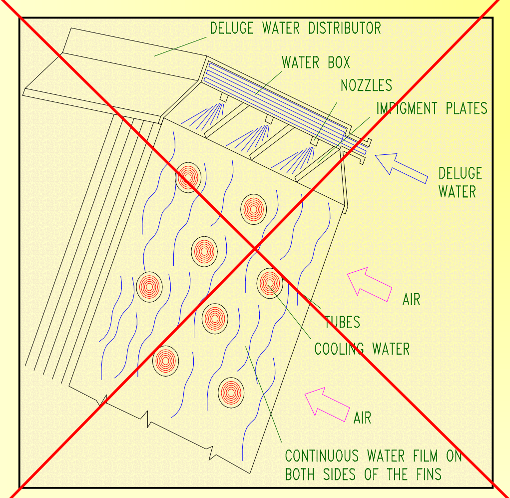
6. Dry/Wet Combinations Derived from HELLER System – cont.

HEAD Cooling System (5-35%)





- A flexible solution ideally suited to summer peaking power generators or co-generation plants with seasonally changing heat load
- All dry operation throughout a significant part of the year
- A heat exchanger optimal for both dry & wet operation

Dry Tower with delugable Peak Coolers (5-10%)

Dry/deluged Cooling System (10-35%)

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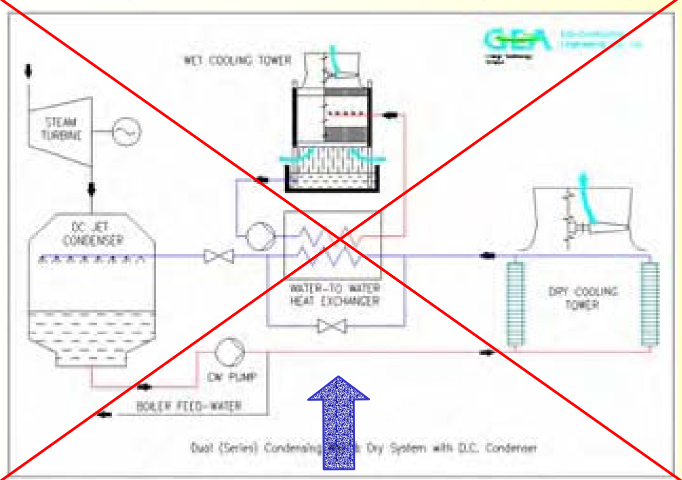
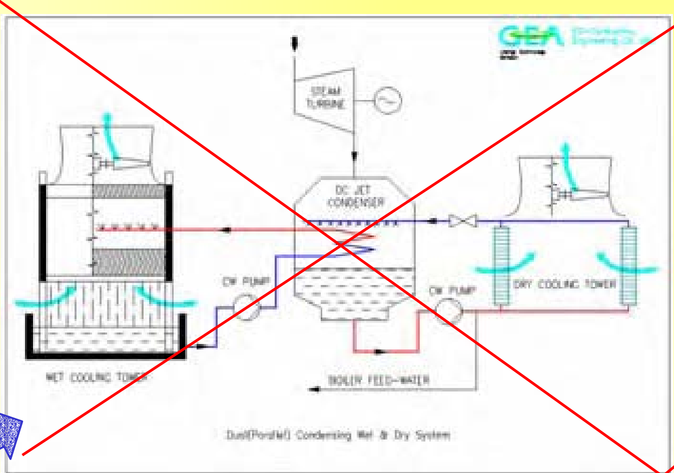
6. Dry/Wet Combinations Derived from HELLER System – cont.

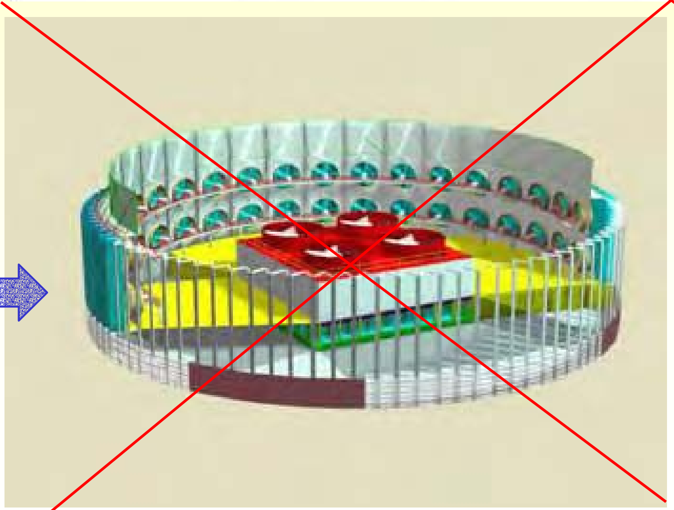
➢ Series HELLER & Evaporative (SH&E) Cooling System (20-70%)



➢ HELLER & Evaporative (H&E) Cooling System (20-70%)



- Both the series and parallel connection provides great flexibility in heat rejection capability and can also be used to convert existing wet cooling towers to dry/wet ones
- They are water conservation type dry/wet systems (water requirement 20-70% that of a wet cooling tower).
- They can be arranged also to provide in addition plume abatement or reduced plume.



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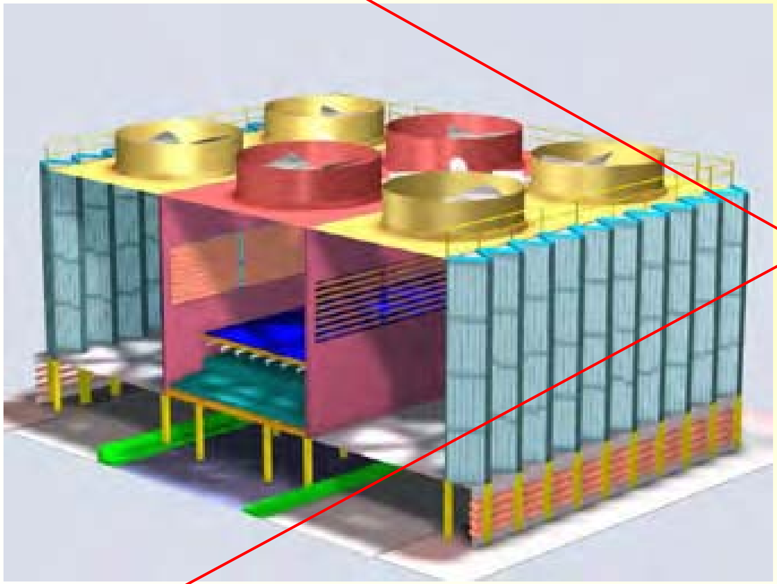
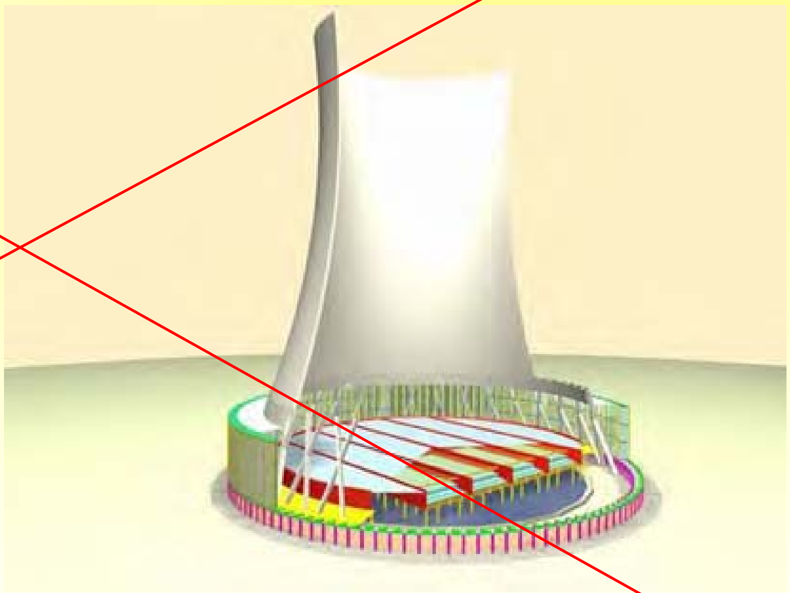
6. Dry/Wet Combinations Derived from HELLER System – cont.



H&E Cooling System - A rectangular arrangement for water conservation & plume abatement plus reduced noise emission



SH&E or H&E Cooling System - All natural draft - for water conservation & reduced plume and reduced noise emission

REFERENCES

[1] Szabó, Z., Tasnádi, C., Combined Dry/Wet Cooling Systems for Water Conservation, Cooling Tower Symposium of IAHR, October 1992, Karlsruhe, Germany

[2] Lees, M., The economics of wet vs. dry cooling for combined cycle, Seminar on Condensers and Cooling Towers for Combined Cycle, April 1994, London

[3] Balogh, A., Takács, Z., Developing Indirect Dry Cooling Systems for Modern Power Plants, EGI Website, 1998

[4] Maulbetsch, J.S., Comparison of Alternate Cooling Technologies for California Power Plants, a PIER/EPRI report for the California Energy Commission, February 2002, Palo Alto (CA)

[5] Szabó, Z., Water Conservation, Journal of Power & Energy 4th quarter, 2002 – Asia Pacific Development

[6] Szabó, Z., Cool for Coal, Journal of Power & Energy 1st quarter, 2004 - Asia Pacific Development

[7] Takács, Z., Flue Gas Introduction - Advantages of Dry Cooling Towers, 5th Int. Symp. on Natural Draft Cooling Towers, May 2004, Istanbul

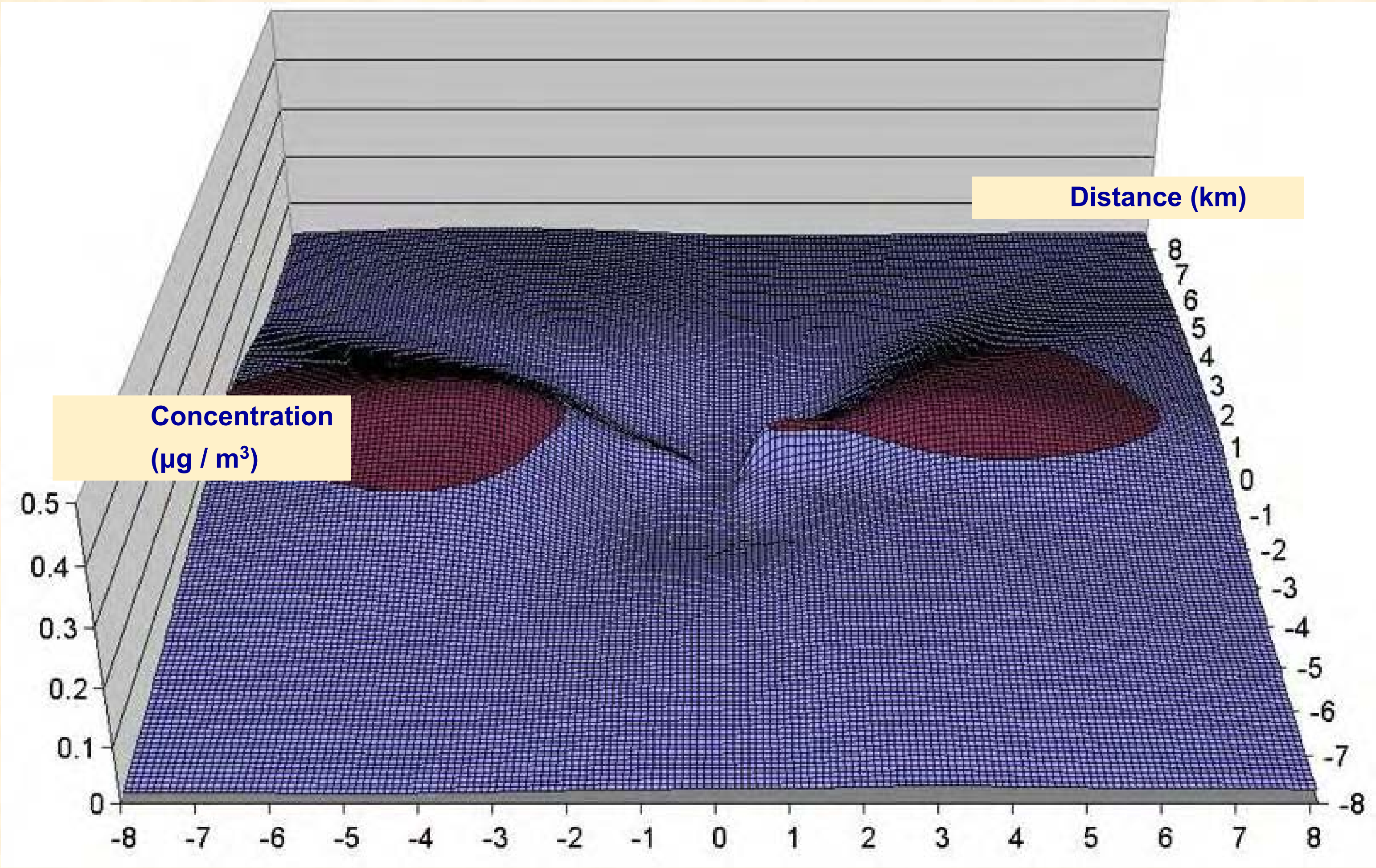
[8] Balogh, A., Szabó,Z., Advanced Heller System to Improve Economics of Power Generation, EPRI Conference on Advanced Cooling Strategies/Technologies, June 2005, Sacramento (CA)

EGI

Advanced HELLER System - Technical

Ground level SO_2 concentrations for an 800 MW_e Supercritical Cycle

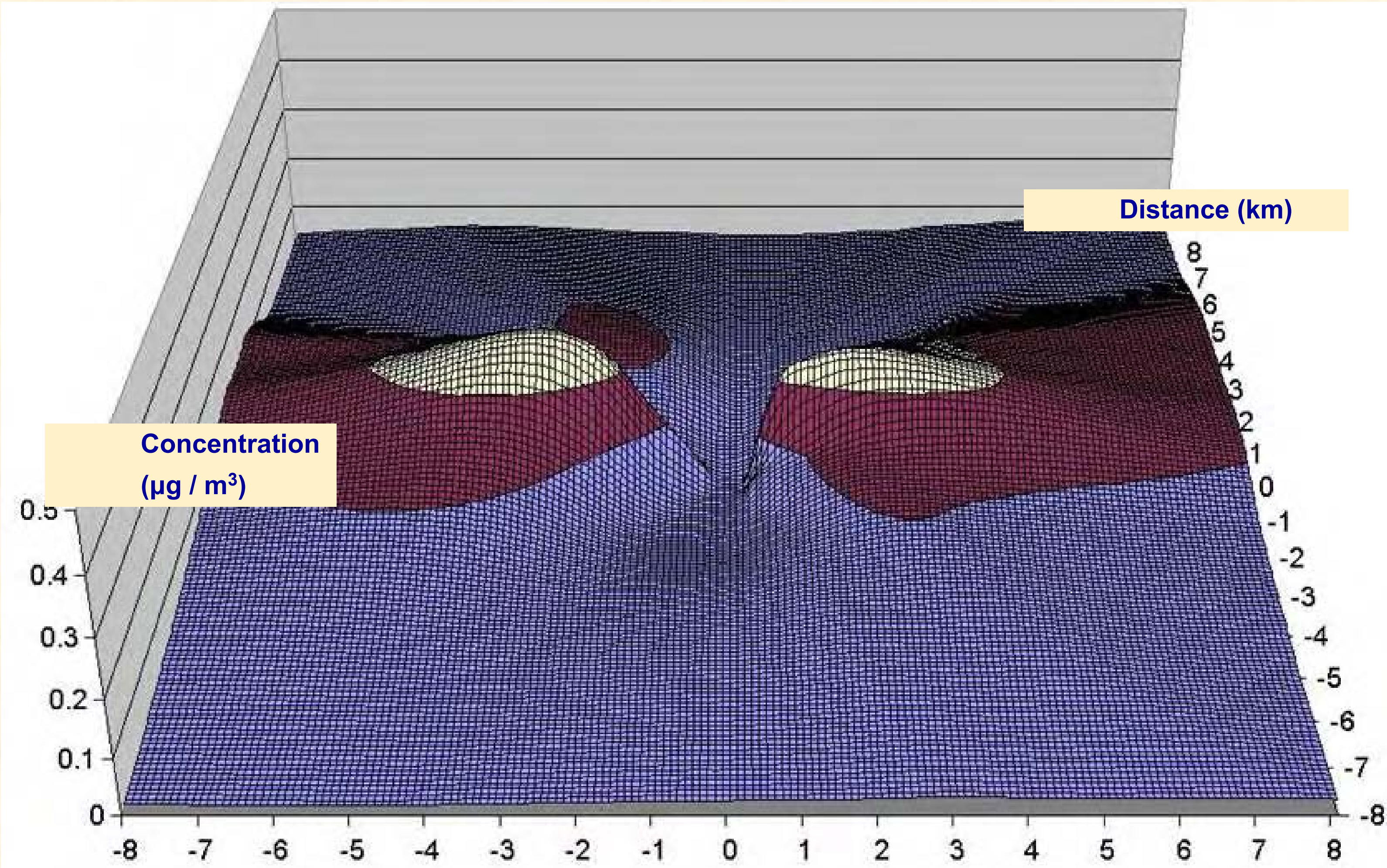
Yearly average – HELLER System with stack-in-tower (VDI S/P model)



Distance (km)

Enclosures - Ground level SO_2 concentrations… - cont.

Yearly average – Evaporative CS with stack-in-tower (VDI S/P model)



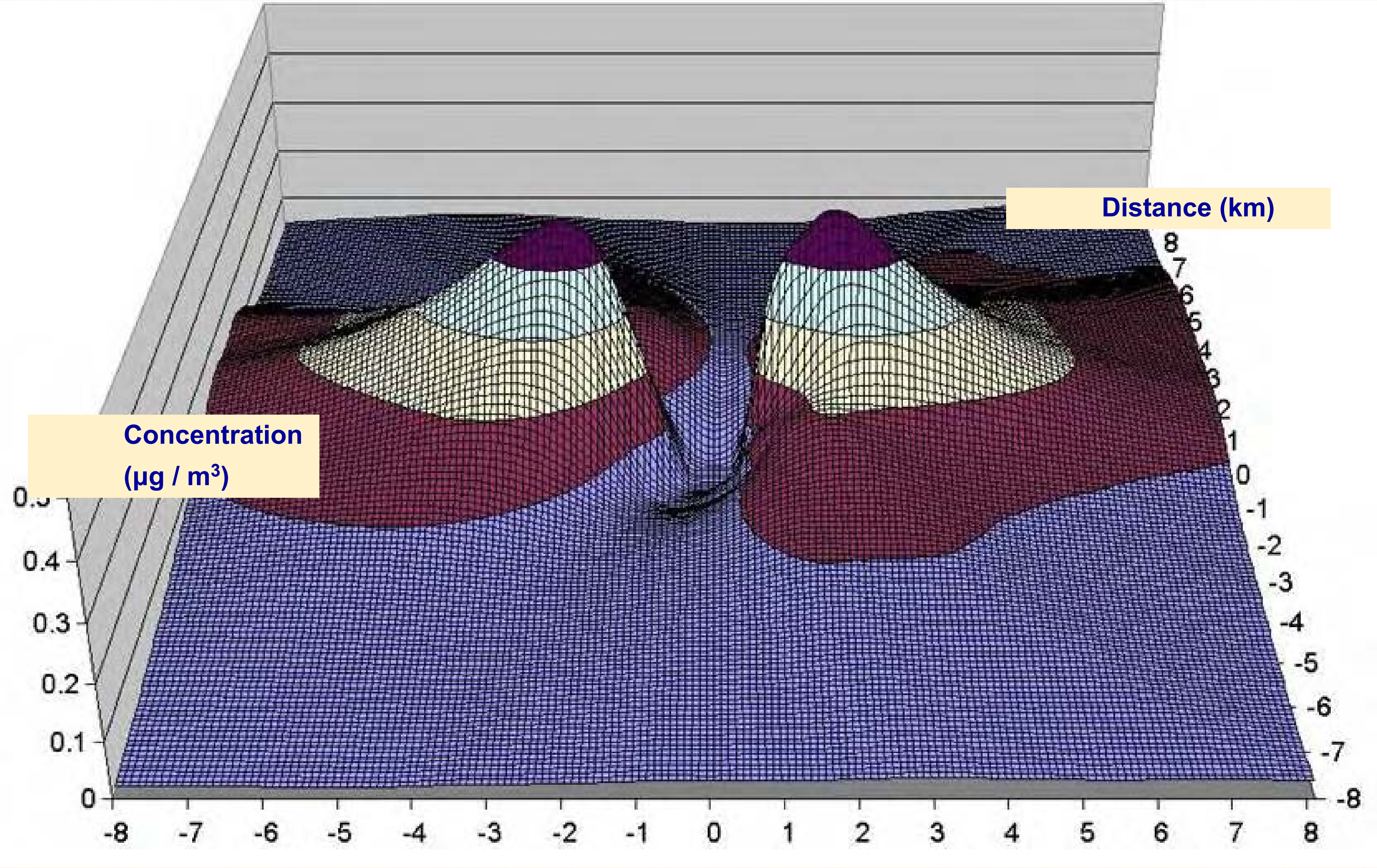
Distance (km)

Enclosures - Ground level SO_2 concentrations… – cont.

EGI

Advanced HELLER System - Technical

Yearly average – Direct ACC with 250 m chimney (TA Luft / VDI model)

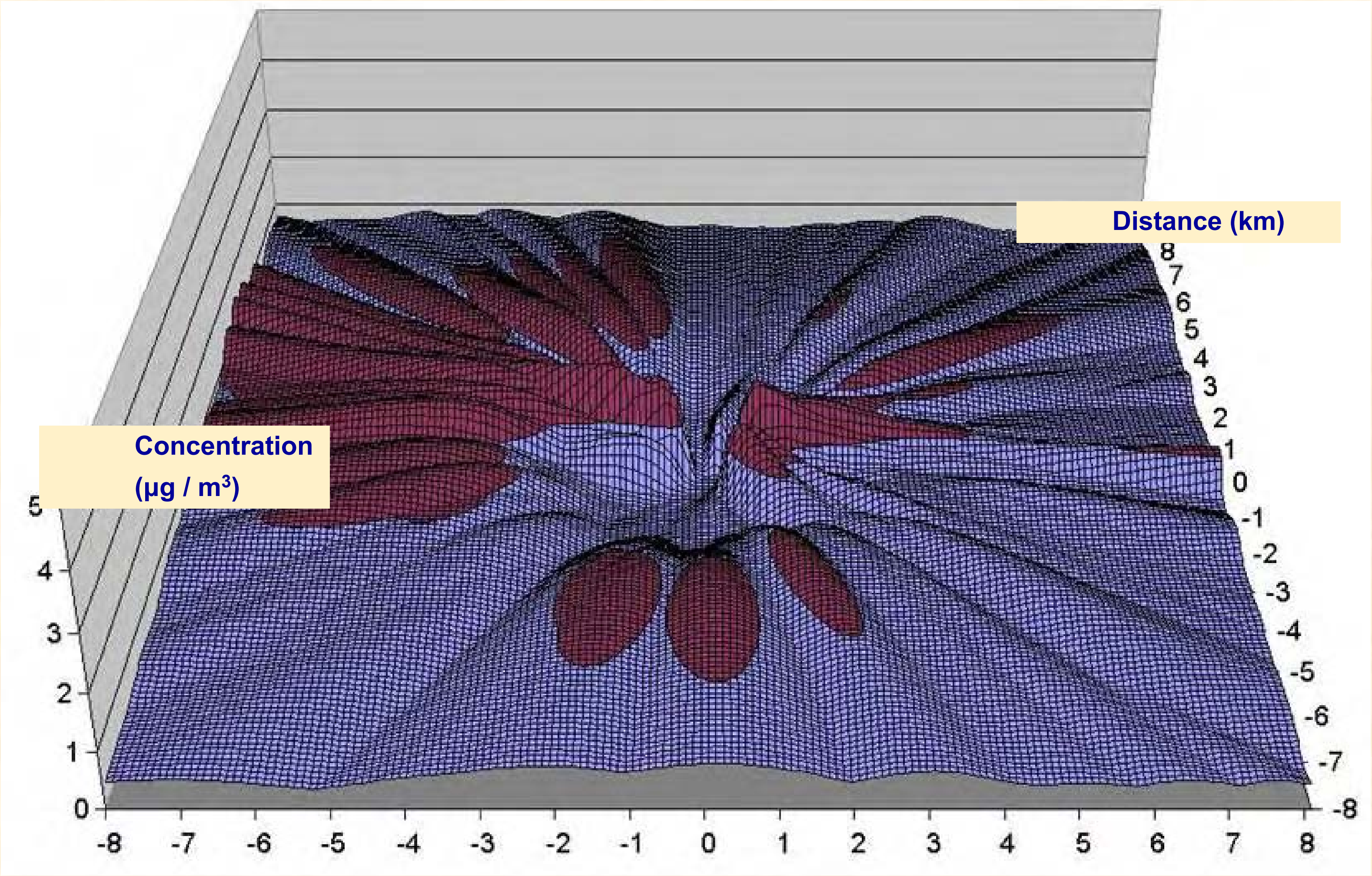


Distance (km)

Enclosures - Ground level SO_2 concentrations… – cont.

EGI

Daily average – HELLER System with stack-in-tower (VDI S/P model)



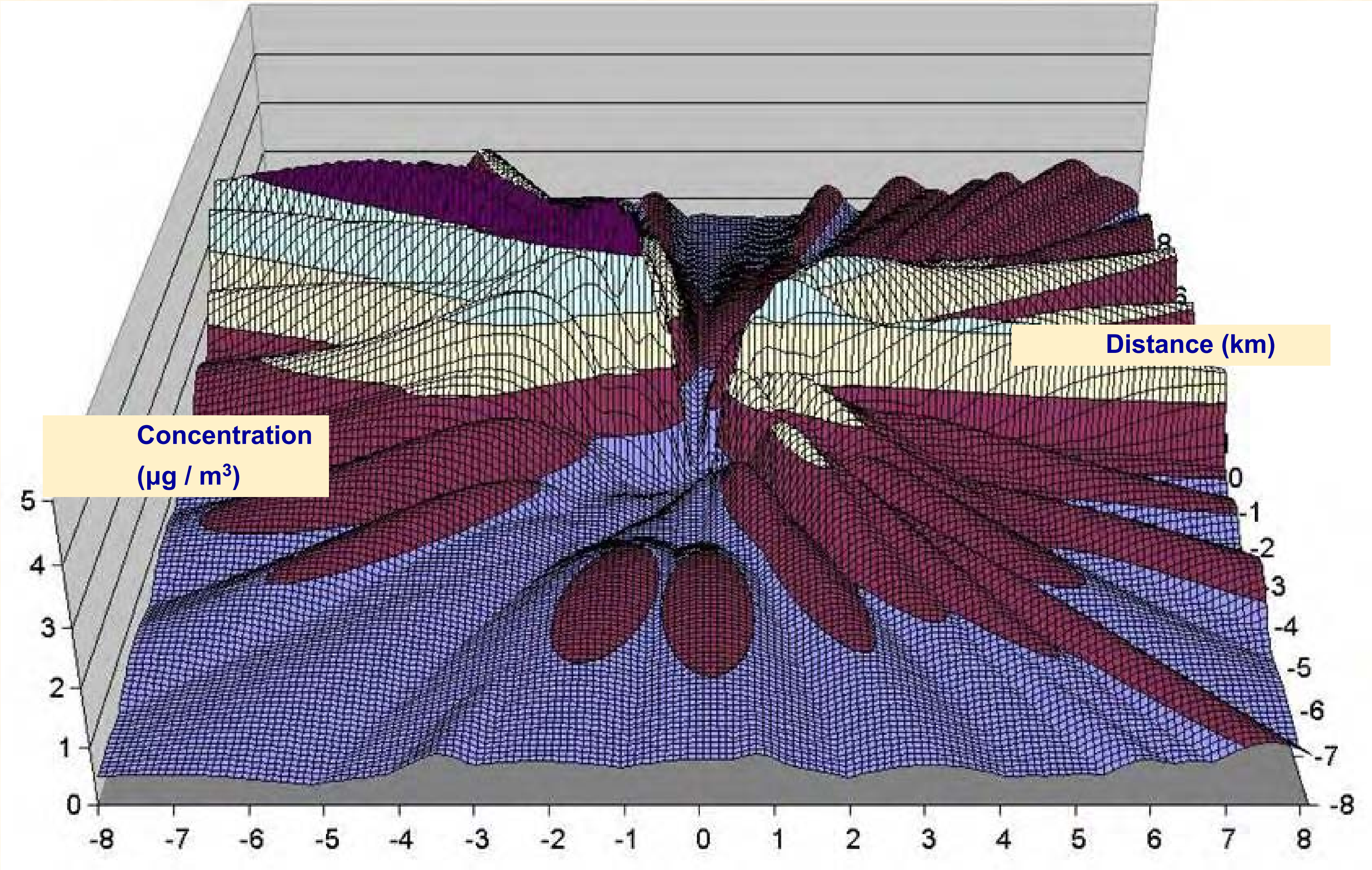
Distance (km)

Enclosures - Ground level SO_2 concentrations… – cont.

EGI

Advanced HELLER System - Technical

Daily average – Evaporative CS with stack-in-tower (VDI S/P model)

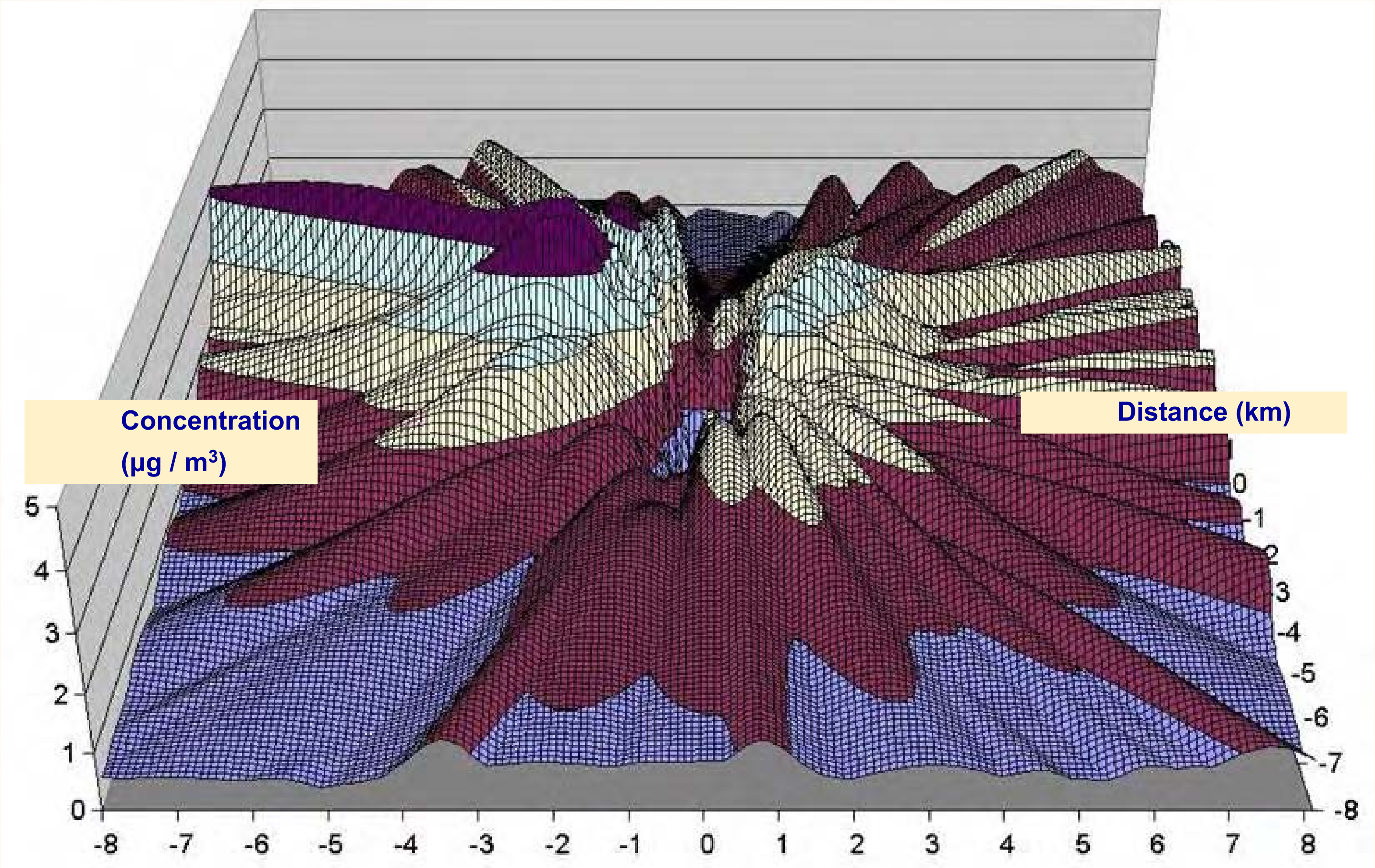


Enclosures - Ground level SO_2 concentrations… – cont.

EGI

Advanced HELLER System - Technical

Daily average – Direct ACC with 250 m chimney (TA Luft / VDI model)

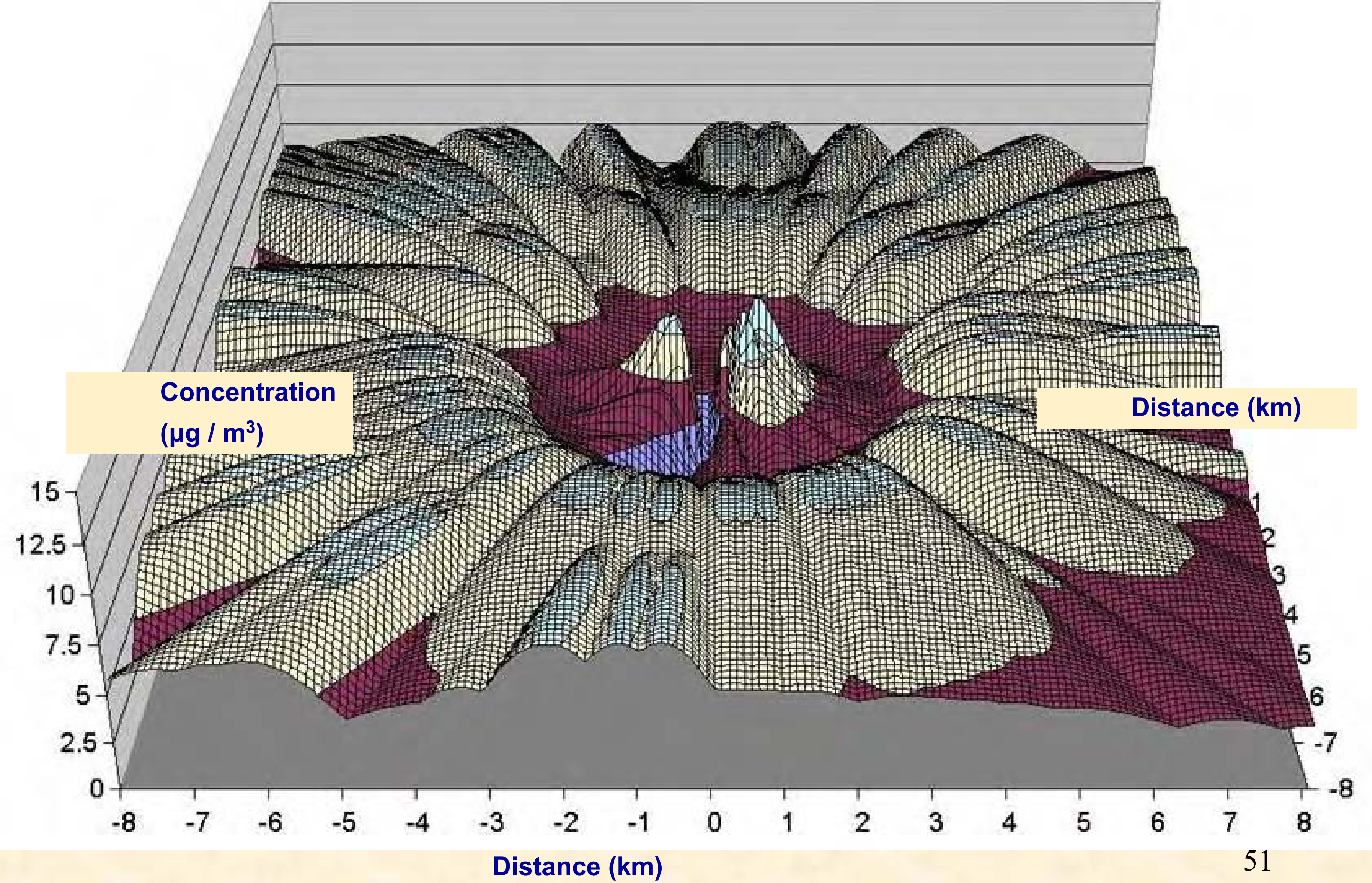


Distance (km)

Enclosures - Ground level SO_2 concentrations… – cont.

EGI

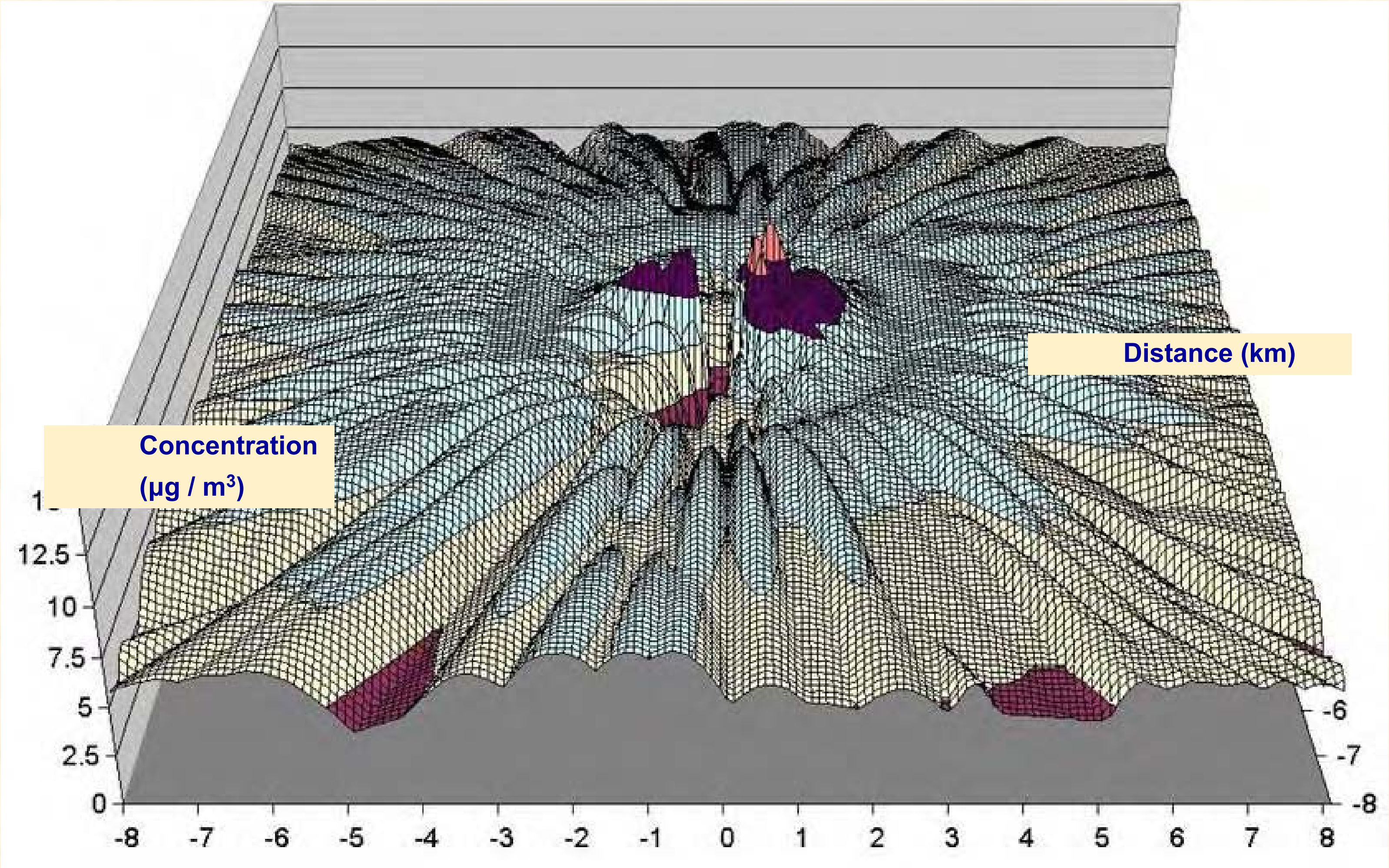
Hourly maximum – HELLER System with stack-in-tower (VDI S/P model)



Enclosures - Ground level SO_2 concentrations… – cont.

EGI

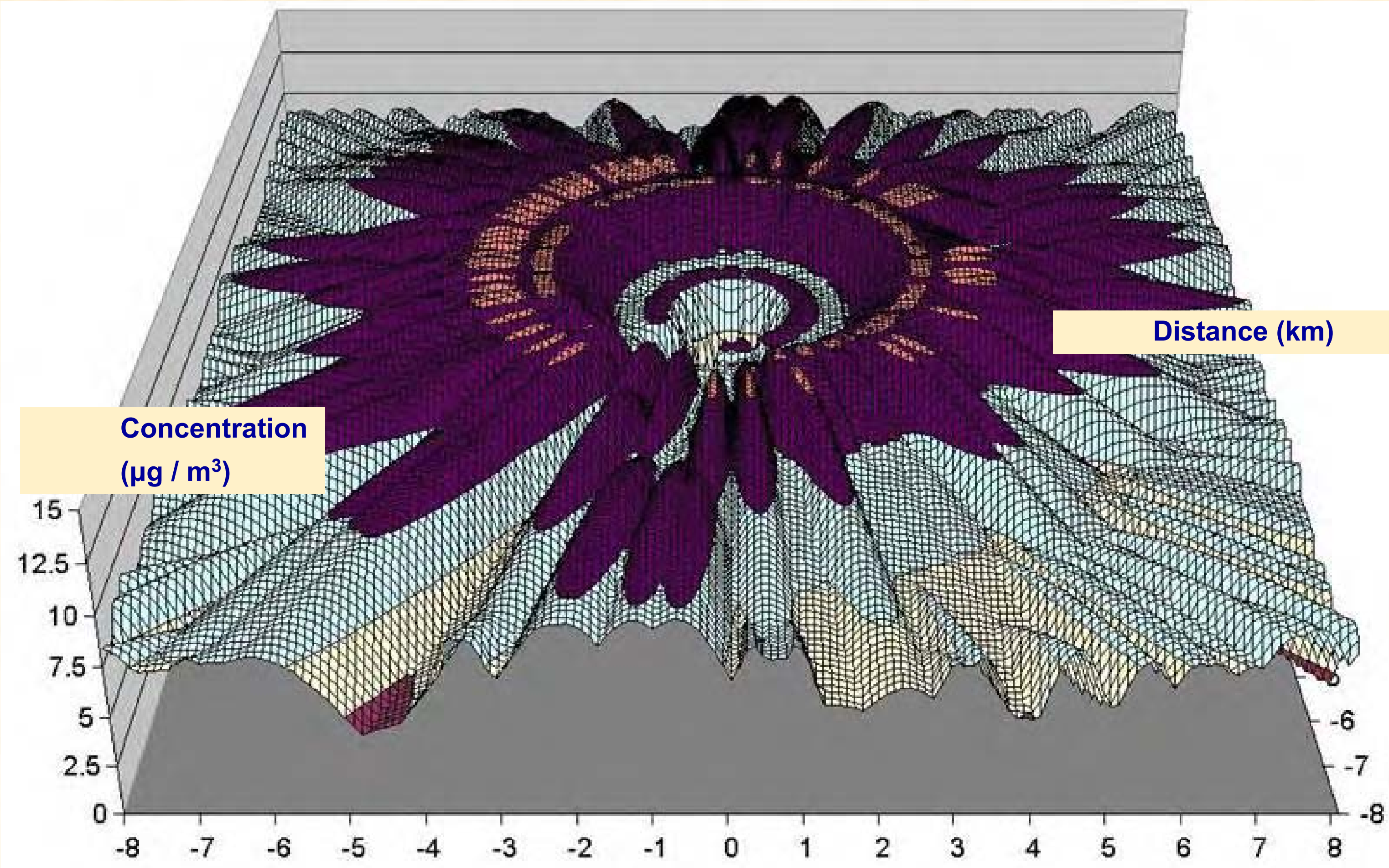
Hourly maximum – Evaporative CS with stack-in-tower (VDI S/P model)



Distance (km)

Enclosures - Ground level SO_2 concentrations… – cont.

Hourly maximum – Direct ACC with 250 m chimney (TA Luft / VDI model)



Distance (km)