inter.noise
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HONG KONG

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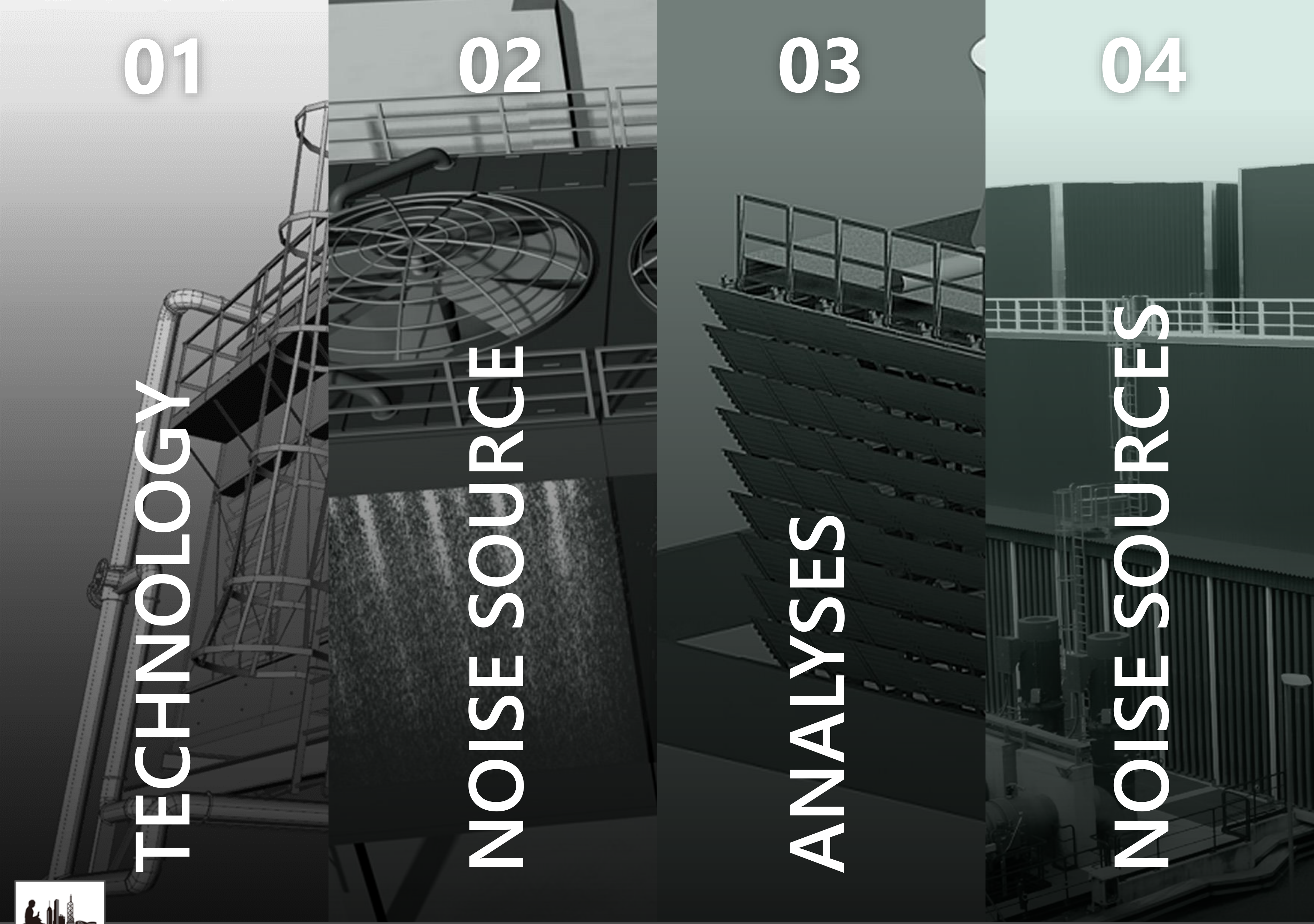
NOISE CONTROL OF LARGE **WET COOLING TOWERS**



01 TECHNOLOGY

02 NOISE SOURCE

03 ANALYSES

04 NOISE SOURCES

01 TECHNOLOGY

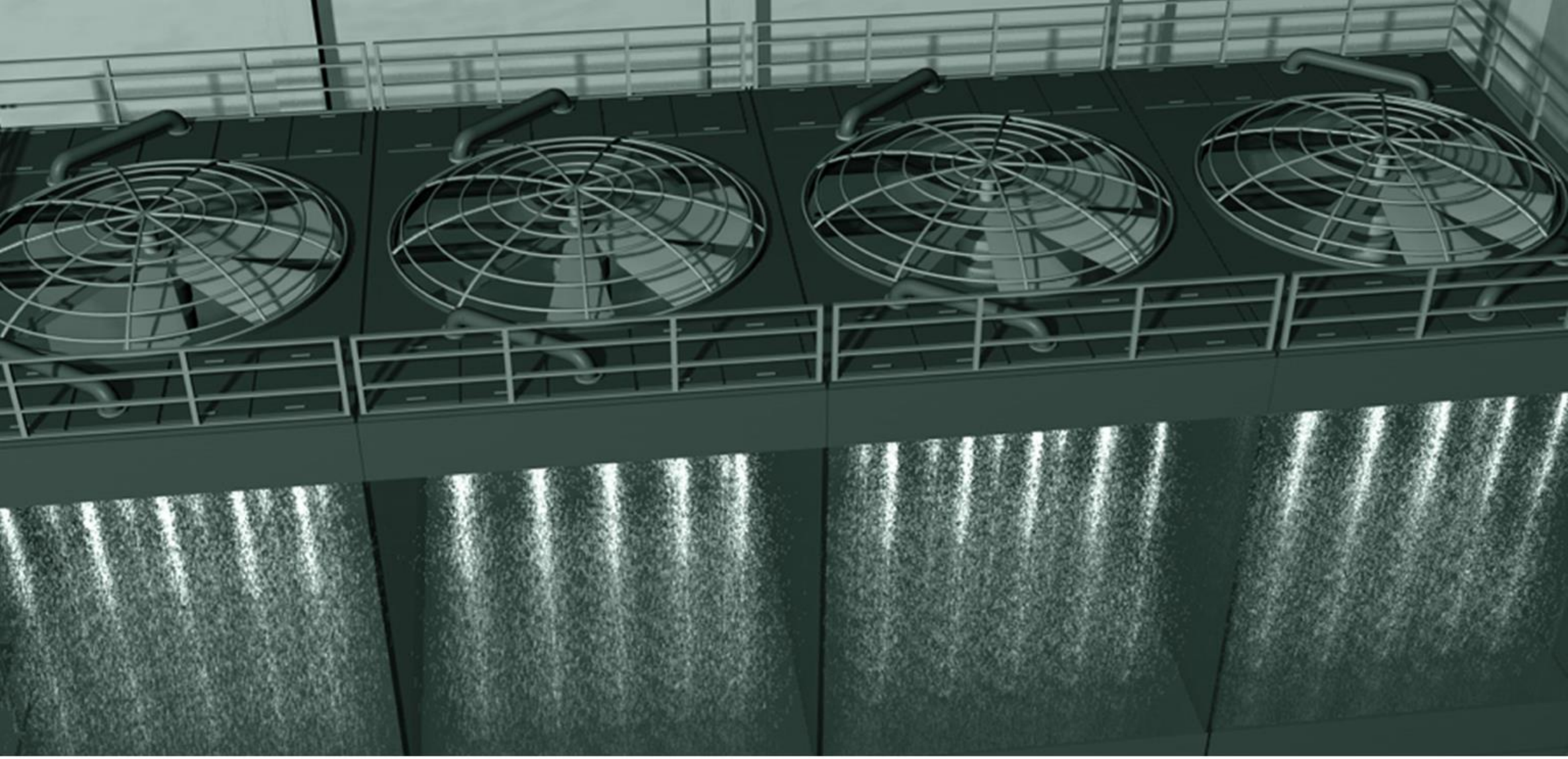
open evaporative wet cooling system

The technology discussed in this presentation is closely related to last year's presentation in which I was reporting on the noise control action plan of Hungary's largest chemical factory. The subject of this presentation is one of the most widespread industrial cooling technologies.

HOW IT WORKS

open evaporative wet cooling system

The cooling agent is in contact with the environment. In the cooling tower, the airflow, which is required for heat transfer, is generated by fans. The water contacts the air in a droplet form. To avoid the recirculation of the discharged air, the distance between the discharge and intake locations of the air should be as large as possible.



02 NOISE SOURCE

the typical noise sources of this technology

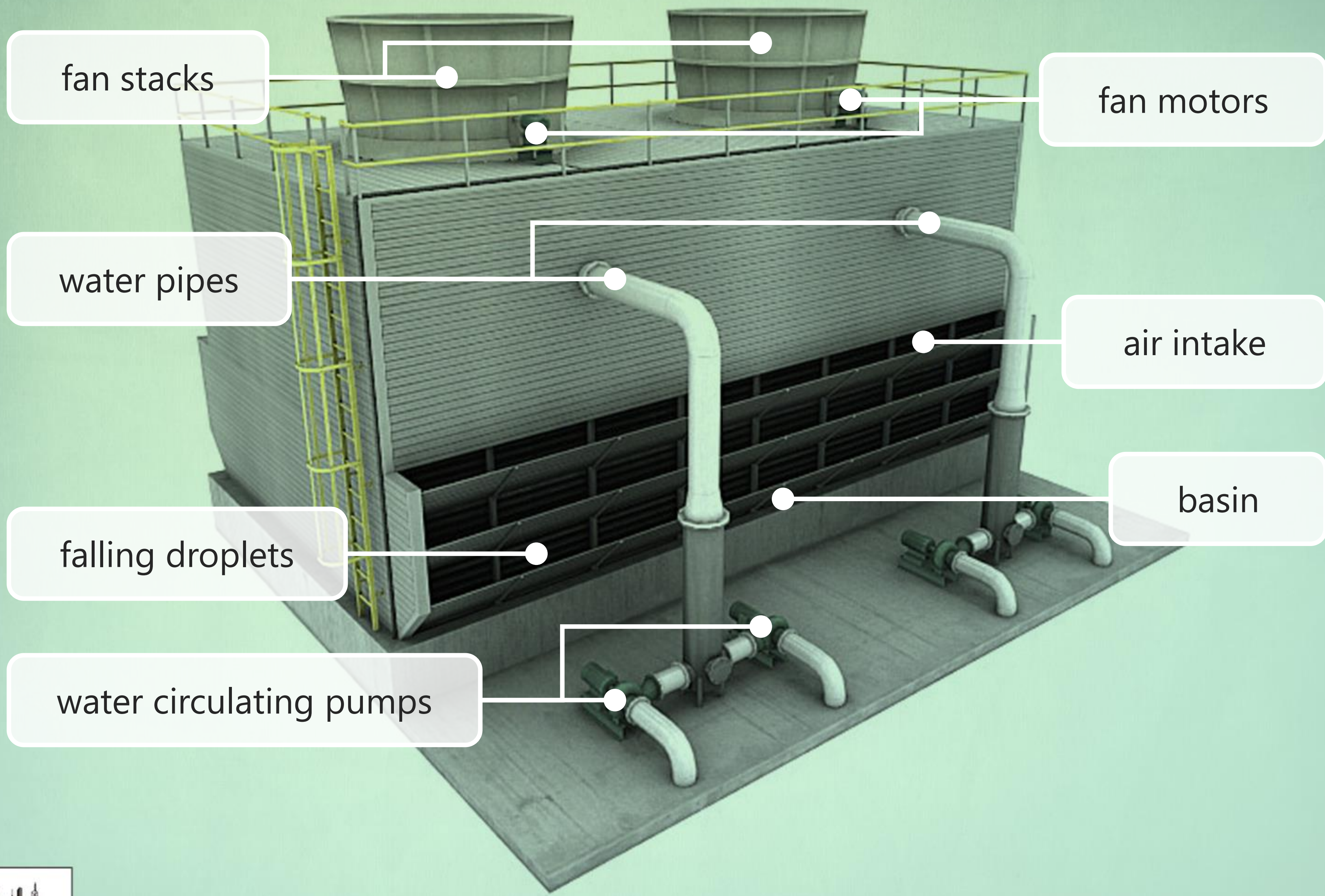
droplets falling into the water basin

air flowing through the fans

fans for airflow

water circulating **pumps**

02 NOISE SOURCE



FANS

noise-generating mechanism

The components of the noise generated by the fans are essentially fall into **mechanical and aerodynamic categories** and the mechanical noise components are negligible compared to the aerodynamic noise components (in the case of a properly constructed and operated fan).

The mechanical noises are generated by the **bearings**, by the **unbalanced rotating elements**, by the **fan motor** and by the **power transmission**. Apart from the rotational noise that generates pure sound and the rotor-casing interaction, the components of aerodynamic noise can also include the **vortex noise** and the **turbulence-induced noise** generating broadband noise emission.

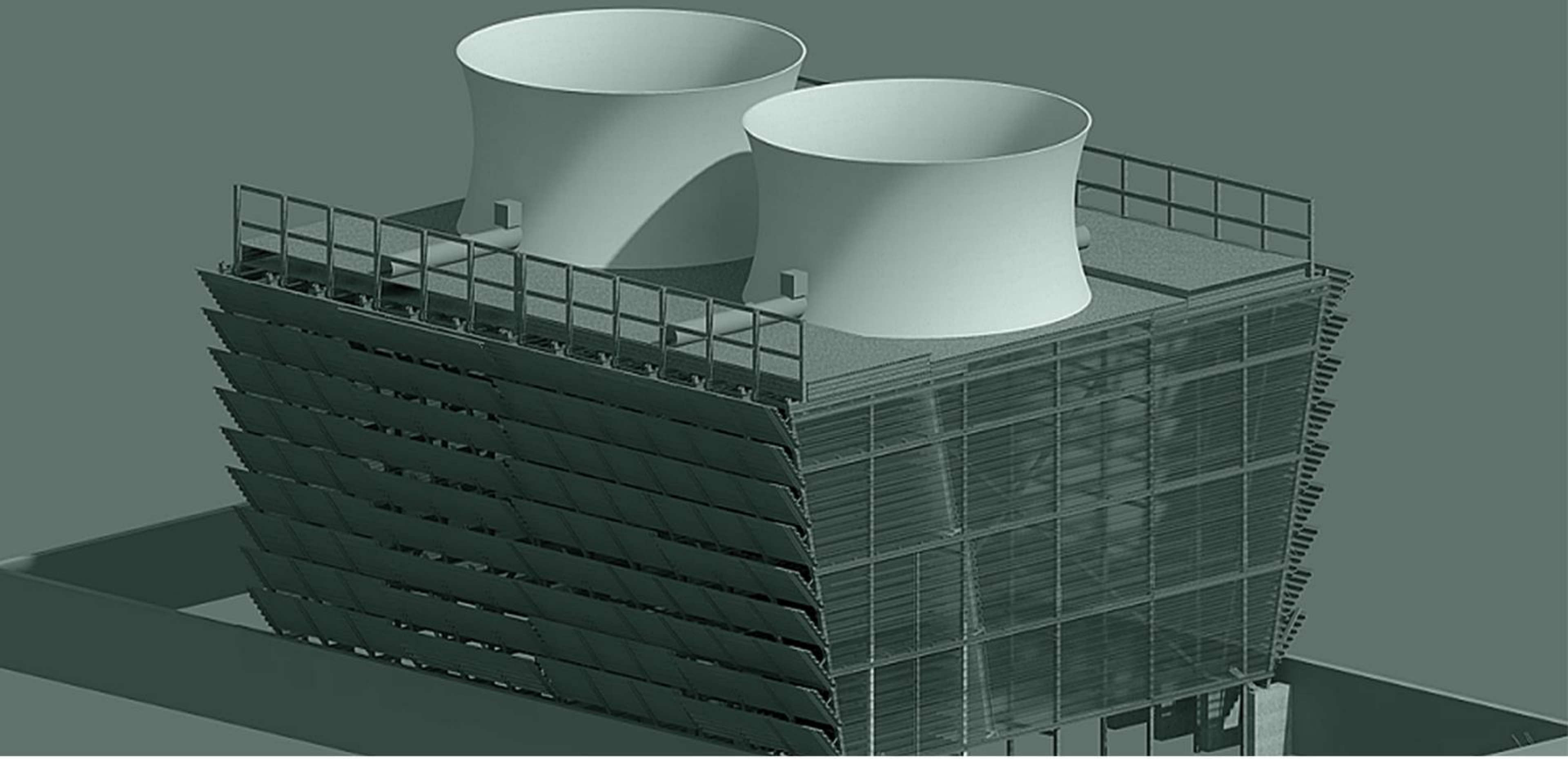
COOLING AGENT

noise-generating mechanism

The noise itself is generated by the **water droplets** falling on the water surface of the **basin**. During the **impact**, the **motion energy** is transformed in a very short time, and a significant part of that energy will be lost in the form of **sound energy**, heat energy and the energy of the permanent transformation.

$$E_t = \frac{1}{2} m v^2$$

The reason for this is that water is basically **not compressible**. It's an inflexible liquid, so the collision will resemble the physical parameters of an **ideally inflexible collision**. The sound energy generated by the impact of water droplets depends on the magnitude of the motion energy. The noise emission is affected by the **size** and the **mass** of the water droplets, their falling **height** and their falling **speed**.



03 ANALYSES

the cooling tower of the nitric acid plant

subjective analysis based on hearing

frequency analysis

noise measurement

software noise model with IMMI


WANHUA 万华
BorsodChem
Chemistry for generations

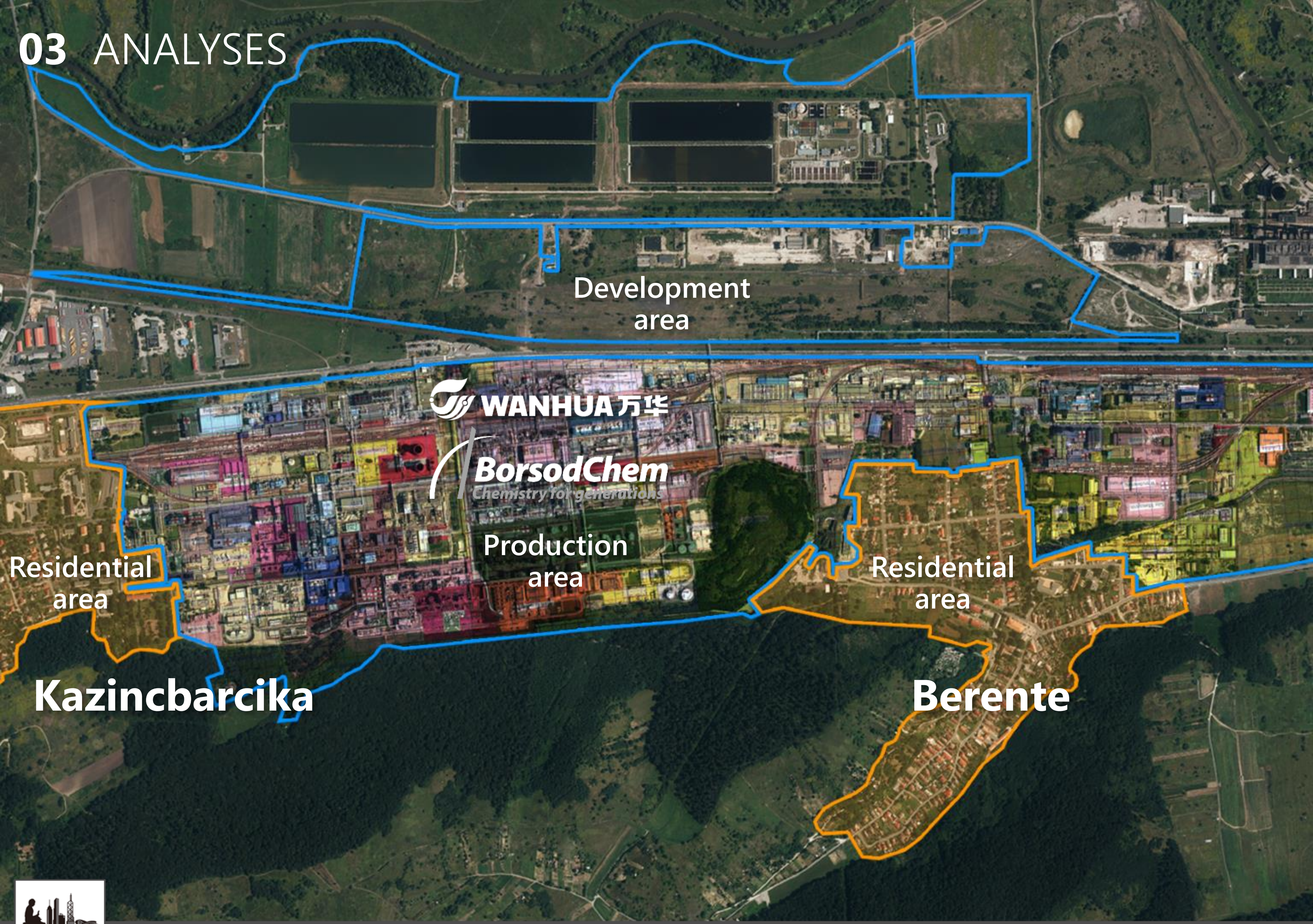
03 ANALYSES

fifteen

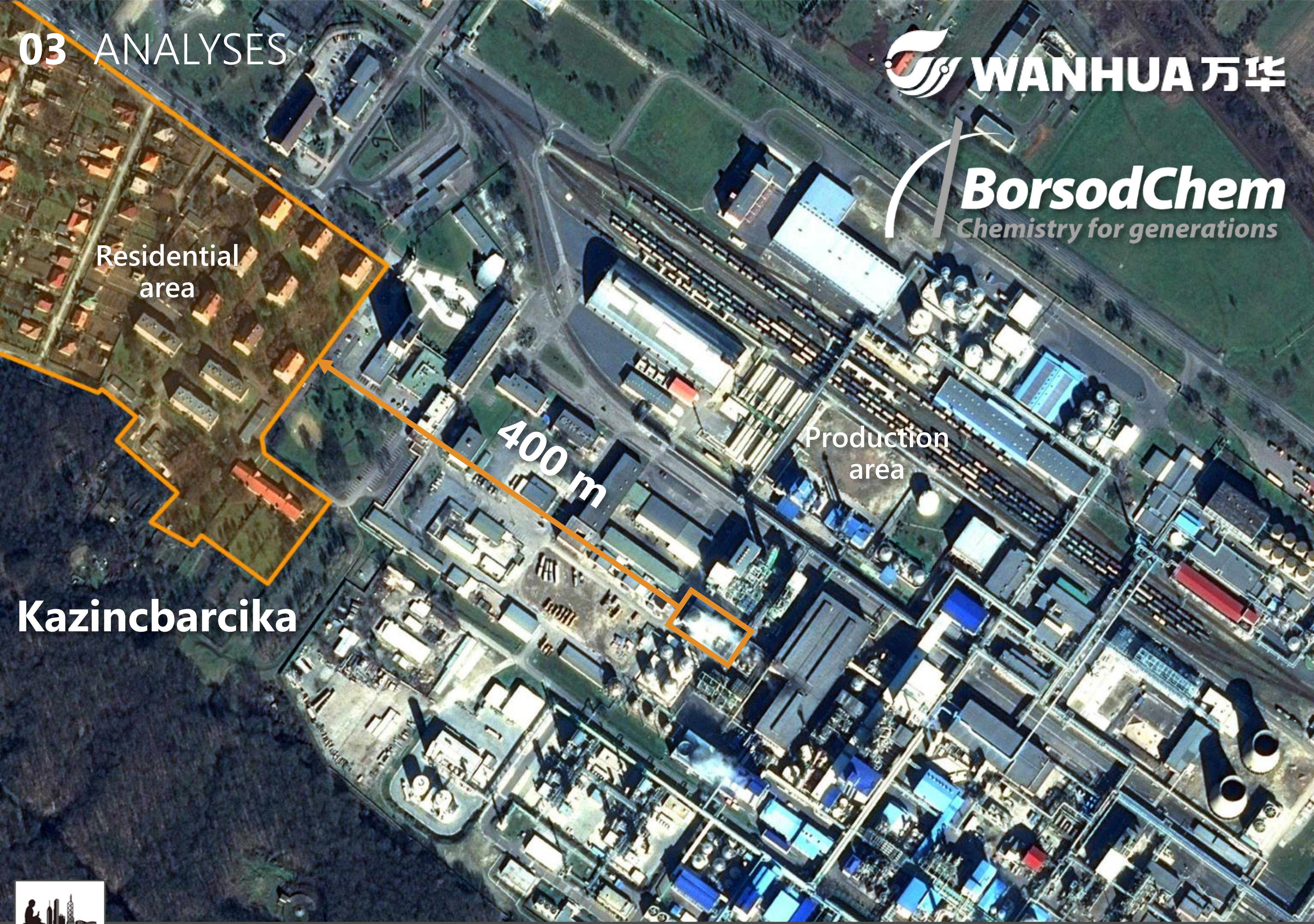
of such large cooling towers are in operation in the area of Hungary's largest chemical factory

Therefore, it’s not surprising that these are the noise sources which dominantly determine the environmental noise pollution of the facility. The entire industrial area is nearly 4 km^2, of which the densely built-up production and development area is close to 2.5 km^2.

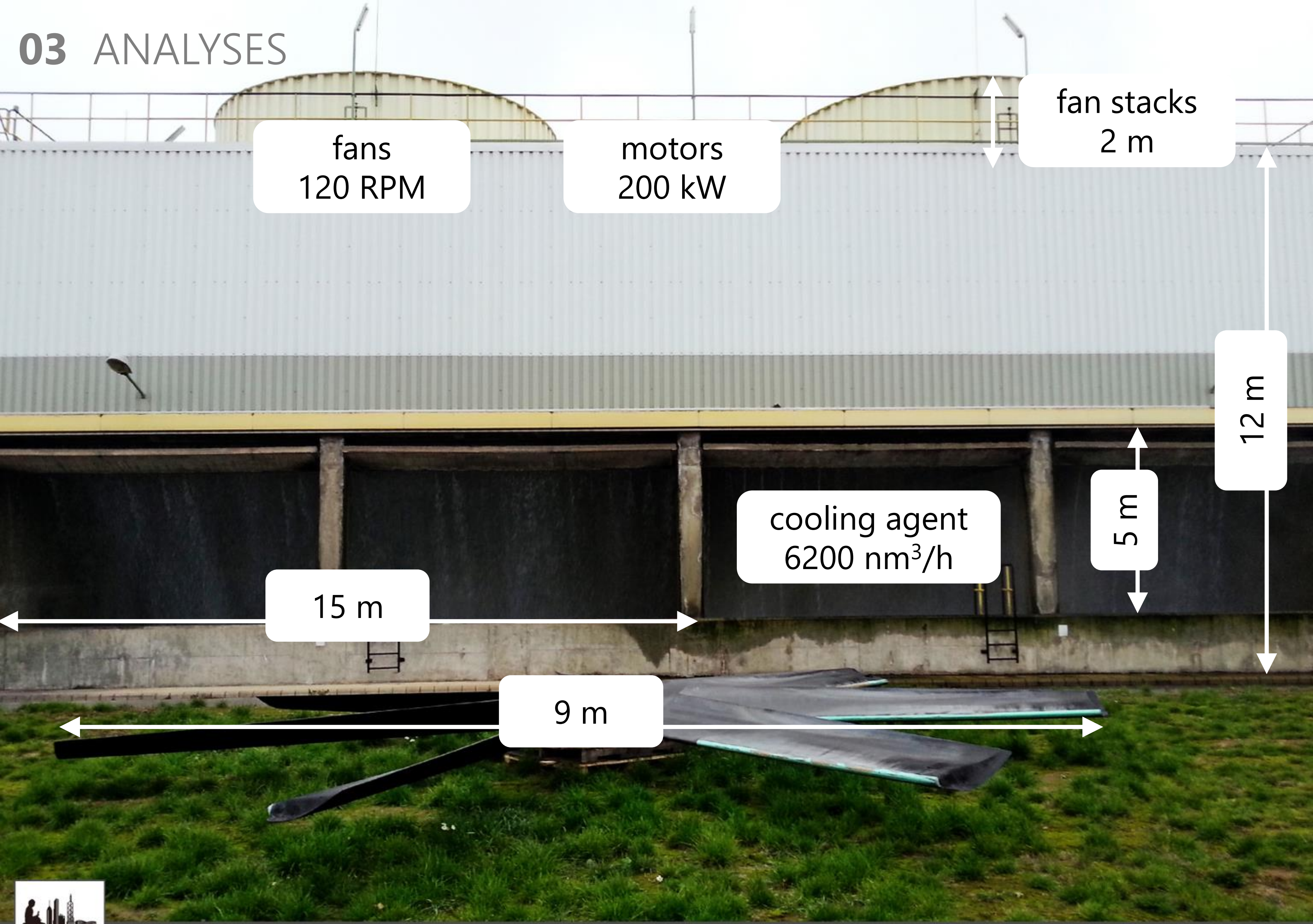
03 ANALYSES


Development area
WANHUA 万华
BorsodChem
Chemistry for generations
Production area
Residential area
Residential area
Kazincbarcika
Berente

03 ANALYSES


WANHUA 万华
BorsodChem
Chemistry for generations
Residential area
400 m
Production area
Kazincbarcika

03 ANALYSES


fans
120 RPM
motors
200 kW
fan stacks
2 m
12 m
5 m
cooling agent
6200 nm³/h
15 m
9 m

03 ANALYSES

THE METHODS OF THE **ANALYSES**

subjective analysis based on hearing

typical noise sources, radiation directions, tone and time function

frequency analysis

analysing and comparing frequency spectrums

noise measurement

at the evaluation points, reference points, in the vicinity of sources

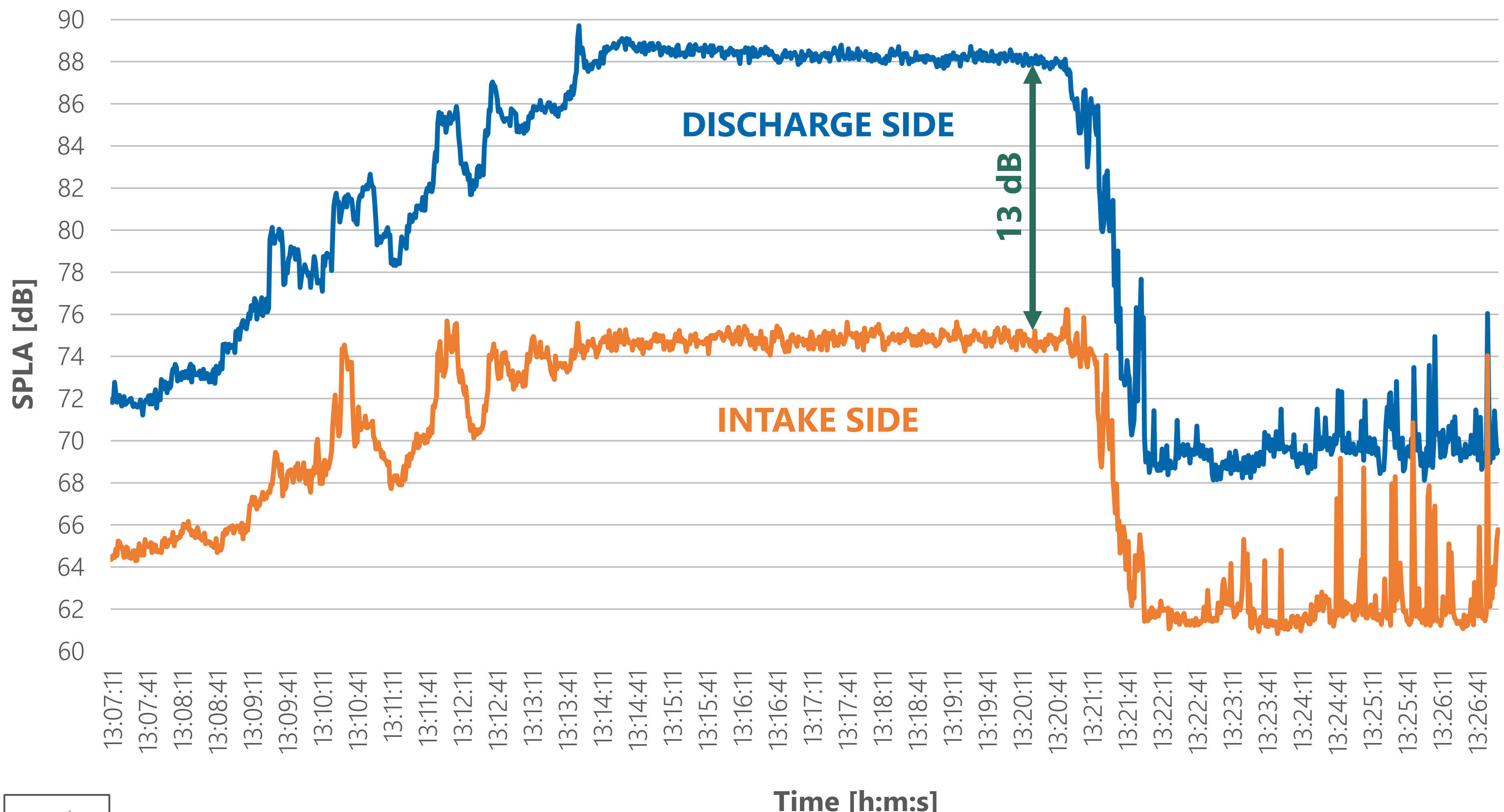
software noise model with IMMI Premium

building a detailed model, calibrating noise model, modelling sound propagation, the dominance of noise sources, noise reduction solutions

MEASUREMENT RESULTS OF THE **FANS**

Date	Plant	Point	Status	d [m]	h_{rel} [m]	L_{Aeq} [dB]	Source (P/S)	D	L_{AW} [dB]
2013.10.03	NAP	Next to the fan stack	General (27 Hz)	1,0	1,5	73	*	*	*
2013.10.03	NAP	Over the fan	General (27 Hz)	4,5	4,5	82	S	1	97
2013.10.03	NAP	Over the fan	Maximum (50 Hz)	4,5	4,5	87	S	1	102
2013.10.03	TDI2	Next to the fan stack	General (80 RPM)	1,0	2,0	74	*	*	*
2013.10.03	TDI2	Next to the fan stack	Maximum (91 RPM)	1,0	2,0	76	*	*	*
2013.10.03	TDI2	Over the fan	General (80 RPM)	6,0	6,0	80	S	1	96
2013.10.03	TDI2	Over the fan	Maximum (91 RPM)	6,0	6,0	83	S	1	99
2013.11.17	NAP	Between the fan motors	Maximum	1,5	1,5	82	P	2	91
2015.08.17	NAP	Over the fan	Turned off	3,0	3,0	72	S	1	85
	NAP	Over the fan	Maximum (50 Hz)	3,5	3,5	88	S	1	102

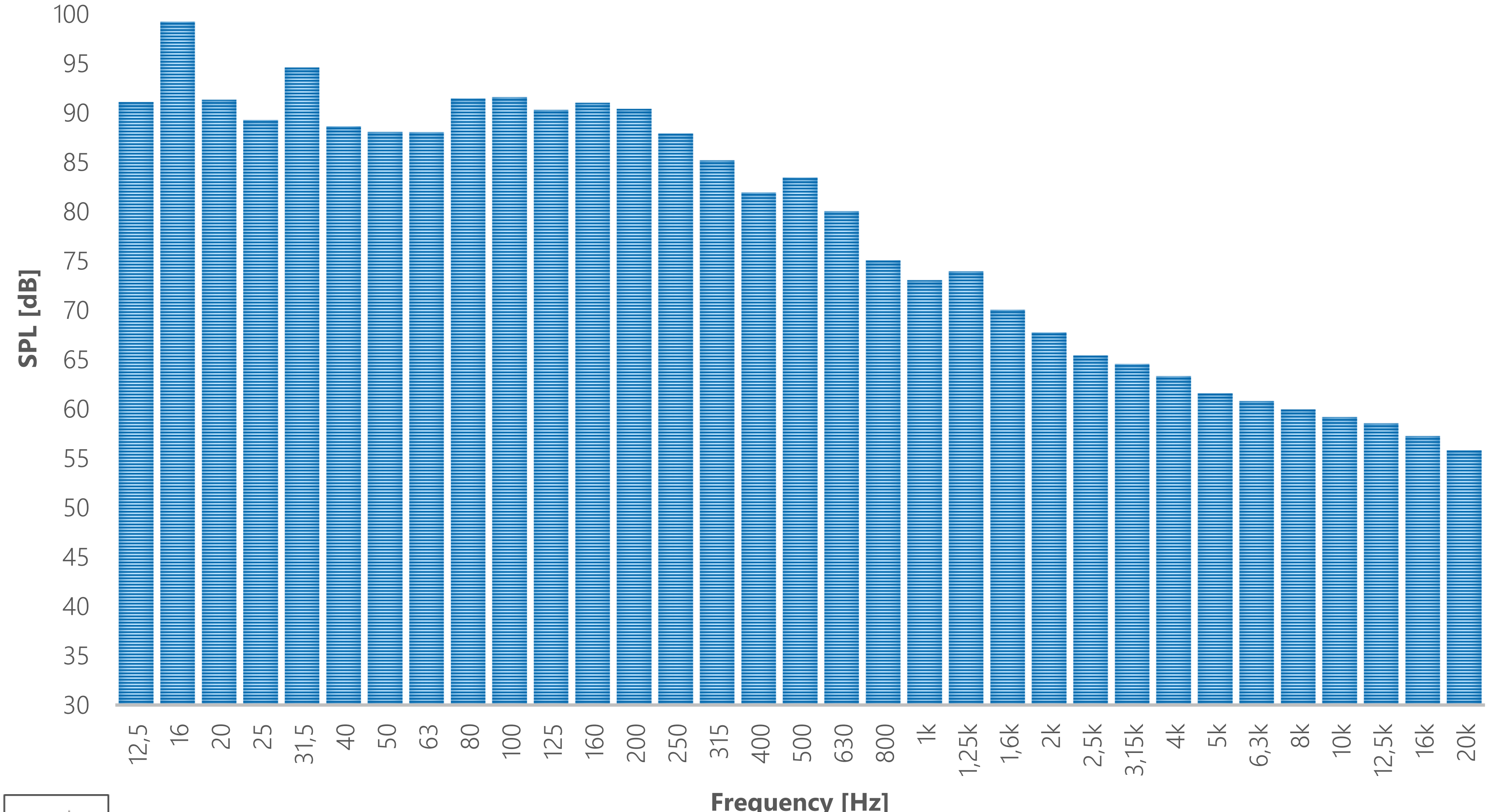
MEASUREMENTS OF THE **VARIABLE-FREQENCY DRIVE**



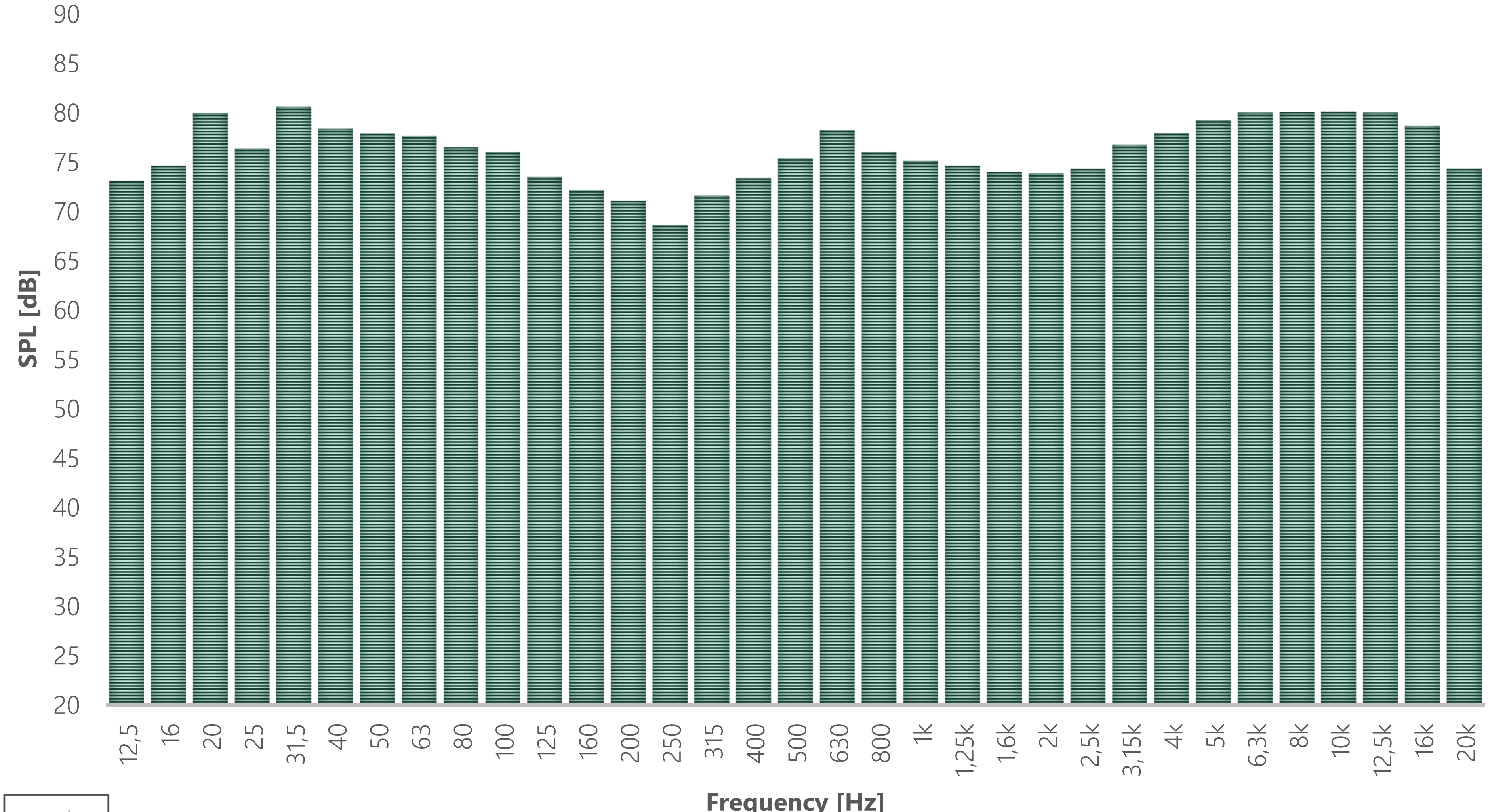
MEASUREMENT RESULTS OF THE **AIR INLETS**

Date	Plant	Point	Status	d [m]	h_{rel} [m]	L_{Aeq} [dB]	Source (P/S)	D	L_{AW} [dB]
2013.10.09	TDI2	South	General	6,0	4,0	80	F	1	**96**
2013.10.09	TDI2	South	General	4,0	1,5	82	F	1	**96**
2013.10.09	TDI2	South	General	4,0	1,5	83	F	1	**97**
2013.11.17	NAP	South	General	1,0	1,5	89	F	1	**97**
2013.11.18	Chlorine	East	General	5,0	1,5	83	F	1	**98**
2013.11.18	Chlorine	East	General	10,0	1,5	80	F	1	**98**
2013.11.18	Chlorine	East	General	15,0	1,5	76	F	1	**96**
2013.11.18	Chlorine	East	General	4,0	1,5	84	F	1	**98**
2015.08.17	NAP	South	Turned off	1,0	1,5	65	F	1	73
	NAP	South	Maximum (50 Hz)	1,0	1,5	75	F	1	83

FREQUENCY SPECTRUM OF THE **FAN**

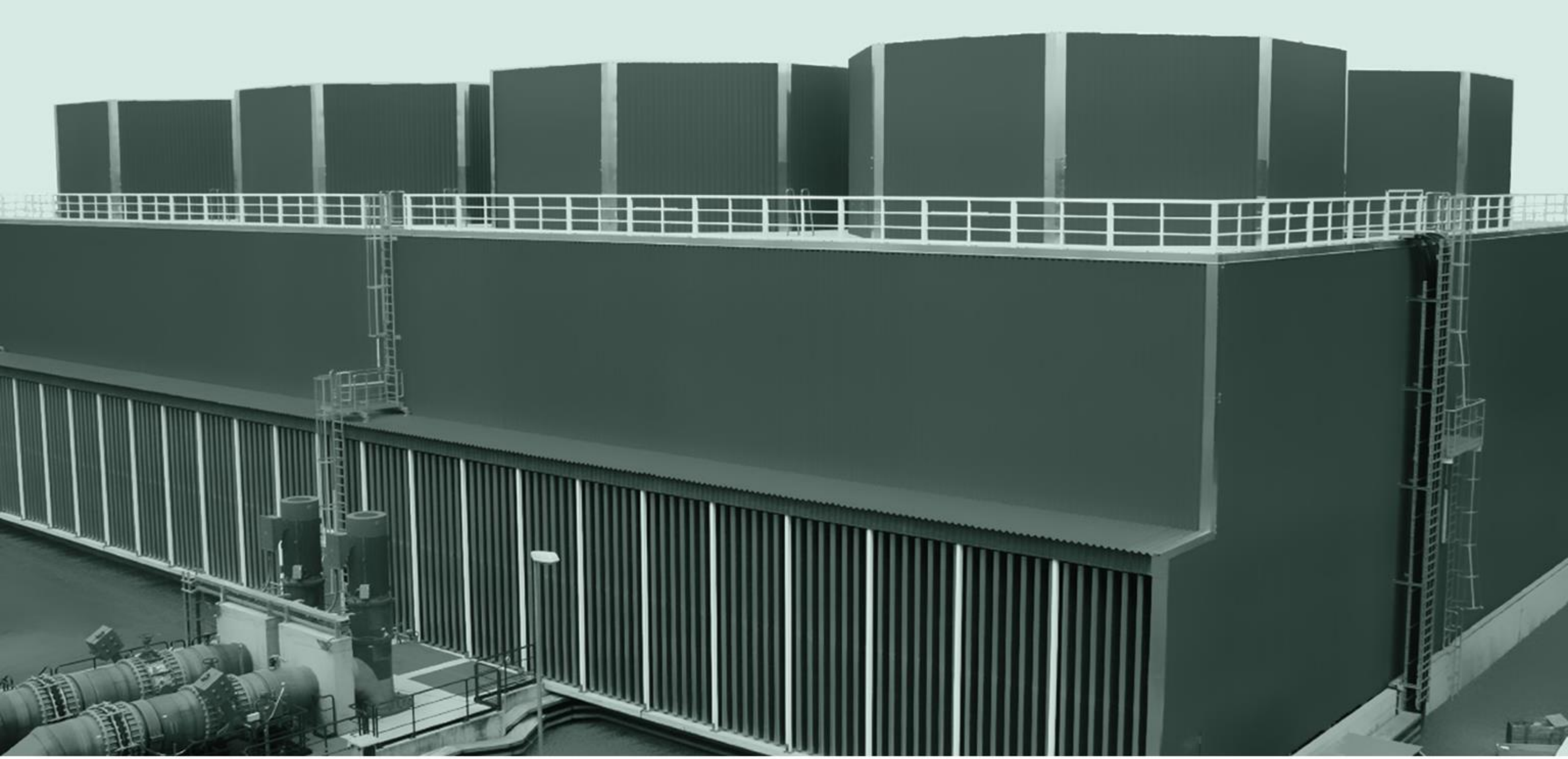


FREQUENCY SPECTRUM OF THE **AIR INLETS**



THE **DOMINANT** NOISE SOURCES

Noise source	L_{Aeqi} [dB]	$\sum L_{Aeq}$ [dB]
South side of the air inlet	44,7	44,7
Fan B	40,2	46,0
Fan A	40,1	47,0
North side of the air inlet	34,2	47,2
Pump #1	25,9	47,3
Pump #2	23,9	47,3
Pump #3	23,7	47,3
Fan B motor	10,9	47,3
Fan A motor	9,5	47,3
		47,3



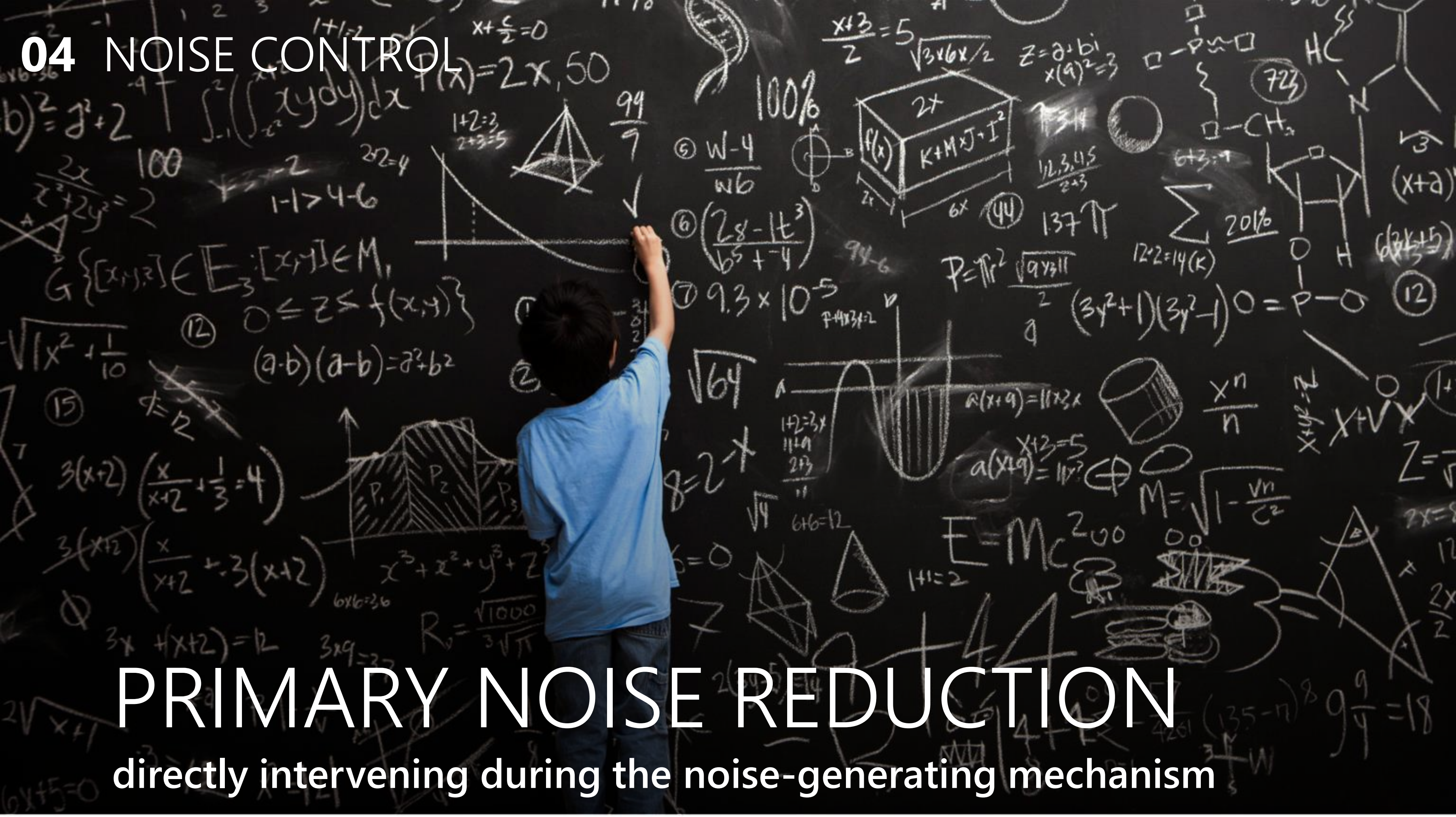
04 NOISE CONTROL

the priority order for noise control solutions

Primary: reduction of noise at source (emission)

Secondary: attenuation of sound during propagation (transmission)

Tertiary: protection of protected areas (immission)



PRIMARY NOISE REDUCTION

directly intervening during the noise-generating mechanism

the aerodynamic sophistication or replacement of fans

the regulation of the rotational speed with a variable-frequency drive

the reduction of the impact noise of water droplets

SIMPLIFIED ANALYSIS OF THE PRIMARY SOLUTIONS

MAIN ADVANTAGES

+ the cooling **performance** changes only slightly (or does not decrease at all),
+ in many cases, energy **efficiency** can be **improved**,
+ **cost savings** can be achieved over a longer period of time,
+ the **geometry** of the cooling tower does not change.

DISADVANTAGES

- the **intervention** options are **limited**,
- usually the achievable noise reduction is less than it could be with **post solutions**,
- in the case of a **complex** solution, intervention will be needed at several points,
- the chance of **breakdown** will be much higher,
- the number of **maintenance** tasks and their costs will increase.

REPLACEMENT OF FANS

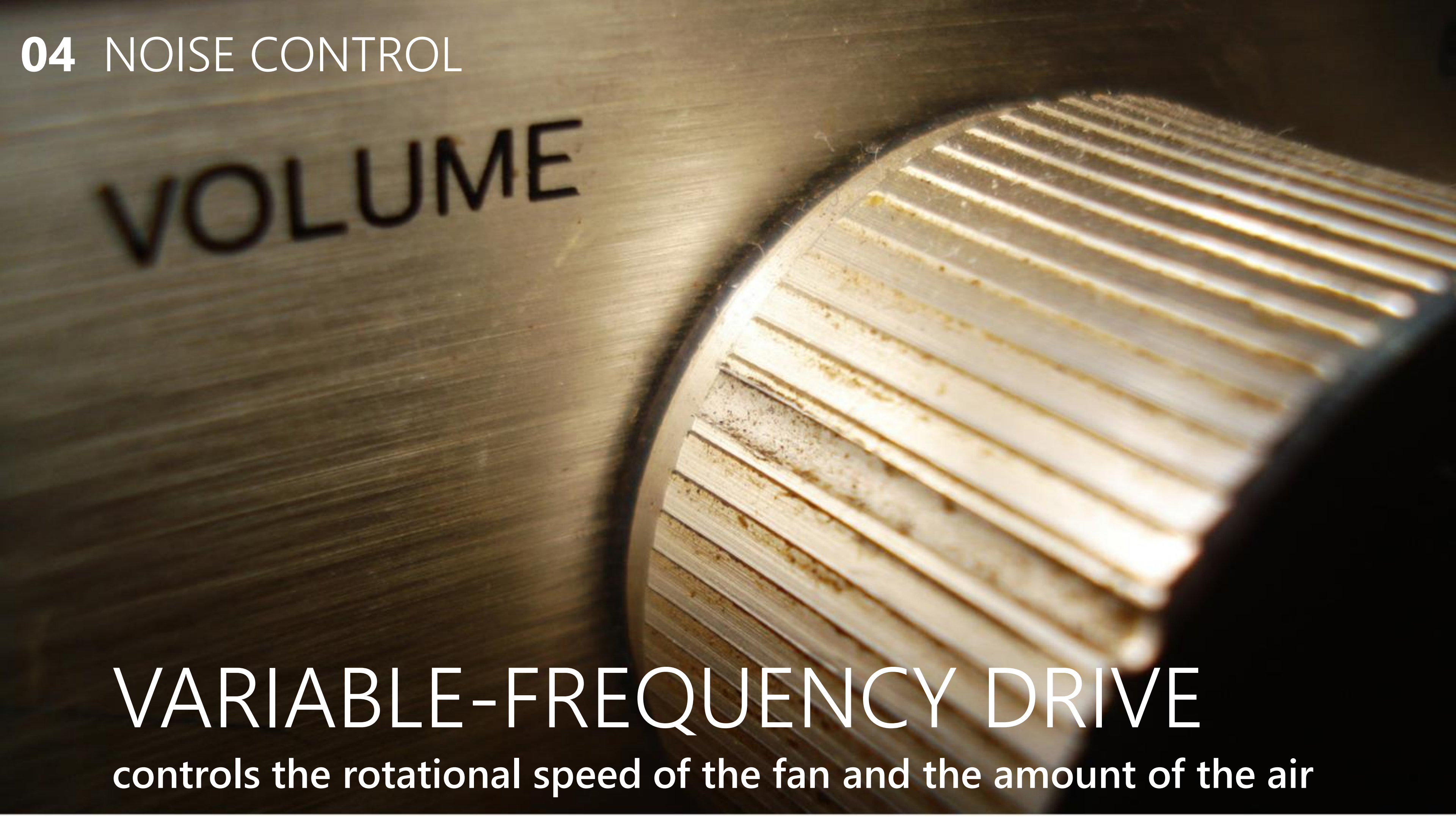
optimised blade profiles and aerodynamic inserts

The proper aerodynamic design – or subsequent optimisation – directly intervenes where the noise is generated without reducing the efficiency of the fan. In principle, we could set an aim to increase the efficiency of the cooling tower in parallel with reducing its noise and reducing maintenance costs. But the replacement of the fan blades is not a simple technical intervention.

Frequency / SPL	31,5	63	125	250	500	1000	2000	4000	8000	A
Cofimco 9144-8-36N/G2.0T	110,0	112,0	112,0	108,0	105,0	102,0	94,0	90,0	86,0	**106,9**
Howden 30-SX 6-blade	98,8	98,8	102,3	97,3	96,4	93,7	87,4	80,3	69,7	**98,1**

$\Delta L \approx 9$ dB

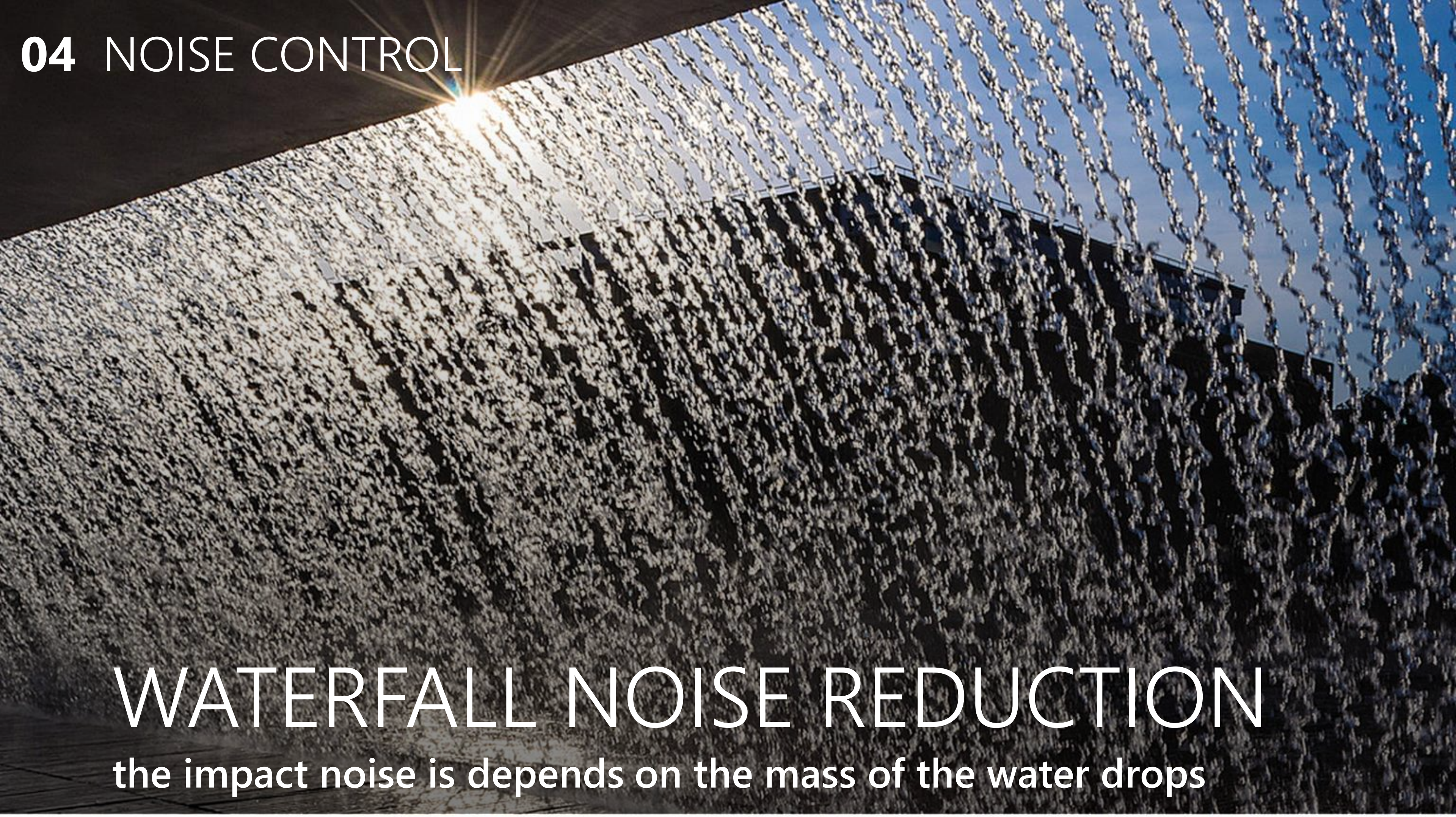
the cost of a new fan can be quite
expensive



VARIABLE-FREQUENCY DRIVE

controls the rotational speed of the fan and the amount of the air

In a noise control aspect, the control of the speed is particularly effective. Nevertheless, during summer, the fans of the cooling tower constantly operate at maximum speed, so the highest environmental noise emission is practically achieved. As the noise limit at night is stricter with 10 decibels (in Hungary), the limit value will be significantly exceeded even at night.



WATERFALL NOISE REDUCTION

the impact noise is depends on the mass of the water drops

It goes without saying that by changing the size of the water droplets, the emitted sound energy will be less as well, but at the same time this also reduce the amount of water flowing through per unit time and reduce the cooling capacity of the tower. The noise generated by the impact of water droplets is essentially due to the fact that the collision is inflexible.

WATERFALL NOISE REDUCTION

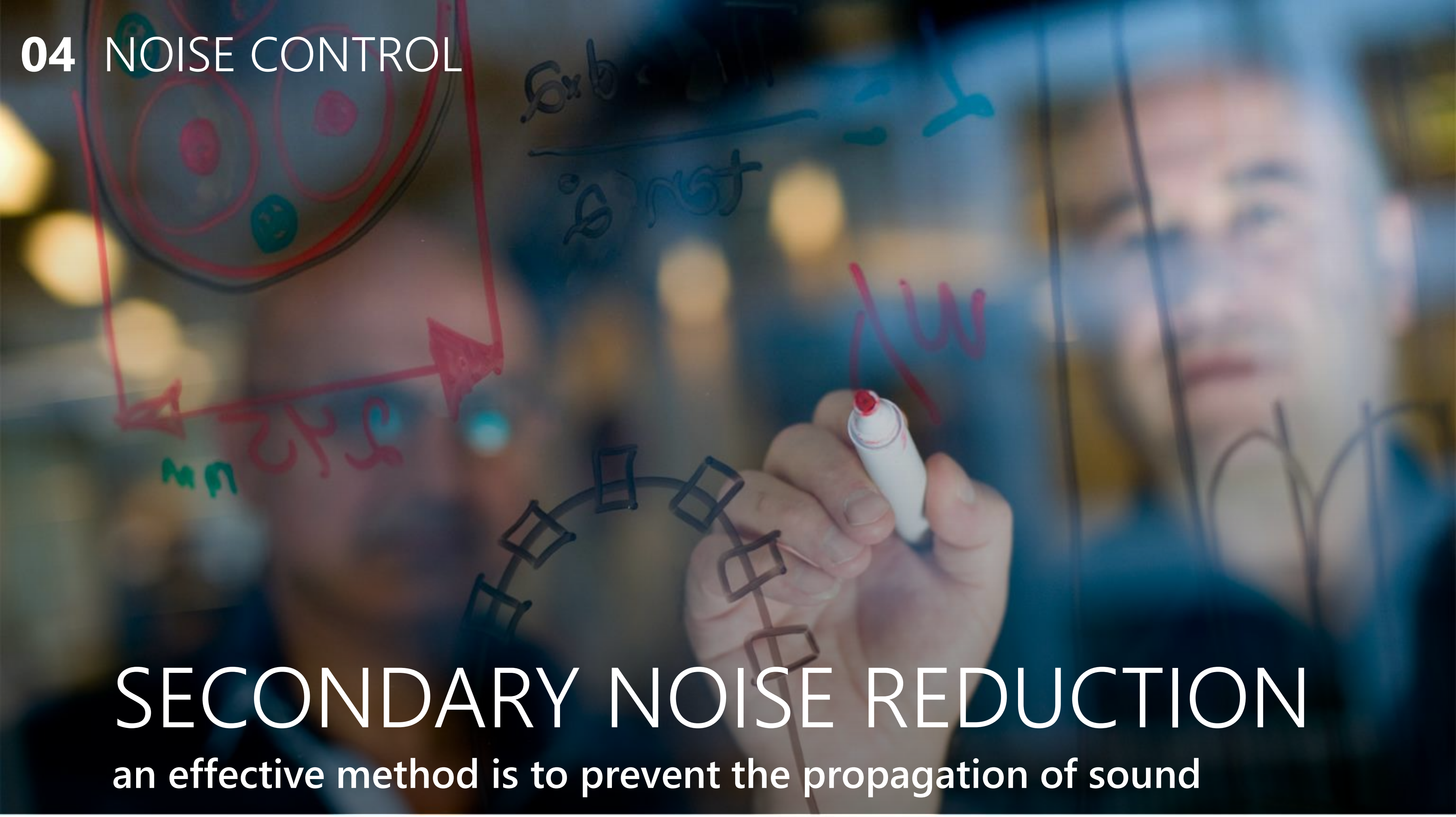
04 NOISE CONTROL

By using a noise reduction mat

the falling water droplets collide with a **flexible** surface instead of the surface of the cooling agent, so the collision becomes **elastic**, and the emitted sound energy will decrease depending on the thickness or the **number of layers** of the mats.

The degree of noise reduction achieved with the mats mainly depends on the **drop height** of the droplets and the number of layers of the applied mat. According to the manufacturer's data, the expected noise reduction rate is

4-9 dB



SECONDARY NOISE REDUCTION

an effective method is to prevent the propagation of sound

using absorbing silencers

creating acoustic louver panels

building sound barrier walls

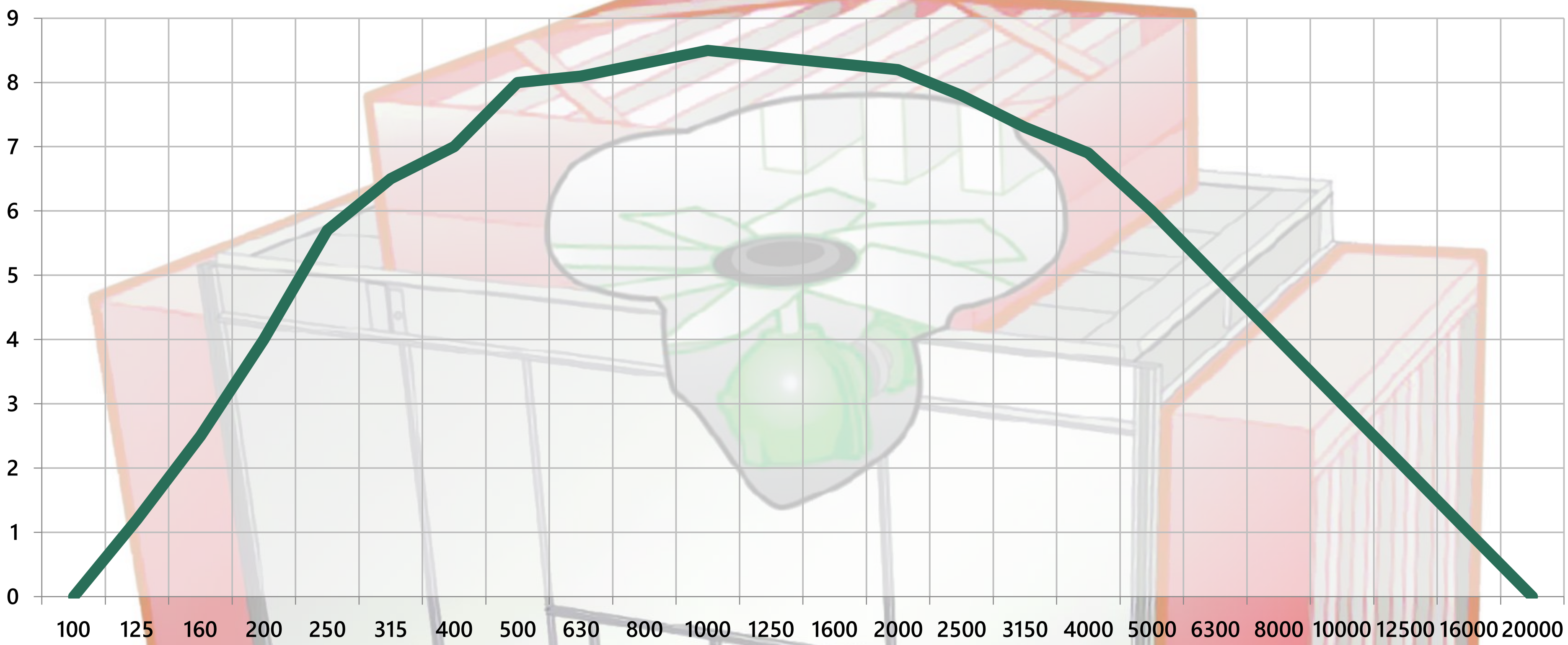
SIMPLIFIED ANALYSIS OF THE SECONDARY SOLUTIONS

MAIN ADVANTAGES

+ it doesn't **interfere** directly with the cooling tower technology,
+ it can be implemented **step by step**,
+ there are more solution **options**,
+ sometimes the reduction is **greater** than in the case of the primary intervention.

DISADVANTAGES

- its **cost exponentially** increases depending on the noise reduction requirement,
- it generally results in a **pressure drop**,
- the cooling capacity and energy **efficiency** of the cooling tower can be **reduced**,
- **access** to mechanical units may be more **difficult**,
- the number of **maintenance** tasks and costs will increase.



ABSORBING SILENCERS

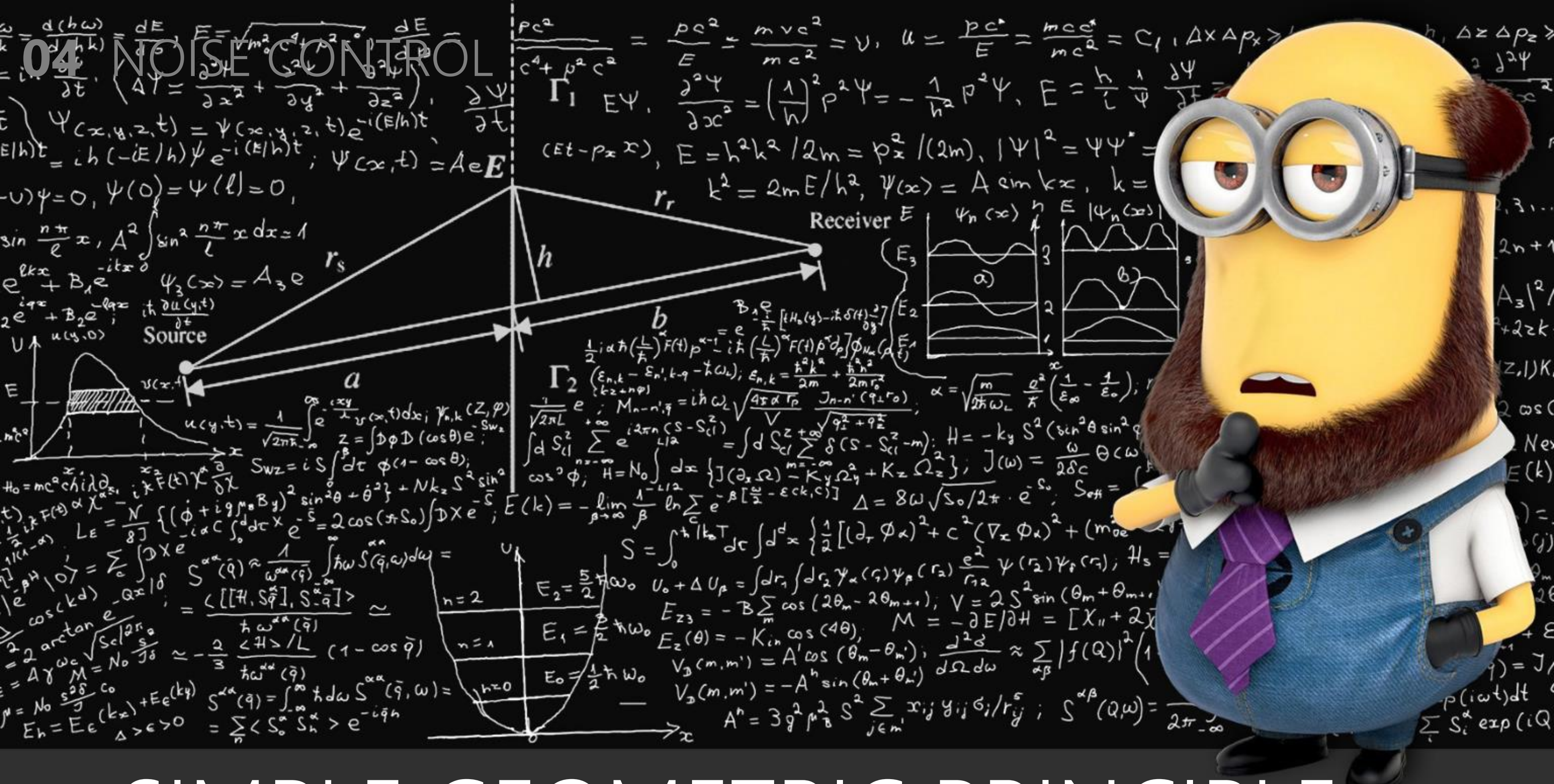
The sound energy is absorbed in the louvers that are in the path of the flowing air, so we usually have to assume that this solution results in a **pressure drop**. Therefore, the absorbing silencers can be used **only when the tower is sufficiently oversized** to compensate for the pressure drop generated by the subsequent noise reduction solution.

SOUND BARRIER WALLS

to provide maximum noise reduction with the lowest pressure drop

In the case of cooling towers, in order to ensure maximum cooling performance, it's crucial to use a solution, which can provide maximum noise reduction with the lowest pressure drop.

The degree of noise reduction that can be achieved with the sound barrier walls can be determined by a simple geometric principle (e.g. Huygens-Fresnel principle). The effectiveness of the barrier depends on the **mass** and **height** of the barrier, and its **distance** from the noise source and the receiver.



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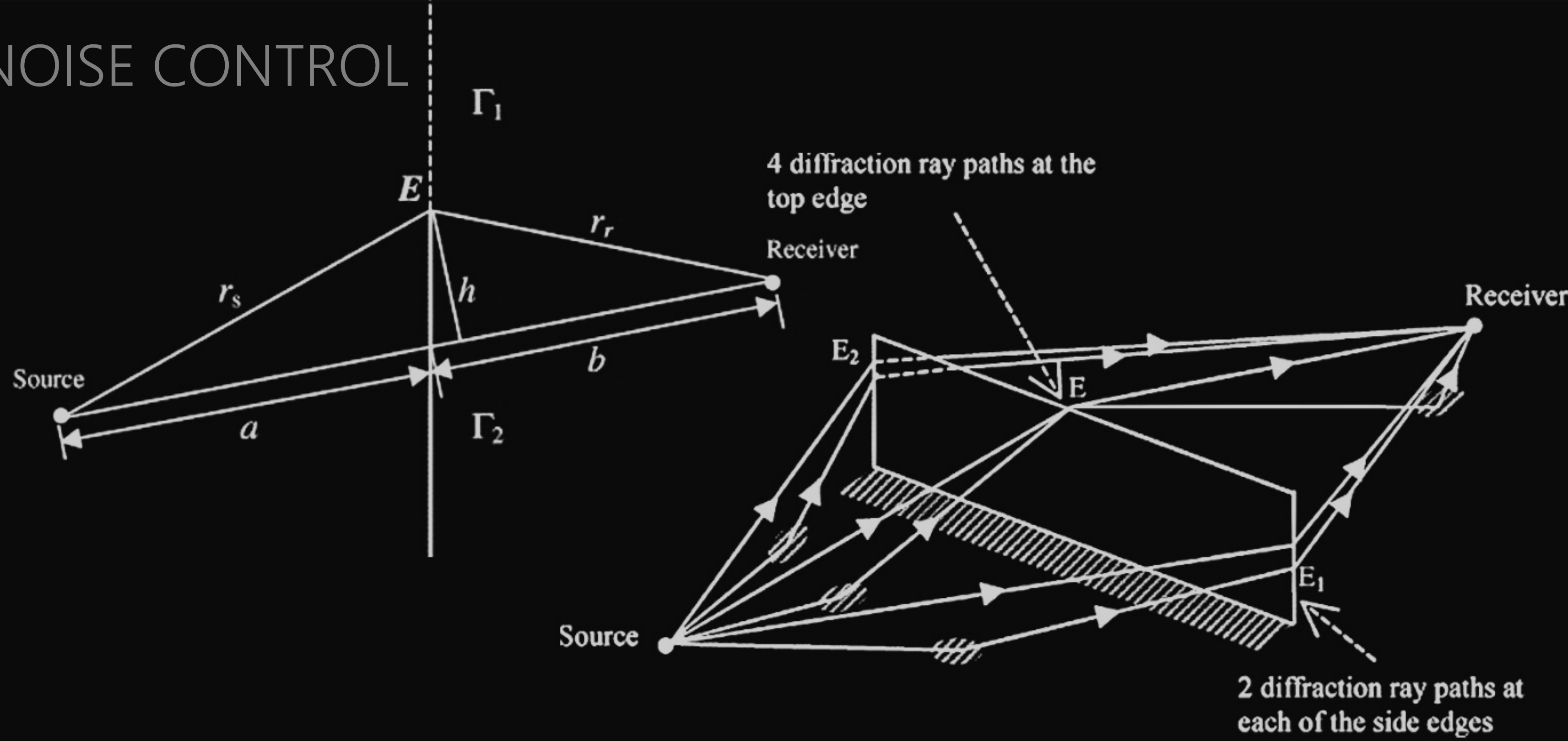

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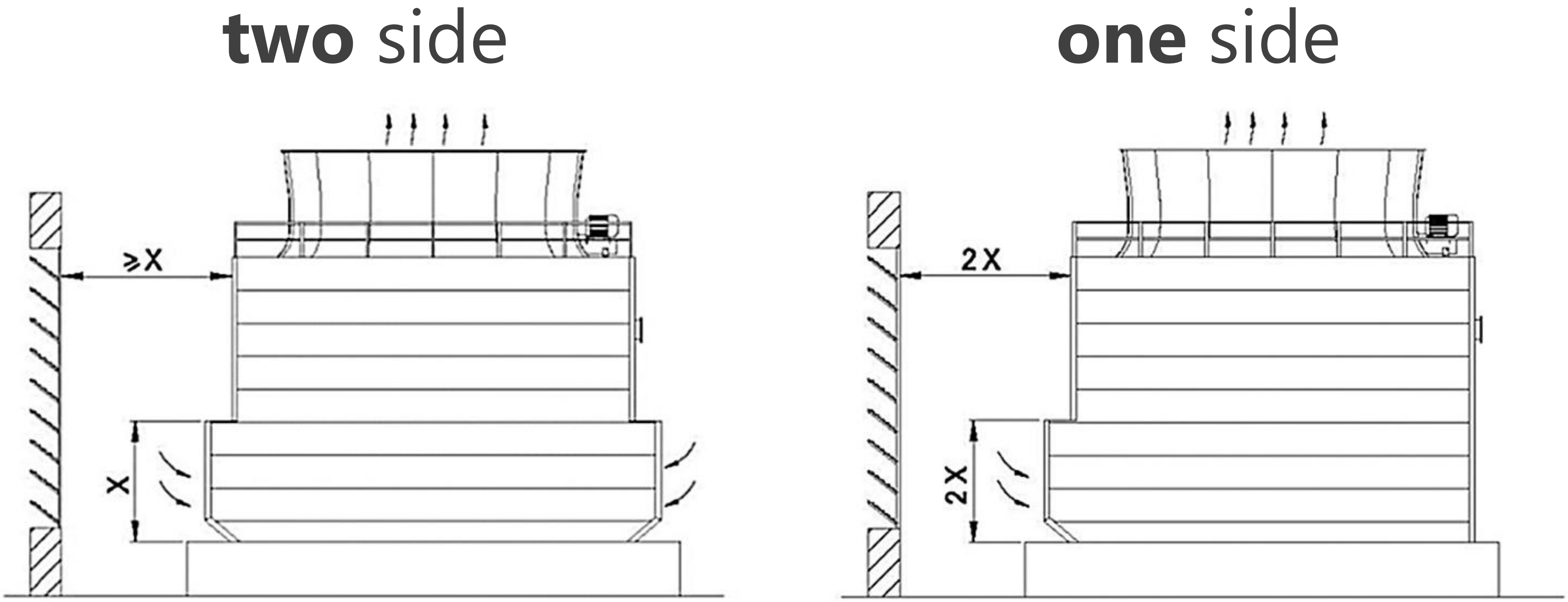
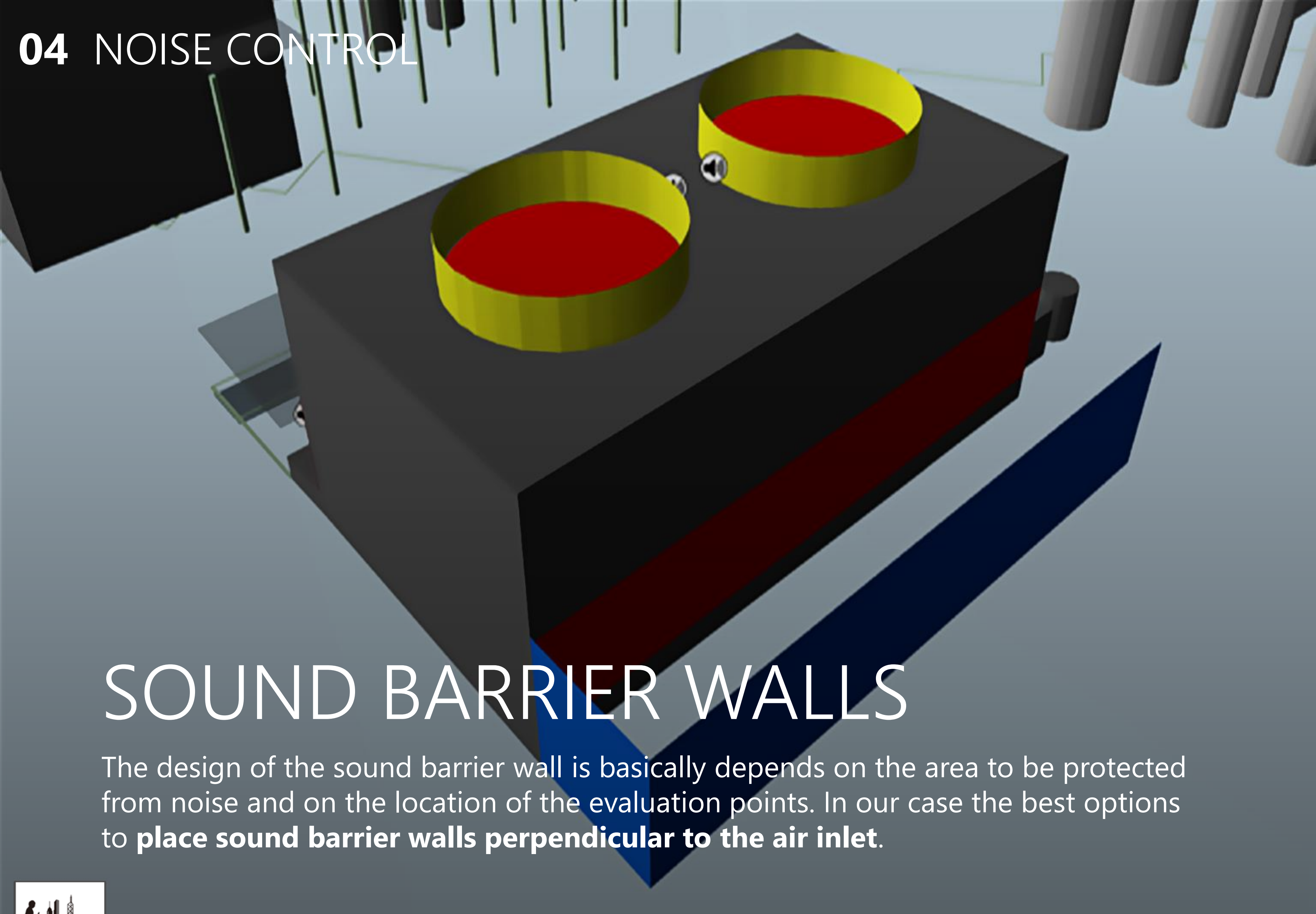


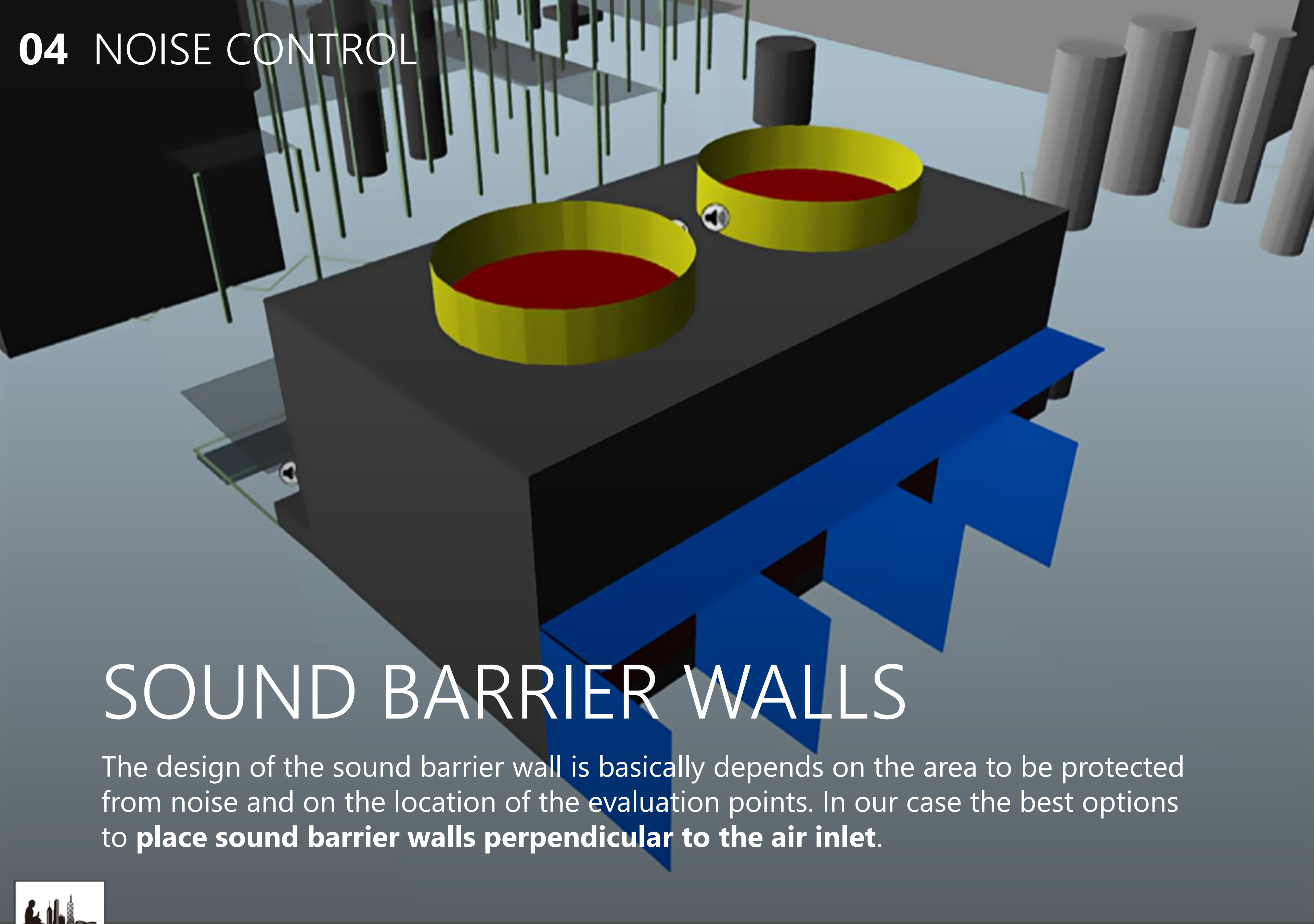
SOUND BARRIER WALLS

The distance between the barrier and the induced draft cooling tower must be larger than the height of the air inlet!



SOUND BARRIER WALLS

The design of the sound barrier wall is basically depends on the area to be protected from noise and on the location of the evaluation points. In our case the best options to **place sound barrier walls perpendicular to the air inlet**.



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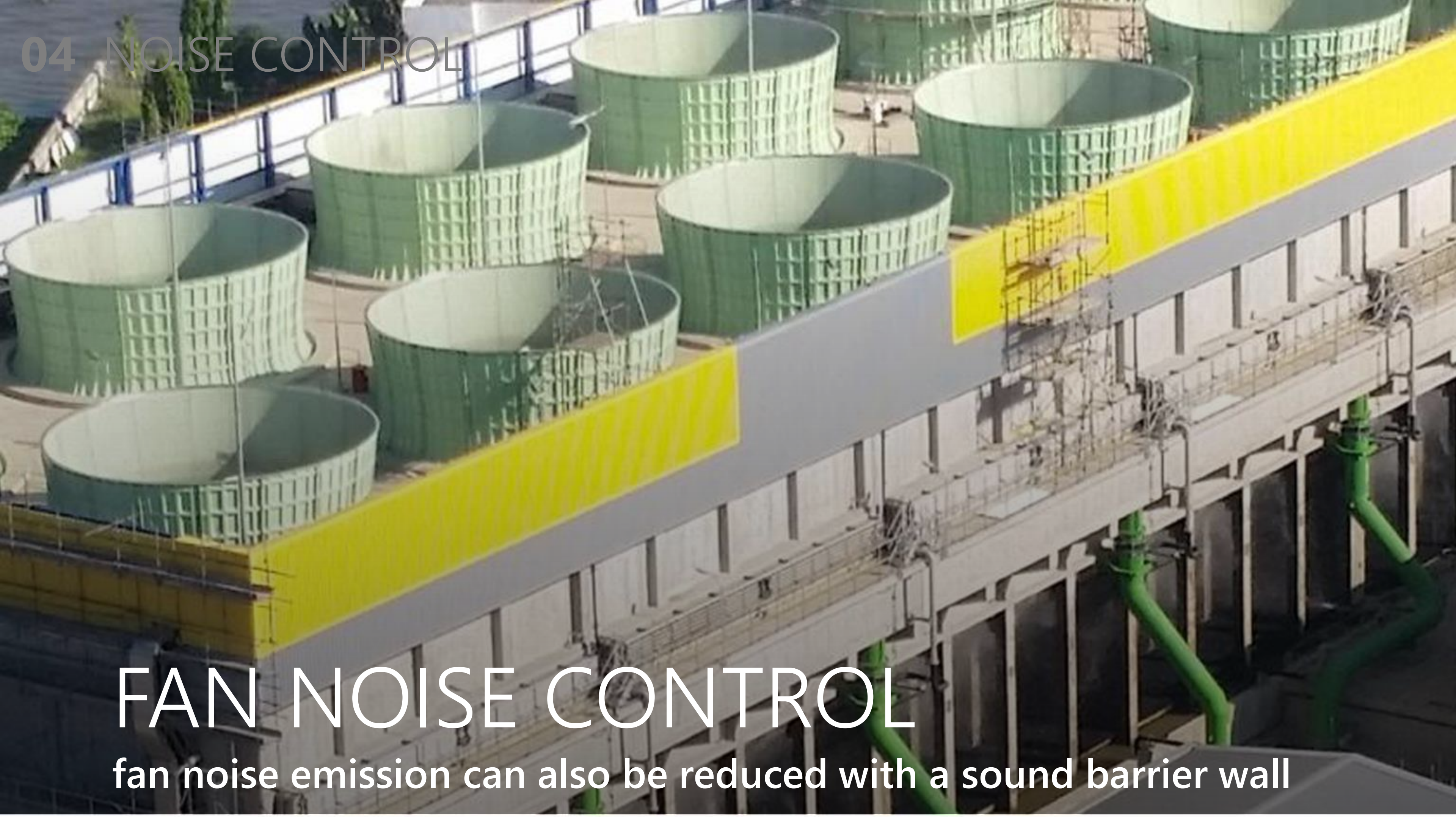
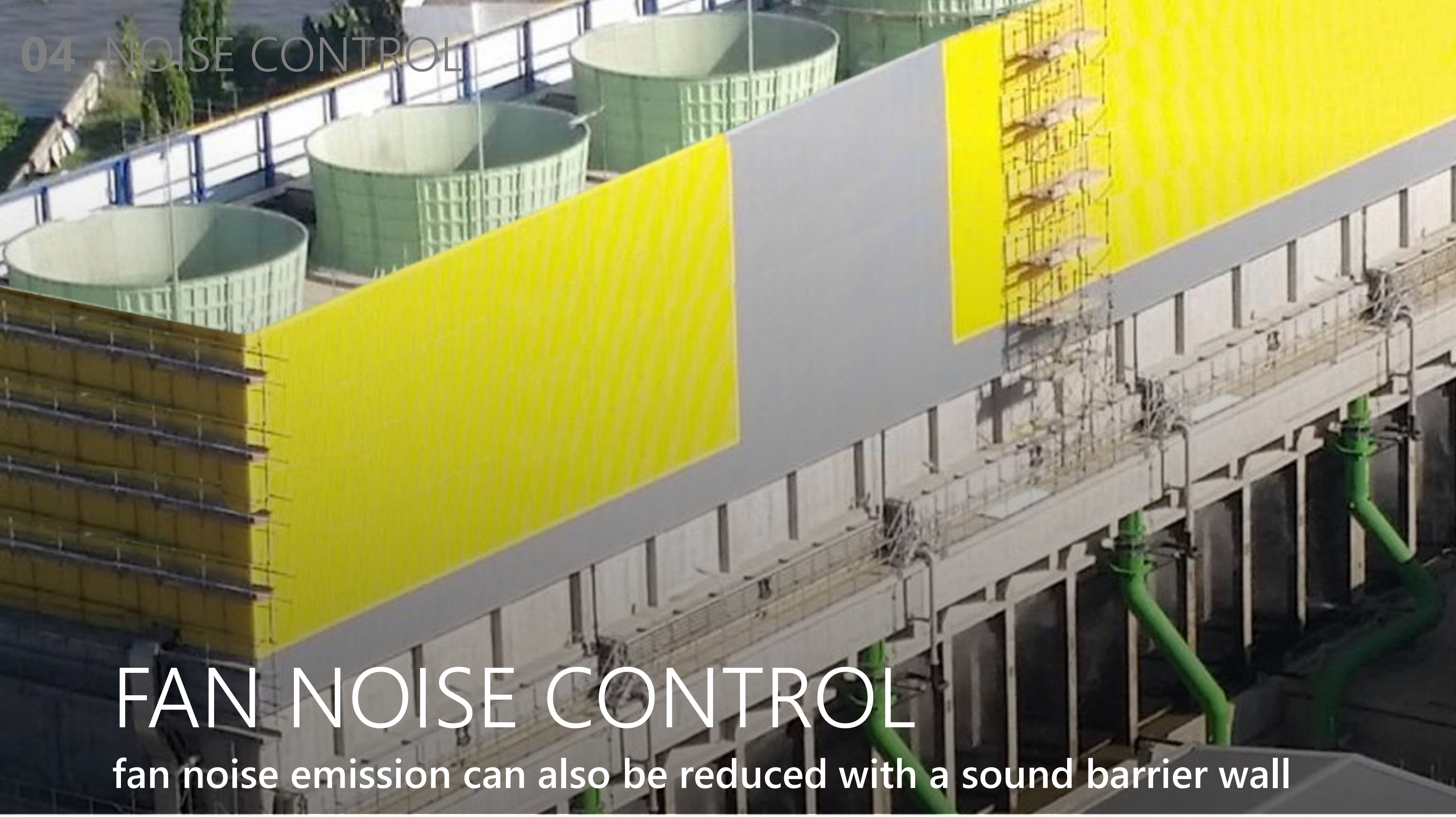


FAN NOISE CONTROL

fan noise emission can also be reduced with a sound barrier wall

It would be possible to construct a sound barrier wall on the edge of the cooling tower (which is statically the strongest), but the required wall would be so high (at least 7 metres), which is not recommended on the edge of the tower, because of the wind pressure.



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FAN NOISE CONTROL

fan noise emission can also be reduced with a sound barrier wall

pre-fabricated **diffuser retrofitted** to be sound absorbent

construction of a **specially designed fan stack**

construction of a **sound barrier wall** directly around the existing diffuser

Thank you for your attention

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