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UV-C Disinfection Technology: an overview of applications & benefits

Sophia Ehmke

Policy Officer

Sophia.ehmke@lightingeurope.org

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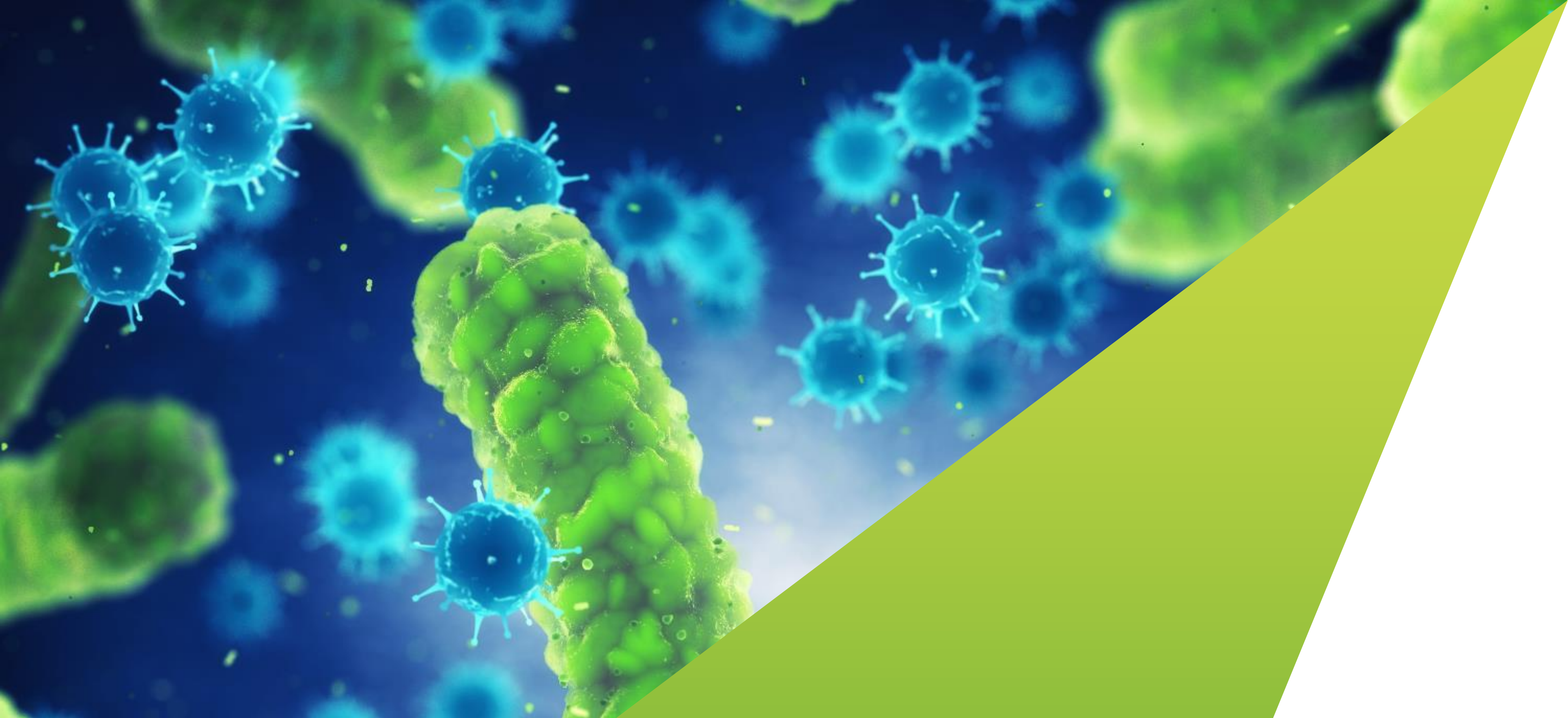
Background

The purpose of these slides is to summarize the understanding of LightingEurope members about the state of UV-C disinfection technology, their applications, benefits, safe use and applicable norms with the wider public.

The information provided in these slides is based on the latest research, studies and applicable regulations and standards at the time of publication and may be subject to review.

Contents



01

Introduction to LightingEurope

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Our Members

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- AFLE
- agid – AYDINLATMA GEREÇLERİ İMALATÇILARI DERNEĞİ
- AGORIA
- anfalum
- assil – Associazione Nazionale Produttori Illuminazione
- Crystal IS – High Performance UVC LEDs
- ERCO
- fedet – federatie elektrotechniek
- FLA – FEDERLEGNOARREDO
- SYNDICAT DU LUMINAIRE – GIL
- ENSEMBLE ignes – DONNONS VIE AU BÂTIMENT
- inventronics
- LEDVANCE
- Lighting Association Ireland – Knowledge | Support | Network
- Lighting Industry Association
- LIGHTING SWEDEN
- LightTech
- LUMILEDS
- LUTRON
- NVFN – de verenigde professionals in noodverlichting
- OSRAM
- POL Lighting
- PZPO – Polski Związek Przemysłu Oświetleniowego
- signify
- STOANE LIGHTING – EQUIPMENT DESIGN + MANUFACTURE
- SYLVANIA
- SYNDICAT DE L'ÉCLAIRAGE
- TRILUX – SIMPLIFY YOUR LIGHT.
- WayPoint
- ZUMTOBEL Group
- zvei – electrifying ideas

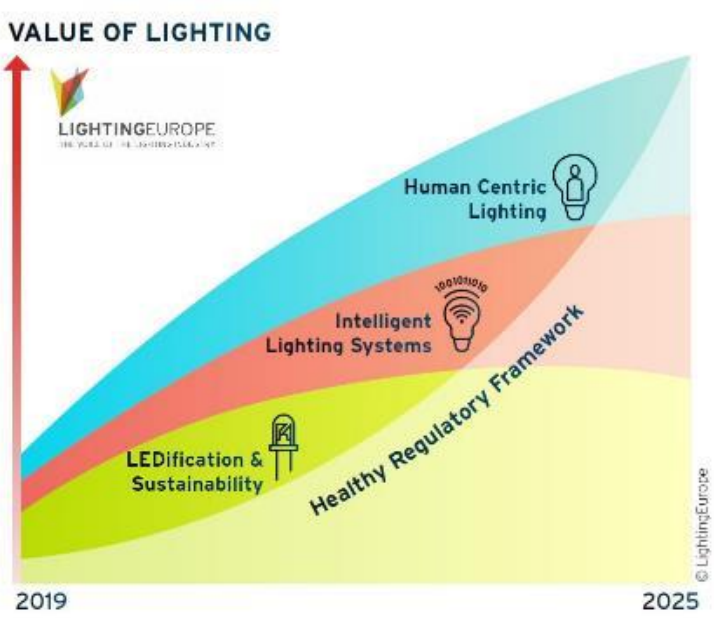
Our Vision

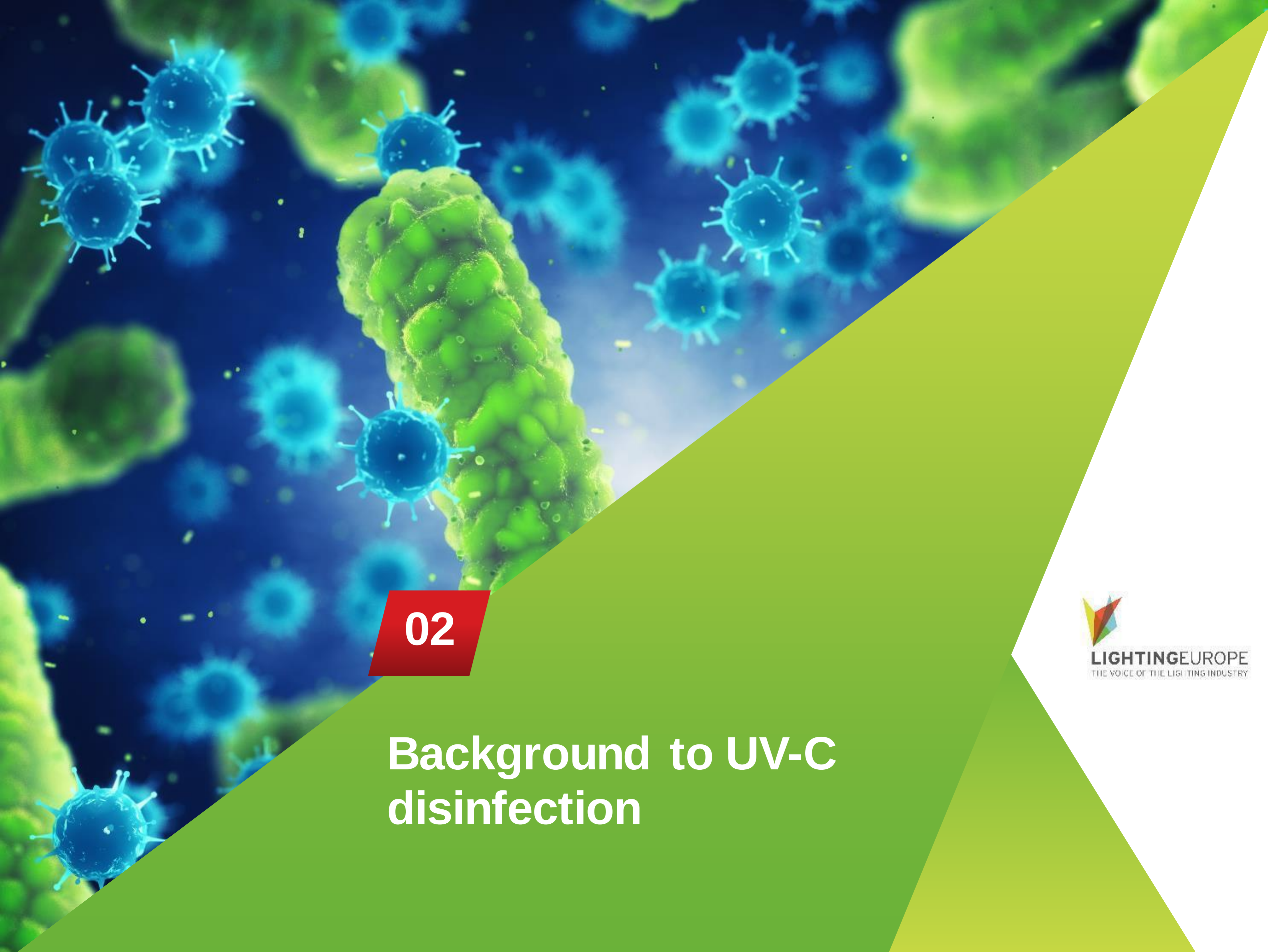
LightingEurope has made progress in achieving the lighting industry's Strategic Roadmap to grow the **Value of Lighting** by 2025.

The lighting industry is harnessing the potential of **LEDification** and **Sustainability** and is delivering energy efficient and sustainable lighting products.

The increased **Value of Lighting** to society will come from **Intelligent Lighting Systems** and **Human Centric Lighting.**

The European lighting industry is working with European legislators to ensure a **Healthy Regulatory Framework**, with simple, sound rules that are better enforced, to foster growth in the market and for people.





02

Background to UV-C disinfection

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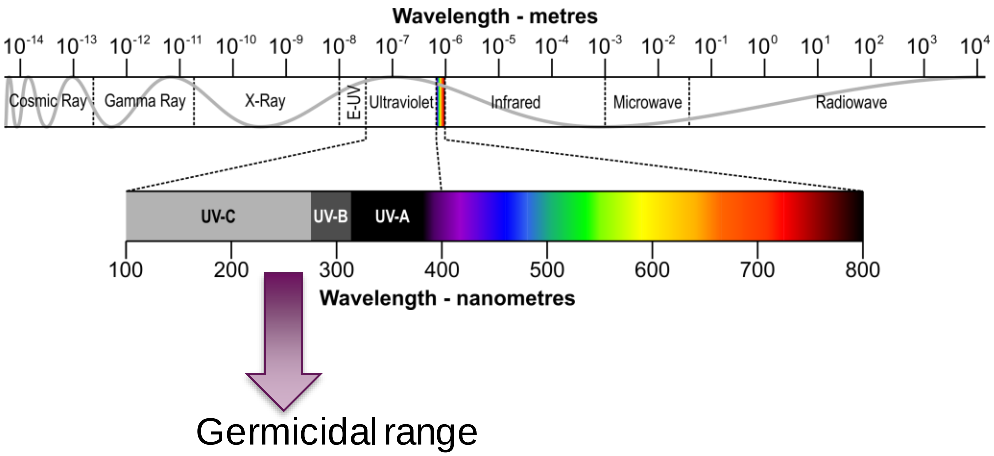
What is UV-C Light?

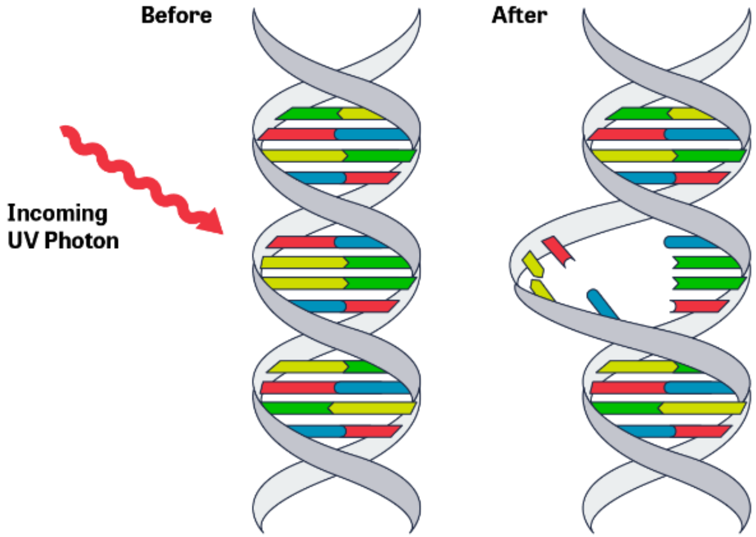
- Ultraviolet (UV) light is non-visible and has higher energy than visible light
- Situated on the electromagnetic spectrum between visible light and X-Rays
- Classified into three wavelength ranges, each having different applications:
    - *UV-A 315 – 400 nm Insect traps, detection of forgeries, drying inks & paints*
    - *UV-B 280 – 315 nm Suntanning, medical therapy*
    - ***UV-C 100 – 280 nm Disinfection** (germicidal range between 250-280nm)*
- UV-C also known as “Germicidal Energy” has the ability to destroy germs
- No UV-C from the sun reaches the Earth surface



© Sylvania

How does UV-C disinfection work?

- UV-C wavelengths destroy the DNA and RNA of pathogens like viruses and biological micro-organisms, including bacteria, protozoa, and yeast
- This prevents pathogens from dividing and multiplying, and effectively deactivating them
- The disinfection process is quantified in log reduction value (LRV), which expresses the number of pathogens inactivated by UV disinfection



Source: https://www.klaran.com/uvc-leds-for-disinfection
*Additional Resources: Webinar by LEDs Magazine given by **Dr. Robert (Bob) Karlicek, Title:** Germicidal UV-C radiation: Fact and fiction about killing pathogens*

Historical Perspective

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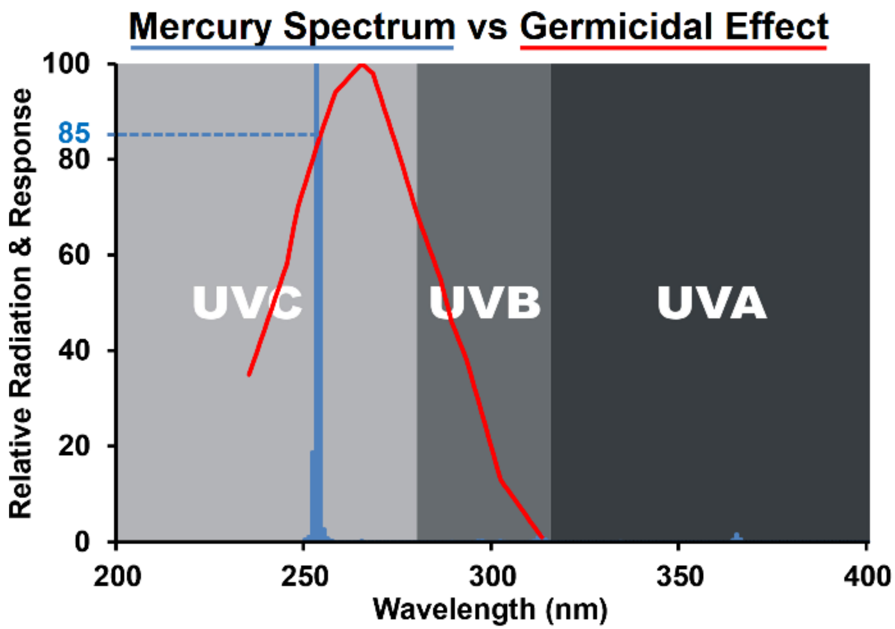
- UV-C sanitisation is nothing new : it has been commercially applied since the 1930s
- Historic track-record in elimination of other pathogens, e.g. tuberculosis and measles
- LightingEurope calls for wider recognition of this proven technology to fight COVID-19

Sources: Sylvania Germicidal Engineering Bulletin 1981; Philips UV-C Technical Manual 1962; WellsWF, WellsMW, WilderTS, American Journal of Hygiene v35 1942 p97-121

Germicidal Effectiveness

- Not all wavelengths of UV-C are equally effective for the destruction of pathogens
- The peak wavelength for the destruction of DNA & RNA is around 265 nm (red line)
- This is very close to the peak emission of a UV-C discharge lamp (254 nm, blue line)
- UV-C discharge lamps radiate at 85% of the theoretical maximum germicidal efficiency



Germicidal Efficiency: IES Lighting Handbook, Application Volume, 1987, Section 14 p.19
Mercury spectrum: radiometry of Sylvania G30T8 lamp

How UV-C allows reliable & consistent performances

- The dose is easily quantifiable, allowing for reliable and consistent disinfection
- Two important factors determine the dose required for inactivation
  - ☑ The intensity of the radiation
  - ☑ The duration of exposure
- Via below formula we can calculate this for air, water and surface disinfection
- Dose cumulates, it does not need to be continuous: air treatment should consider recirculation

Intensity

$$UV\ Dose\ \left(\frac{J}{m^2}\right)\Big|_{\lambda} = \underbrace{\left(\frac{radiant\ flux\ (W)}{Cross\ section\ area\ (m^2)}\right)}_{\text{Intensity}} * exposure\ time\ (s)$$

Source: https://www.iuvanews.com/stories/pdf/archives/180301_UVSensitivityReview_full.pdf

Relation to COVID-19

Spread of virus	Preventive measure
Direct contact	Wash hands, clean surfaces, avoid handshake
Droplets	Keep social distance, wear facemask
Aerosols	(equivalent) ventilation indoor or stay outdoor

- Aerosols are a major route for contamination with SARS-CoV-2 virus causing COVID-19. Scientific evidence confirms this.
- Avoiding direct contact and keeping distance remains important but is not enough to avoid contamination.
- Ventilation (or equivalent) for all indoor areas is important. UV-C is a major tool to increase (equivalent) ventilation rate.
- The WHO confirms that increased ventilation rate is a solution to create healthy and safe indoor environments.

Ventilation rate

- Air quality is typically managed by ventilation rates, expressed in Air Changes per Hour (ACH)
- Each Air Change reduces the virus concentration in the air by 63%
- An Equivalent Air Change has occurred when an alternate technology inactivates 63% of infectious organisms in a room: Equivalent Air Changes per Hour (eqACH)
- Natural ventilation can achieve 1-2 eqACH. Mechanical ventilation usually results in 2 up to 5 eqACH. Equivalent ventilation via UV-C can achieve >> 10 eqACH.
- The CDC recommends eqACH 15-20 for use in healthcare environments to disinfect the air and protect vulnerable patients.
- Hong Kong is already requiring eqACH>6 for restaurants to open up.
- Ventilation rate requirements are already part of building guidelines; increasing eqACH will reduce the number of pathogens in the air.

Opportunity from UV-C: increasing equivalent ventilation

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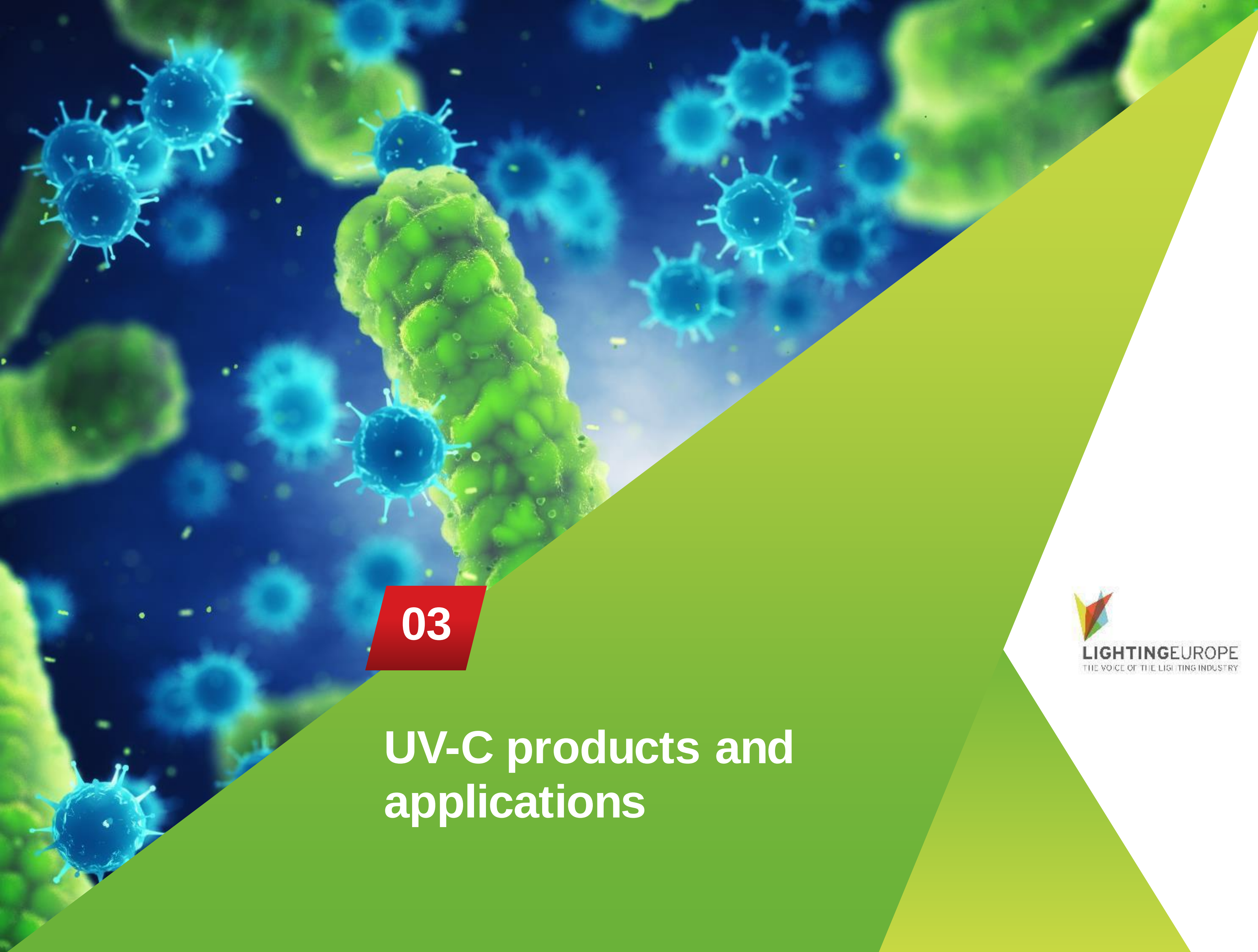
- It is well documented that UV-C disinfection reduces contamination risks by inactivating viruses and other pathogens.
- We can translate the UV-C dose in equivalent Air Changes per Hour (eqACH) without discomfort and with low infrastructural costs.
- For virus disinfection eqACH>10 is recommended. Most mechanical ventilation systems cannot achieve this; UV-C can!
- This means the ability to increase occupancy, residence time and reduce shared spaces down-time between users.
- Work towards simple requirements, which incorporates the space volume, existing ventilation, and localized UV-C solution.
- Increase energy savings with compliance. Studies show UV-C could reduce buildings HVAC energy demand by up to 50%, and allow for localized solutions.



03

UV-C products and applications

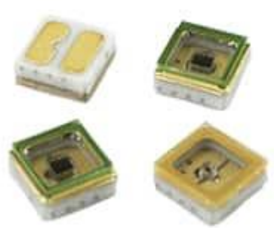
UV-C Disinfection Sources

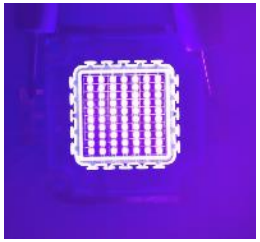
Image sources © Signify and Sylvania

DISCHARGE Lamps

- Highest energy efficiency
- Highest UV-C power
- Long life and reliable
- Mature, proven technology
- Easy to apply in systems

LED Emitters





- Small light sources
- Mercury-free
- Flexible to build arrays of different dimensions

EXCIMER Lamps

- 222nm radiation
- Safer for skin & eyes
- Mercury-free

UV-C Applications

- There are three primary applications for UV-C disinfection:
  - **AIR** disinfection
  - **SURFACE** disinfection
  - **WATER** disinfection

- COVID-19 is primarily an airborne disease, hence most interest is in air disinfection
- Surface disinfection is also beneficial to a lesser extent in certain applications
- The following slides illustrate how UV-C can be applied to protect people

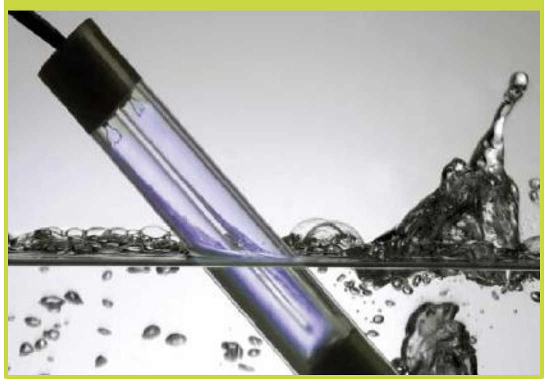
AIR DISINFECTION

© Signify

SURFACE DISINFECTION

Source: University of Idaho- link

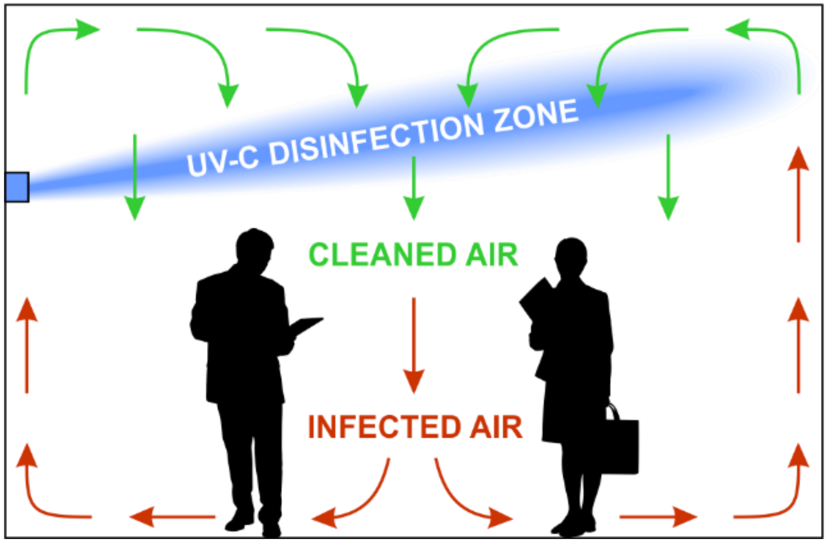
WATER DISINFECTION



Source: Radium

UV-C Upper-Air Disinfection

- The most effective method for indoor air disinfection: easily achieves eqACH >>10
- Simple addition to existing rooms with sufficient width and ceiling height
- Luminaires on walls / ceilings shine a narrow beam of UV-C above head-height
- Natural convection causes sufficient air circulation
- Infected air is continually sanitised each time it passes through the UV-C rays
- Qualified installations are safe for operation in presence of people

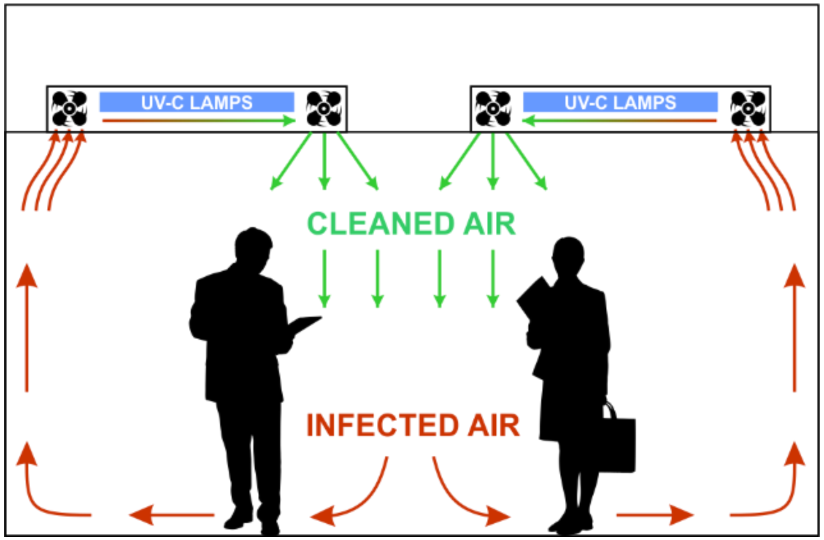


© Sylvania

© Signify

UV-C Closed-Air Disinfection

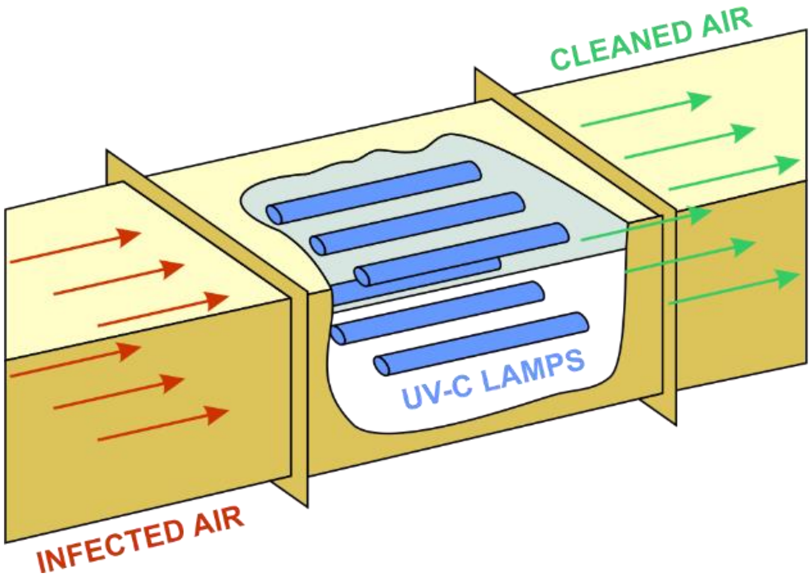
- Air is drawn into the luminaires using a fan, disinfected by UV-C lamps, then expelled
- Totally safe due to completely contained UV-C lamps: unskilled users can easily install
- Less effective vs upper air devices, due to short irradiation time. eqACH typically 2-5
- Ideal for use where low ceilings or smaller rooms do not permit upper air installations
- Exist in ceiling panels, often with lighting
- Also as mobile floor-standing devices

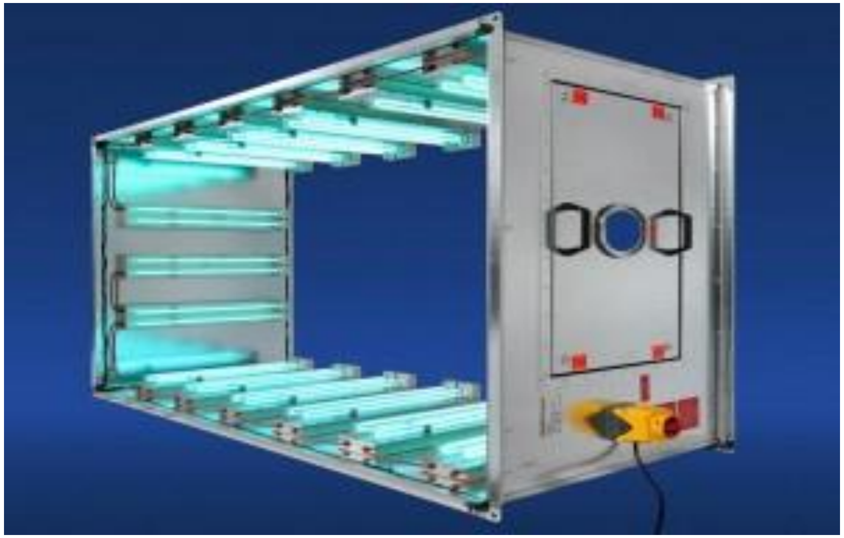


Source: Victory Lighting, UK

UV-C inside HVAC Systems

- High power units integrated in Heating Ventilation & Air-Conditioning systems
- Some older HVAC systems may recirculate the same air around multiple rooms
- UV-C modules prevent risk of cross-infection of air from one room to another
- Special high-power lamps are necessary, optimised to function in chilled air streams





© *Sylvania*

Source: UV-C Factory.com - link

UV-C Surface Disinfection

- Ceiling-mounted direct irradiation luminaires irradiate air and surfaces in line-of-sight
- Also used in sealed cabinets for disinfecting objects e.g. facemask, hairdressers' tools
- Not suitable for operation in the presence of people, animals, or indoor plants
- Must be used with multiple safety systems to prevent accidental UV-C exposure
- Limited effect due to shadows, especially on rough / textured surfaces (micro shadows)

Source: University of Idaho - link

Recent UV-C Application Examples 1/2

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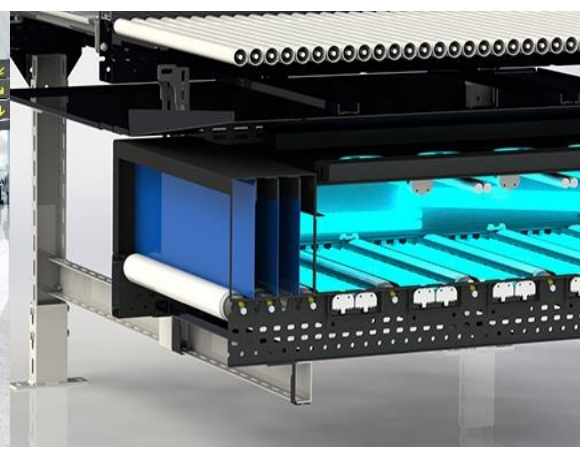
- Pharmacy chain deploys upper-room UV-C mercury lights
  Lux Review (UK), 2021 March : Link
- Gatwick Airport installs first UV-C disinfection of luggage trays
  Airport Business News (UK), 2020 September : Link
- St.Pancras train station installs virus-busting UV-C systems
  Evening Standard (UK), 2020 September : Link
- Heathrow Airport : UV-C robots disinfect furniture & handrails
  Lux Review (UK), 2020 August : Link



Recent UV-C Application Examples 2/2

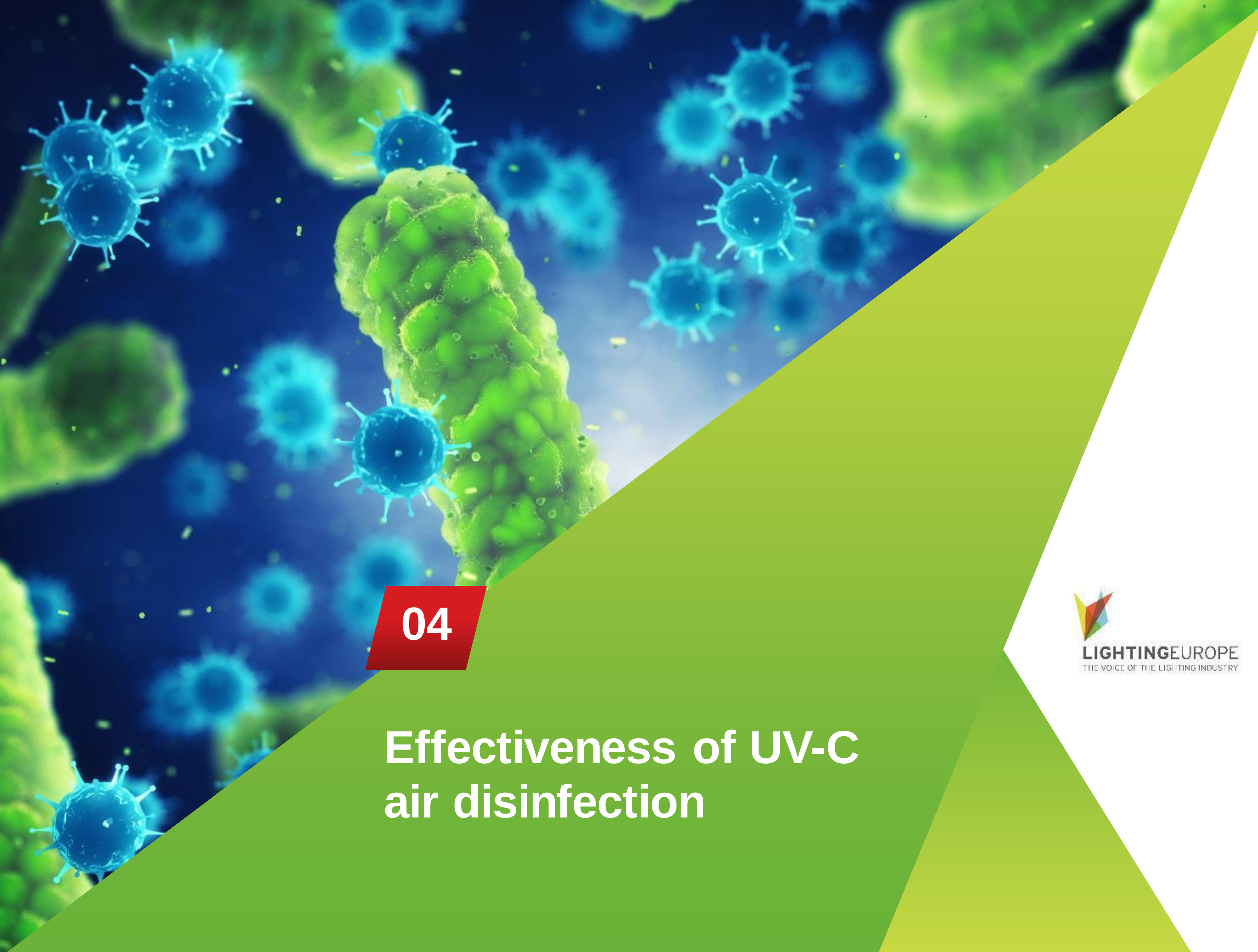
PRESS RELEASE | 23 NOVEMBER 2020

Coronavirus: Commission to provide 200 disinfection robots to European hospitals

As part of its continued efforts to tackle the spread of coronavirus and provide Member States with necessary equipment, the Commission launched the purchase of 200 disinfection robots that will be delivered to hospitals across Europe.

iStock Getty Images Plus

Source: https://digital-strategy.ec.europa.eu/en/news/coronavirus-commission-provide-200-disinfection-robots-european-hospitals



04

Effectiveness of UV-C air disinfection

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The Wells-Riley model for airborne infection probability

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Based on recent test results, we now can calculate eqACH levels for SARS-CoV-2 UV-C upper air disinfection installations

Wells –Riley model for airborne infection

$$P_{event-airborne} = 1 - exp\left[\frac{-Ipqt}{ACH+eACH}\right]$$

With:

I = # infector individuals in the space
p = Average breathing of individuals in the space
q = Infection Quanta generation rate
t = Exposure time
ACH = Conventional Air Changes per Hour
eACH = Equivalent Air Changes per Hour

The *Wells-Riley model* expresses the Airborne Infection Probability in terms of:

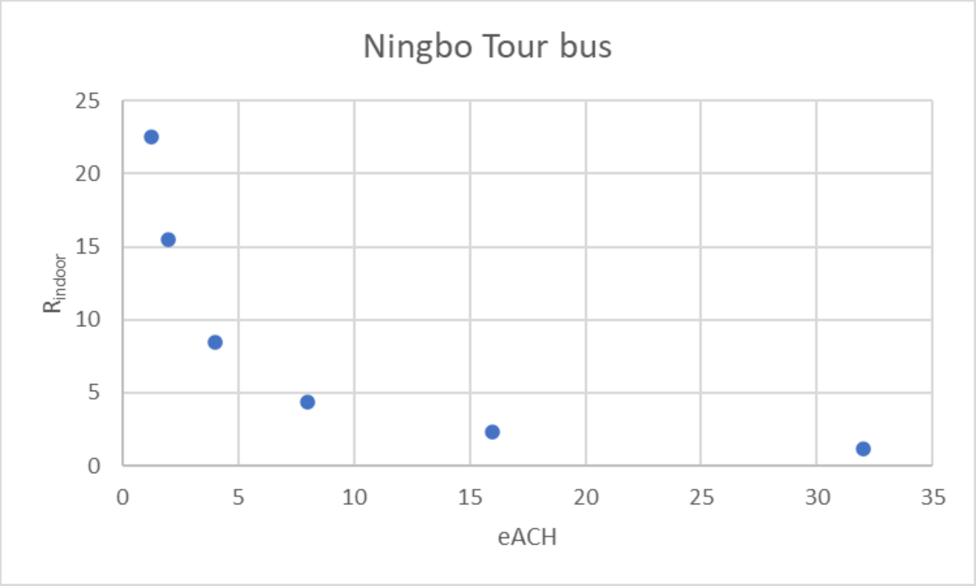
- Number of infectors
- Exposure time
- Breathing rate & infection quanta
- Air Changes per Hour (ACH), and
- *Equivalent* Air Changes per Hour (eqACH)

The ACH can be realized by traditional natural and/or mechanical ventilation

The eqACH can be realized by complementary disinfection technologies, such as UV-C or ionization

Real life example:
Ningo Bus tour, Jan 2020

- During a 2-hour bus journey in Ningbo, China, 23 of 68 passengers were infected.
- Seat locations were uncorrelated with distance to index case
- >37 eACH required for Revent, airborne < 1
- UV-C can contribute to achieve this eqACH level.

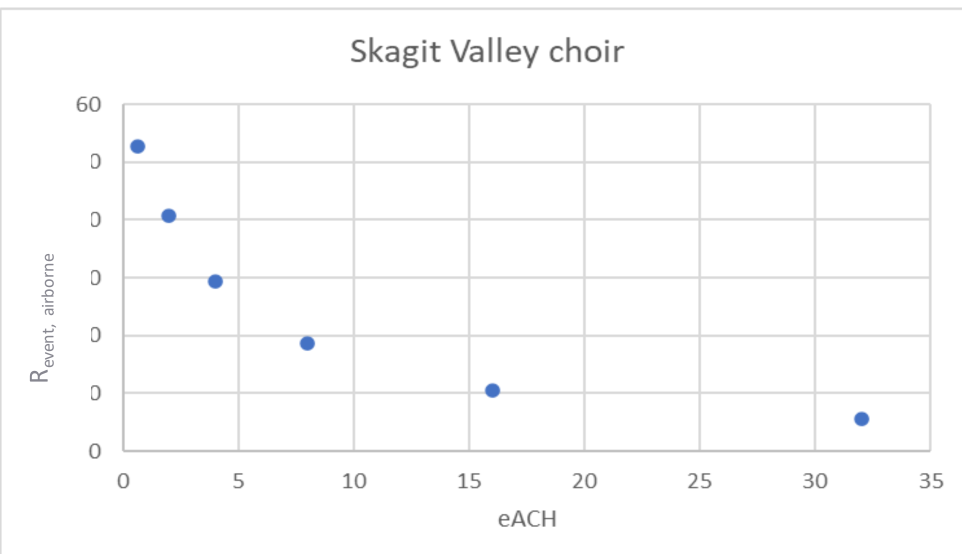


Parameter	
# of infected people	1
# of people (total)	68
Breathing rate (m^3/hr)	0,5
Quanta/hr (*derived*)	30
Exposure time (hr)	1,7
ACH (air changes per hour)	1,25
Volume space (m^3)	45
# of people infected	23

Data, graph, image source © Signify

Real life example:
Skagit Valley Choir, March 2020

- At a 2.5-hour-long Skagit Valley Chorale choir practice in Washington State, some 53 of 61 attendees were infected
- Not all of them within 6 feet of initially infected individual
- >177 eACH required for $R_{event,\ airborne} < 1$
- eqACH > 30 could have significantly reduced infections (by approx. 90%)

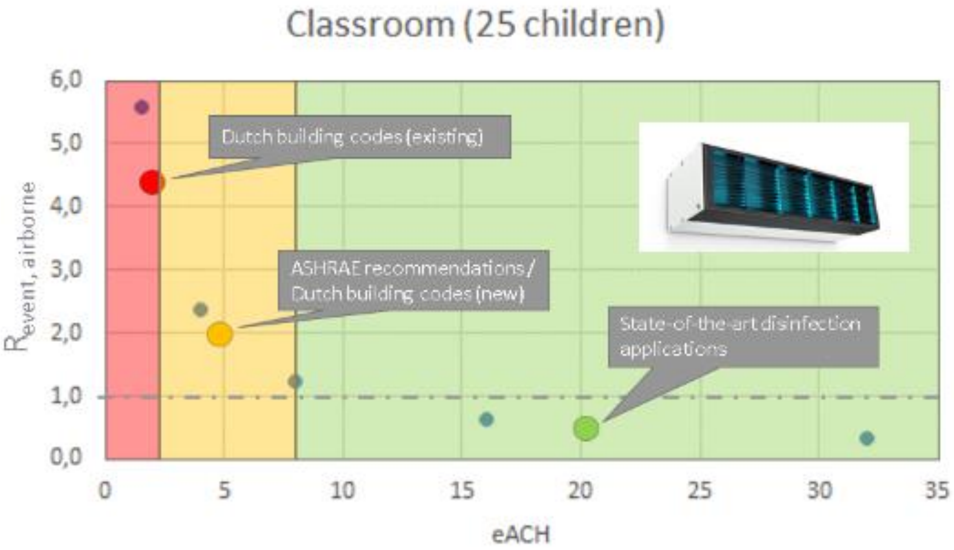


Parameter	
# of infected people	1
# of people (total)	61
Breathing rate (m^3/hr)	1,0
Quanta/hr (*derived*)	970
Exposure time (hr)	2,5
ACH (air changes per hour)	0,65
Volume space (m^3)	810
# of people infected	53

Data, graph & image source © Signify, Case study: COVID-19 infiltrated Mt. Vernon choir, killing 2 members and infecting others | KATU

Model example:
A classroom with 25 children

- >10 eqACH required for $R_{event,\ airborne} < 1$
- Upper air UV-C luminaire technology can achieve this eqACH level
- Note this is not a real-life case, but a projection, based on the Wells Riley model

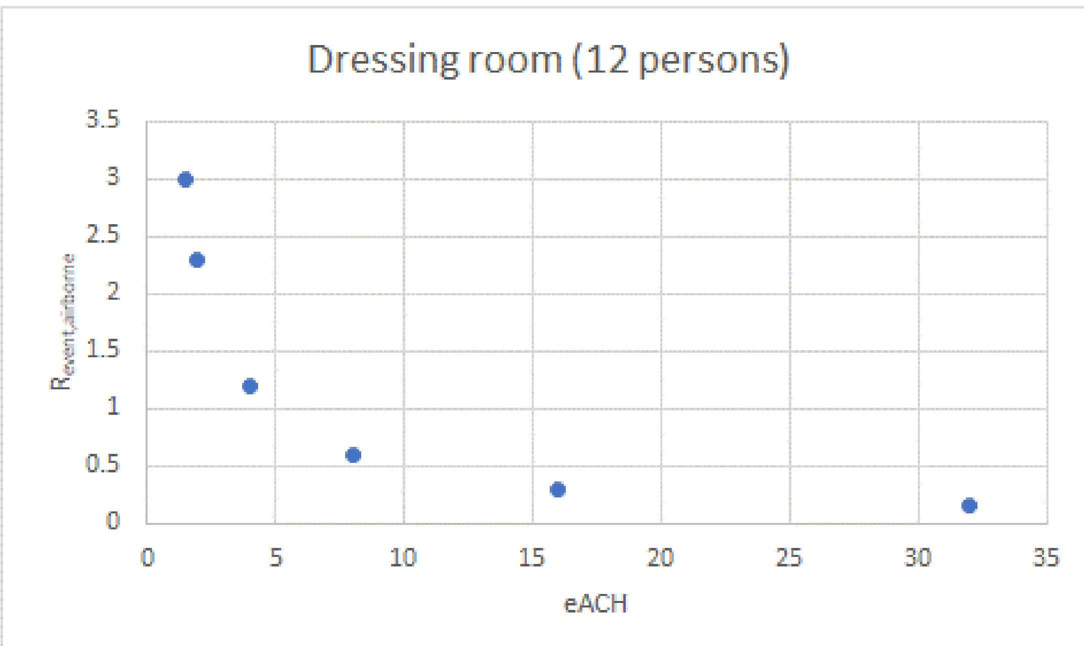


Parameter	
# of infected people	1
# of people (total)	25
Breathing rate (m^3/hr)	0,4
Quanta/hr (*assumed*)	25
Exposure time (hr)	6
ACH	1,5
Volume space (m^3)	147
Airborne Infection Probability	23%
Expected # of children infected without extra protection	5-6

Data, graph, image source © Signify

Model example: Dressing room (12 persons, 1 hr exposure)

- >5 eqACH required for $R_{event,\ airborne} < 1$

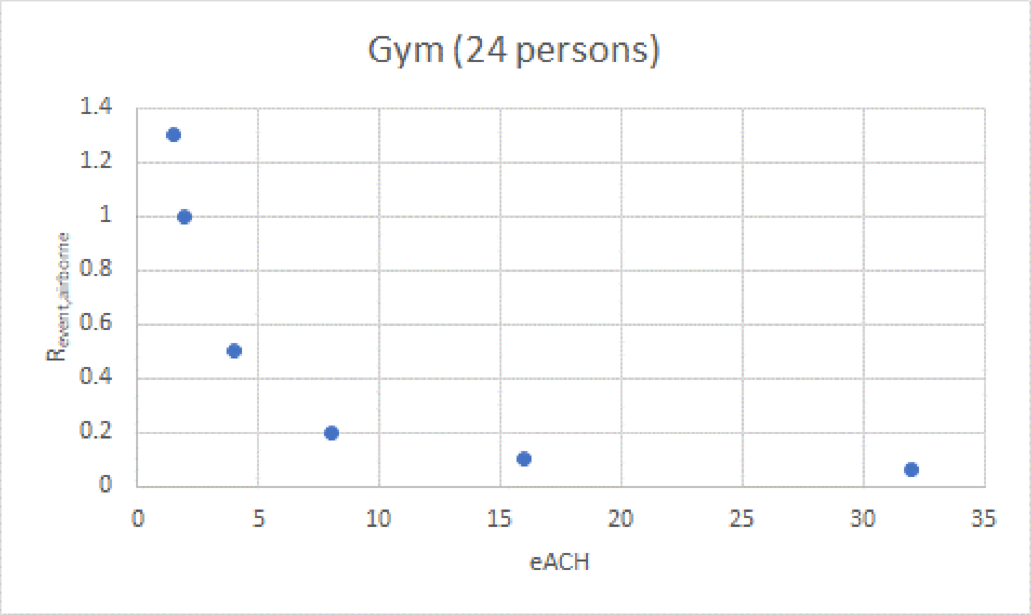


Parameter	
# of infected people	1
# of people (total)	12
Breathing rate (m^3/hr)	1
Quanta/hr	25 (250)
Exposure time (hr)	1
eACH (equivalent air changes per hour)	4
Volume space (4 x 6 x 2.4 m^3)	58
Expected # of people infected ($R_{event,airborne}$)	1.2 (7.95)

Data, graph © Signify, case study: Hoe zetten we virussen buitenspel? | Philips verlichting
Image Credit @PSV Media Visitors dressing room

Model example: Gym
(24 persons, 2 hours workout)

- >2 eqACH required for $R_{event,\ airborne} < 1$



Parameter	
# of infected people	1
# of people (total)	24
Breathing rate (m^3/hr)	3
Quanta/hr	25 (250)
Exposure time (hr)	2
eACH (equivalent air changes per hour)	4
Volume space (14 x 22 x 6 m^3)	1848
Expected # of people infected ($R_{event,airborne}$)	0.5 (4.4)

Data, graph, image source © Signify

05

Standards and legislation

EU legislation and standards are in place

UV-C technology is not new
EU legislation, standards and industry guidance are already available for **safe use of UV-C**

EU Legislation

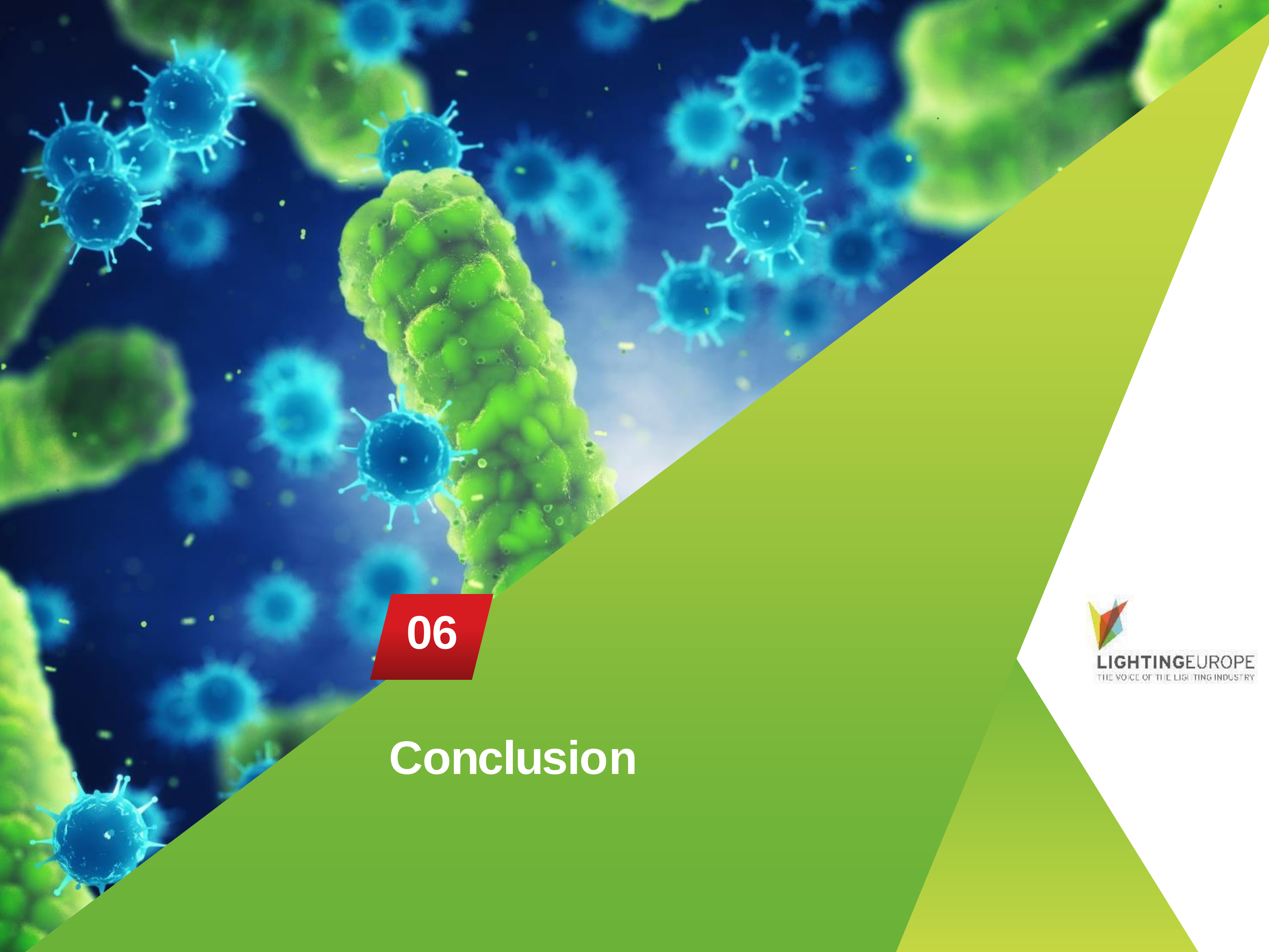
- Low Voltage Directive 2014/35/EU
  - Electric product must be safe, including the harm caused by the function of the electrical equipment
- Directive for limits of exposure of workers to artificial optical radiation 2006/25/EC
  - Valid for optical radiation form 100nm to 1mm, this includes UV-C

Standards

- EN 62471 Photobiological safety of lamps and lamp systems
- IEC PAS 63313 GLA Germicidal UV-C Irradiation – UV-C Safety Guidelines
- ISO EN 15858 UV-C Devices - Safety information - Permissible human exposure

Industry guidance:

- GLA - UV-C Safety Guidelines – link



06

Conclusion

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Conclusion

UV-C is well-known and well understood

- UV-C has a long history and track record in effective disinfection
- The scientific basics of UV-C germicidal efficiency are well understood

UV-C helps address the pandemic

- Proof for effectiveness of UV-C against SARS-CoV-2 has emerged
- UV-C helps mitigate impact of the current pandemic in several ways
- UV-C reduces the transmission risk of all airborne transmitted diseases

UV-C is effective

- Upper-air UV-C systems can inhibit the airborne transmission route of SARS-CoV-2 and are a cost-effective technology, complementary to mechanical ventilation
- Surface UV-C disinfection systems are an effective method to help reduce infection rates

UV-C is safe

- Safe use of UV-C is enabled by existing legislation, standards and industry guidelines

Other LightingEurope publications on UV-C

Please find below an overview of other LightingEurope publications and contributions on UV-C:

1. LE Position Paper on UV-C - September 2020 - link
2. LE FAQ on UV-C - December 2020 - link
3. Contributed to GLA letter to the World Health Organization - February 2021 and sent it to the European regional WHO office - link
4. Reference to UV-C in the Joint statement on “No renovation without an upgrade of the lighting installations” – February 2021 - link
5. Contributed to the LightingEurope EPBD roadmap consultation paper - March 2021 - link
6. LpS article on UV-C with contributions from LE UV-C experts - March 2021

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THANK YOU

Sophia Ehmke

Policy Officer

Sophia.ehmke@lightingeurope.org

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