



18 – 19 April 2023

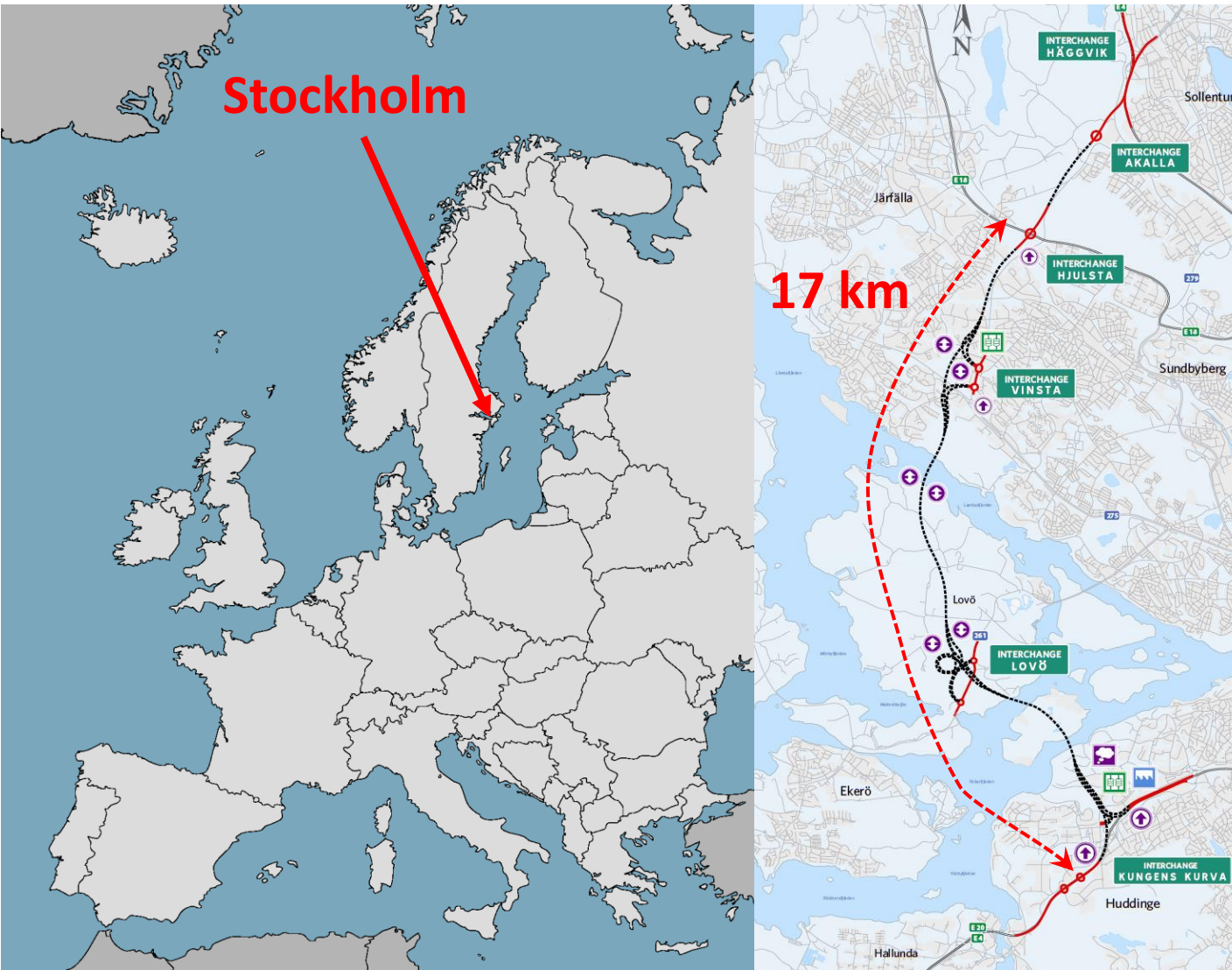
NVF Seminarium – komplexe vägtunnlar
Tunnelventilation – E4 Förbifart Stockholm

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Content



Theory

Longitudinal ventilation

- Normal operation
- Jet fans
- Air-exchange station
- Portal-air extraction
- Low-pressure shaft fan

Smoke management

Anti-recirculation at portals

E4 Förbifart Stockholm (E4FS-Södra)

Overview

Ventilation equipment

Tunnel-ventilation Control

Ventilation modes

Normal operation

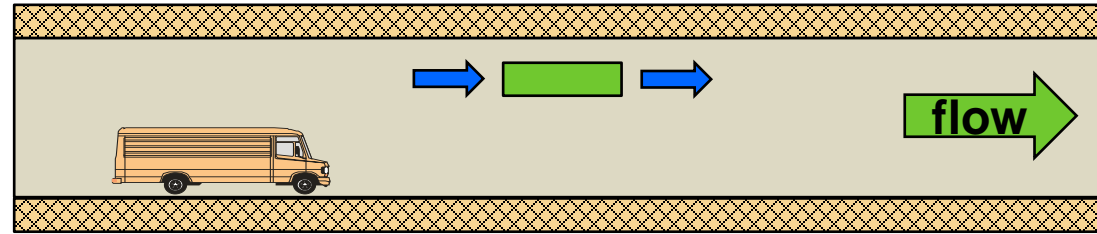
- Stepwise controller principle
- Application

Smoke management

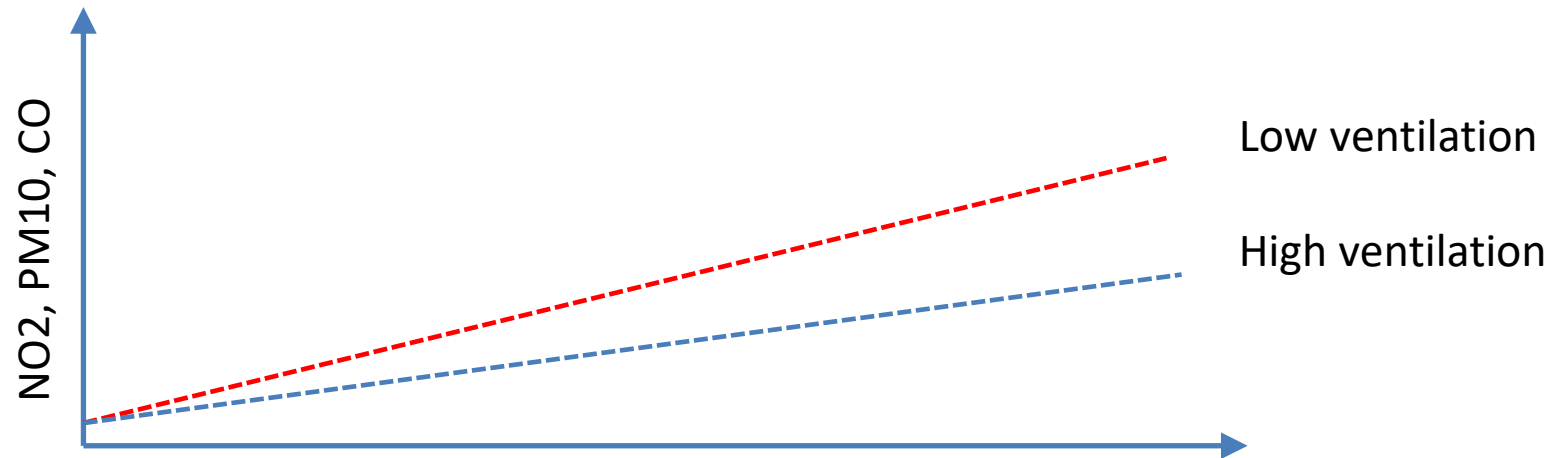
Tunnel-ventilation simulator

Longitudinal ventilation: normal operation

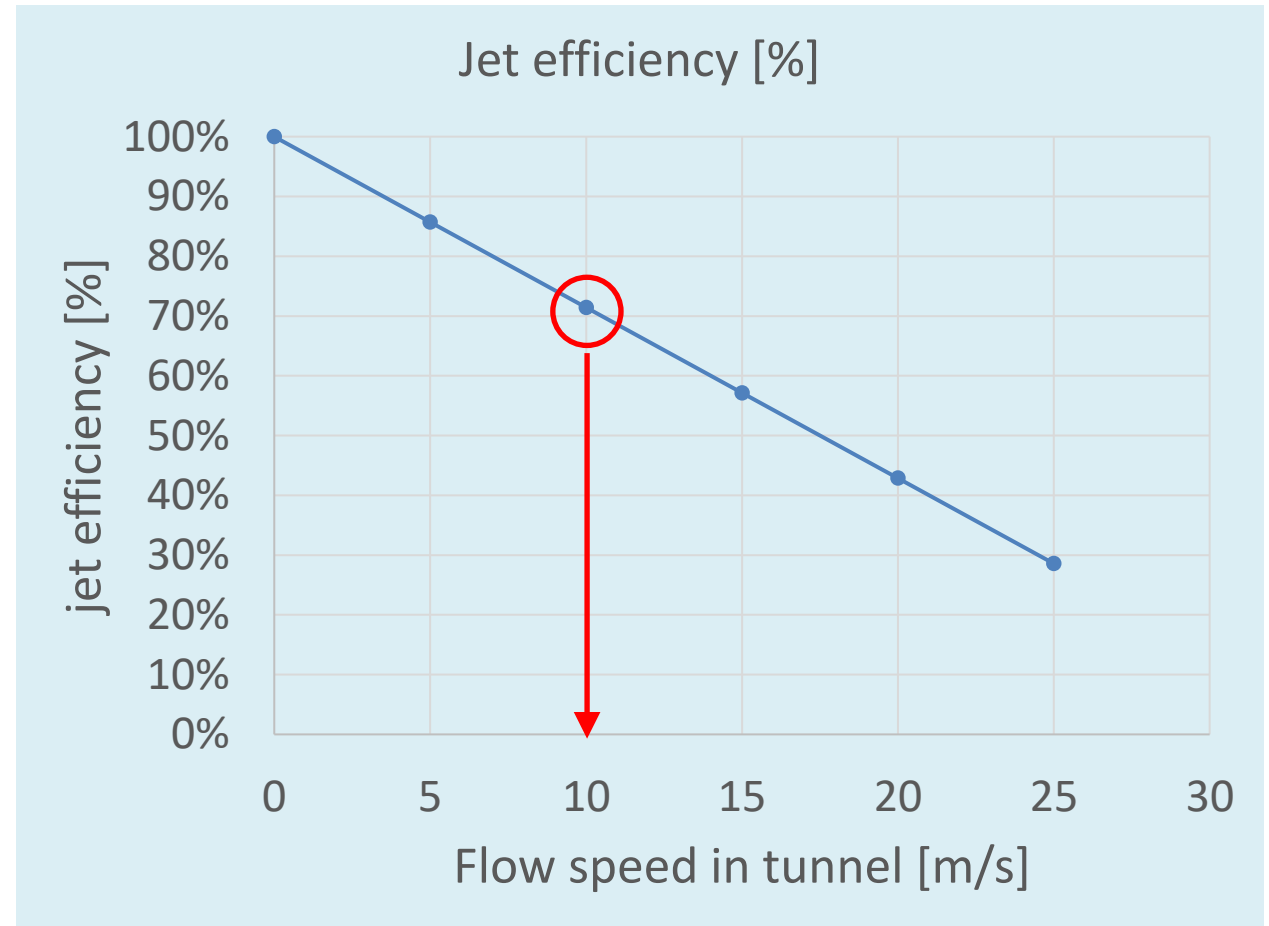
- Jet fans adding impulse to the flow:



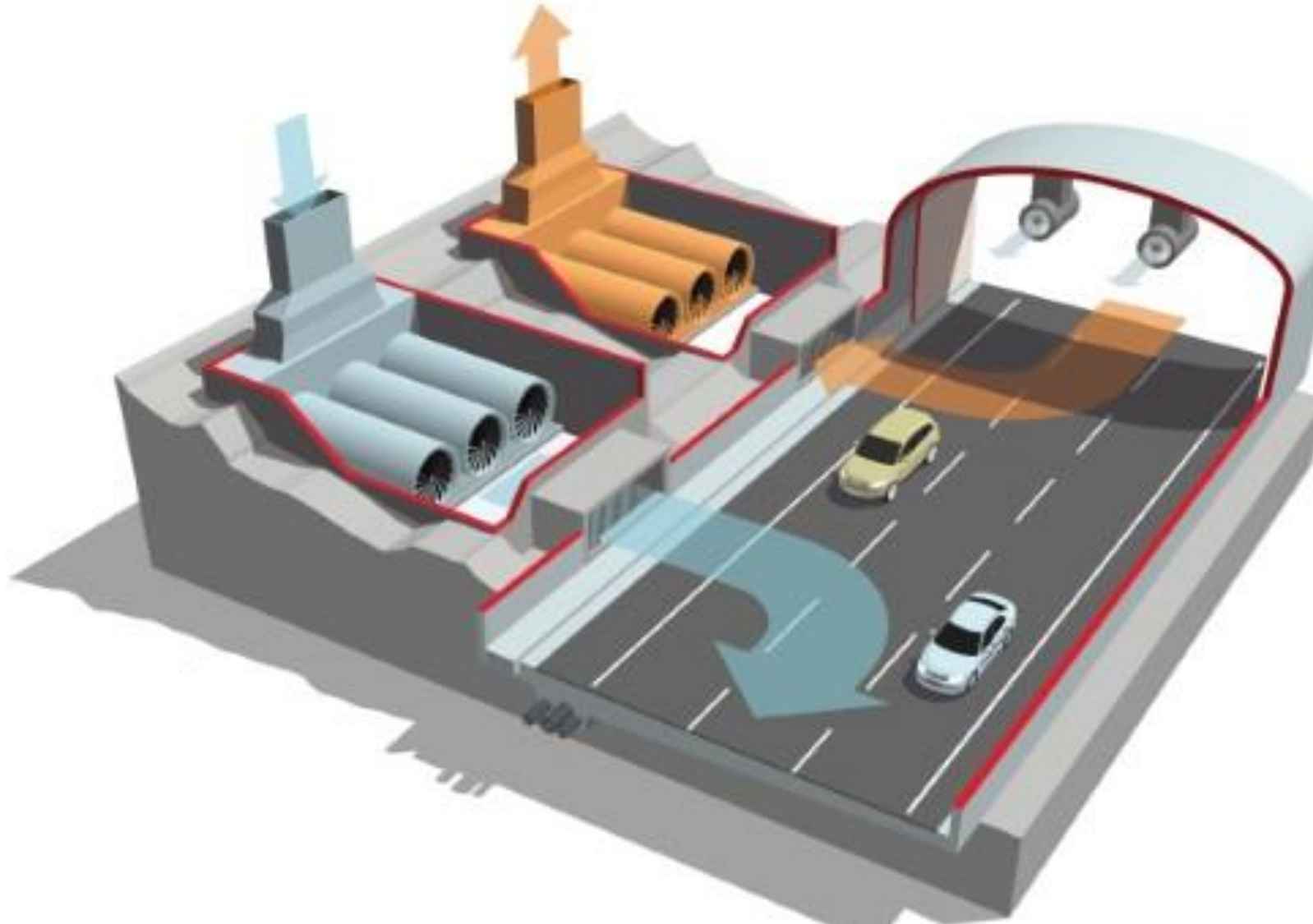
- In-tunnel air quality



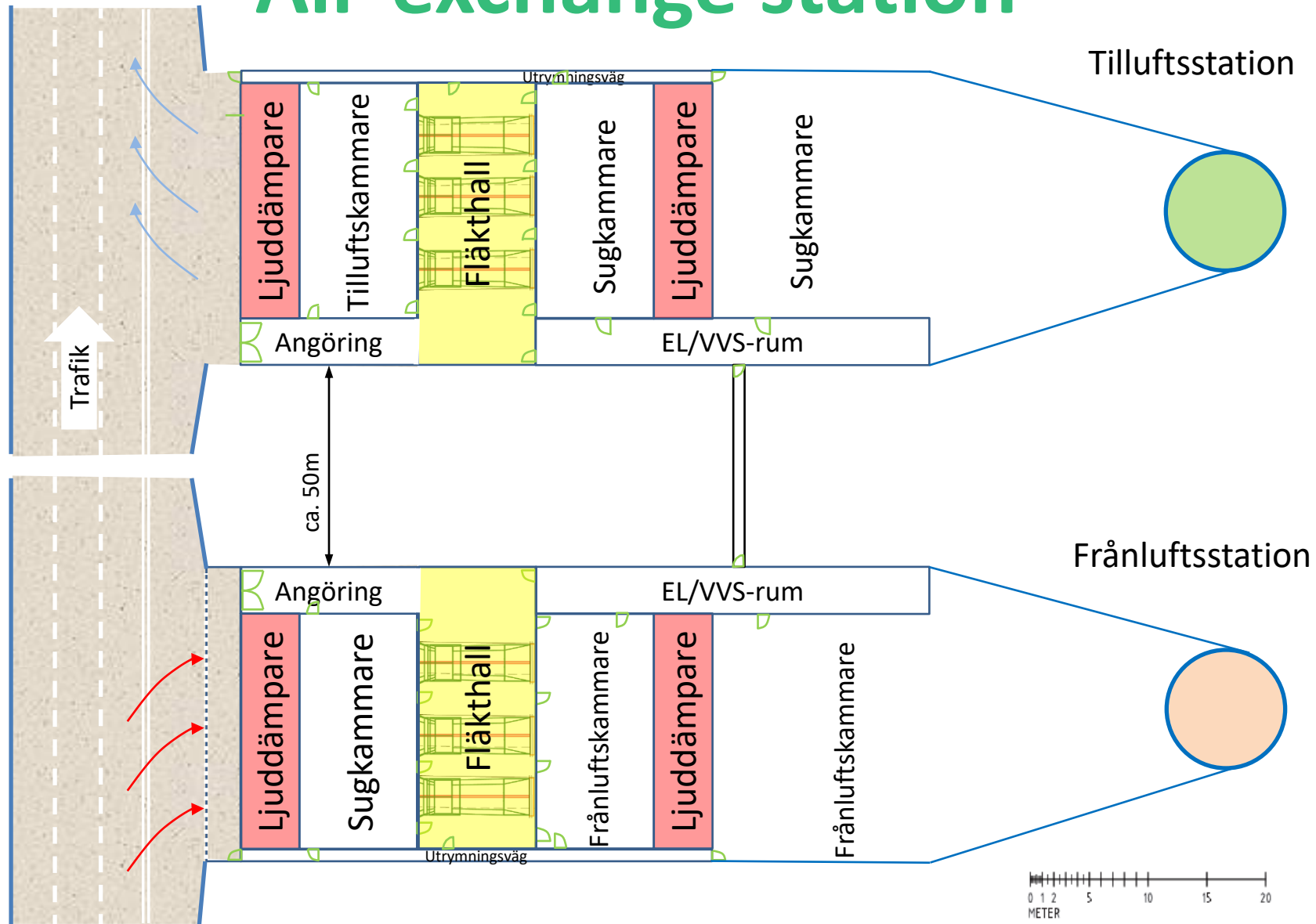
Longitudinal ventilation with jet fans



Air-exchange station



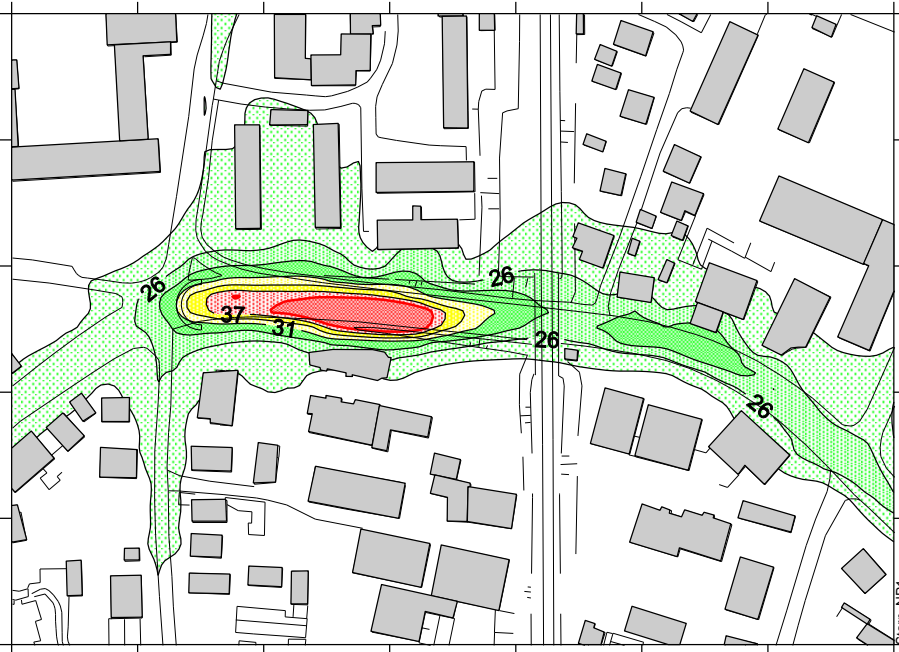
Air-exchange station



Portal-air extraction

PM10 concentrations:

Without

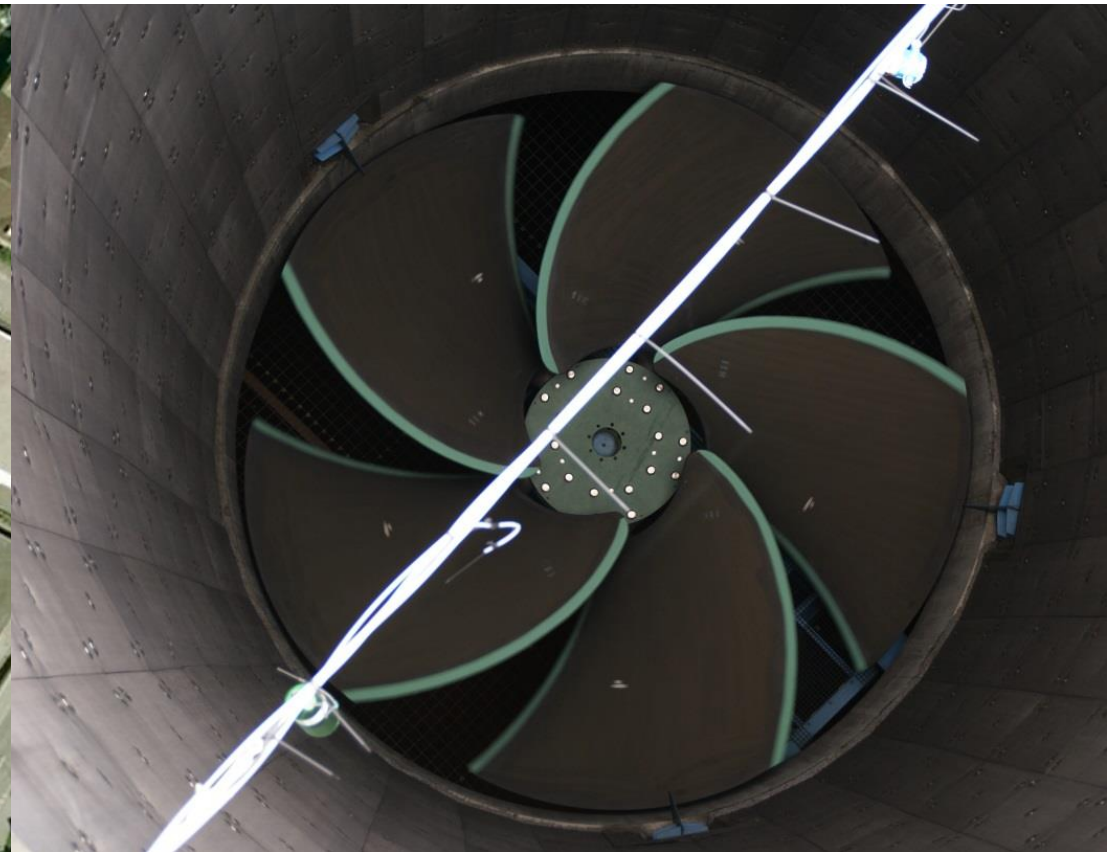
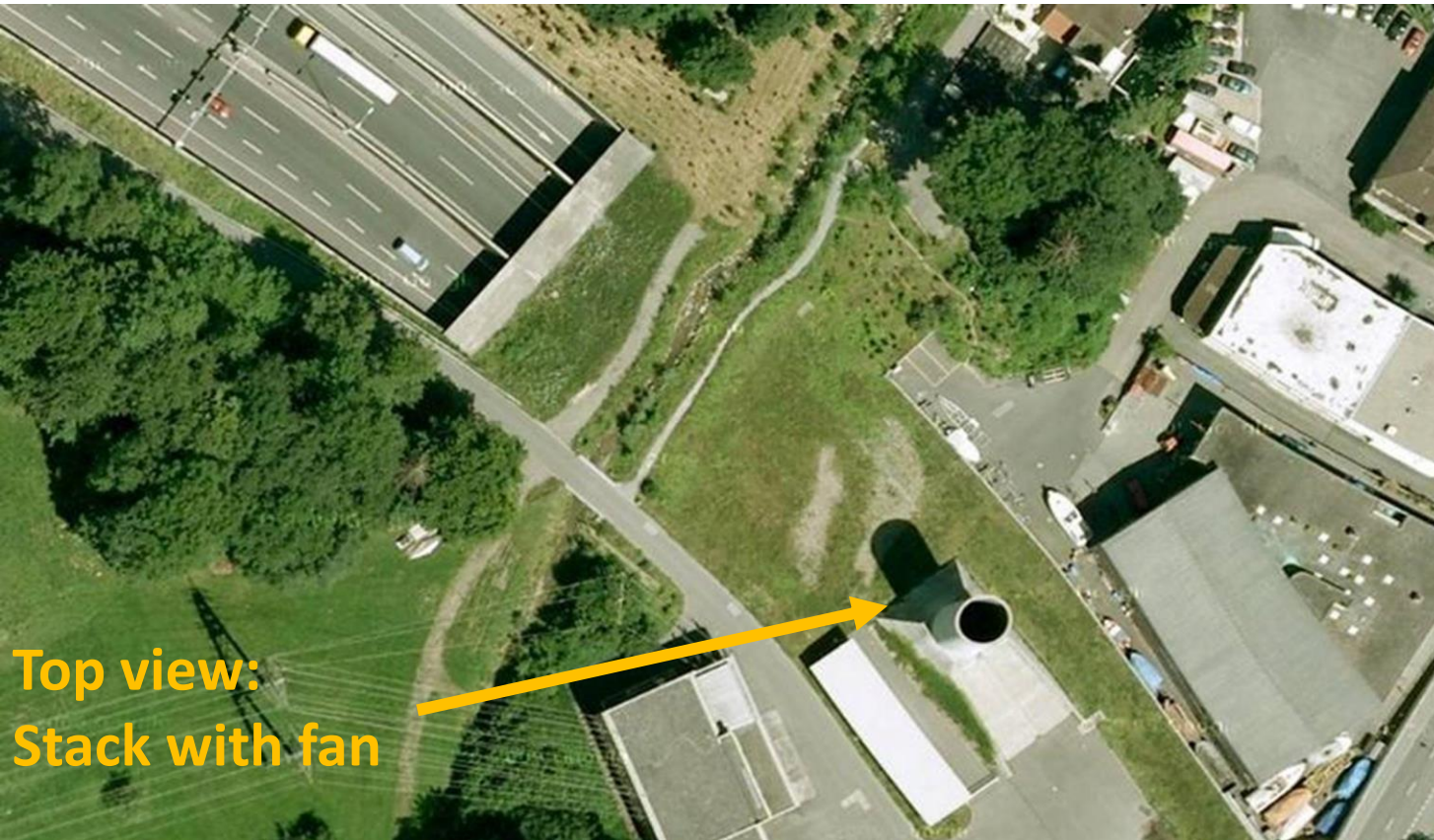


With

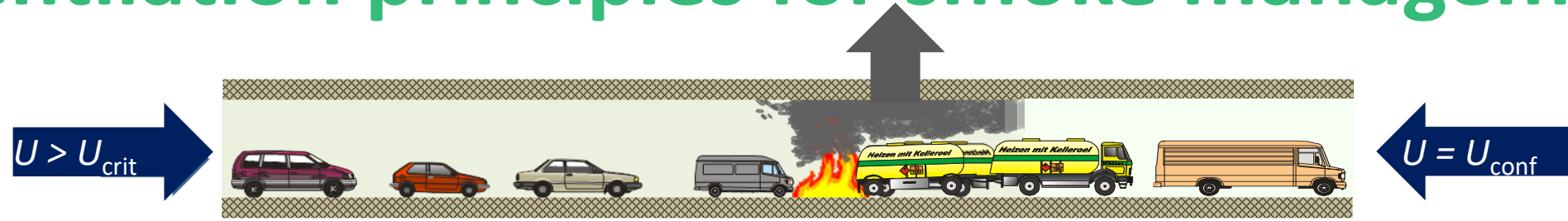


0 m 50 m 100 m

One portal-air extraction as one large GRP fan in stack



Ventilation principles for smoke management



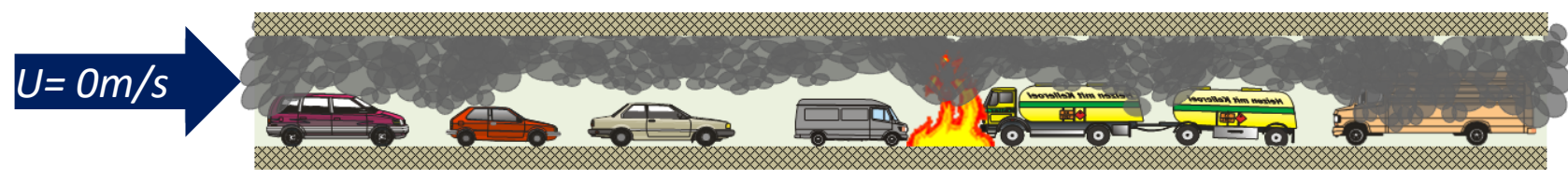
A: Smoke extraction at the vicinity of the fire



B: Longitudinal ventilation, no smoke backlayering: smoke spread only in one direction, smoke dilution



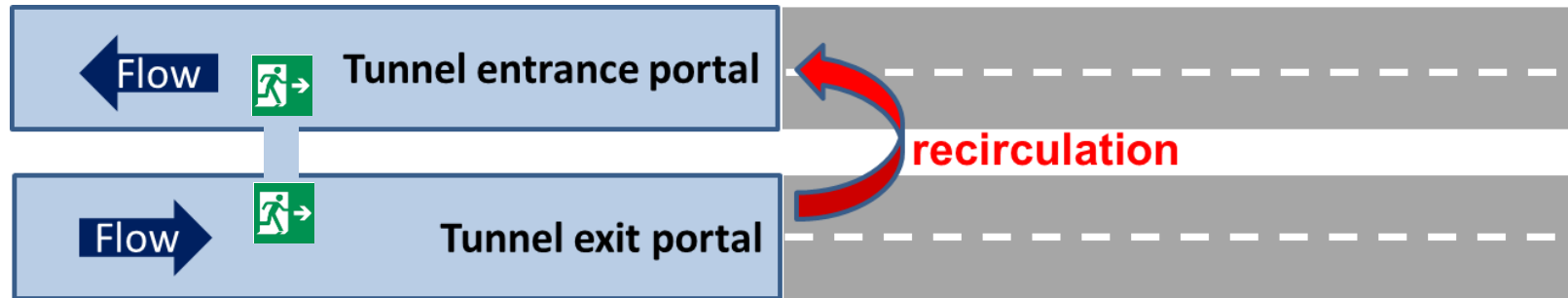
C: Longitudinal ventilation, some smoke backlayering: favourable conditions for smoke stratification



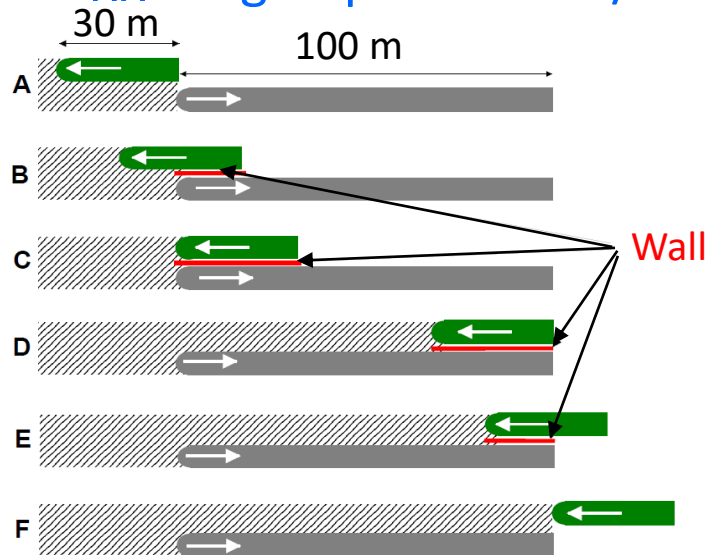
D: Longitudinal ventilation, minimise speed of smoke spread: resulting in high CO concentrations

Anti-recirculation measures at portals

Problem: smoke exiting at portal inhibits the egress route to adjacent tube



Solution: staggering of portals and/or separation wall



- a) Entrance is 30 m behind exit
- b) Between situation A and C
- c) A 30 m long wall separates the two portal zones
- d) Between situation C and F
- e) Between situation C and F
- f) Exit is 100 m prior to entrance

E4 Förbifart Stockholm



Safety features

- Emergency exits: 100 / 150 m
- Fixed fire-fighting system
- Longitudinal ventilation

Tunnel ventilation

- Jet fans: 250
- Axial fans: 47
- Low-pressure fan: 1
- Air-exchange stations: 6
- Smoke-extraction station
- Portal-air extractions: 4

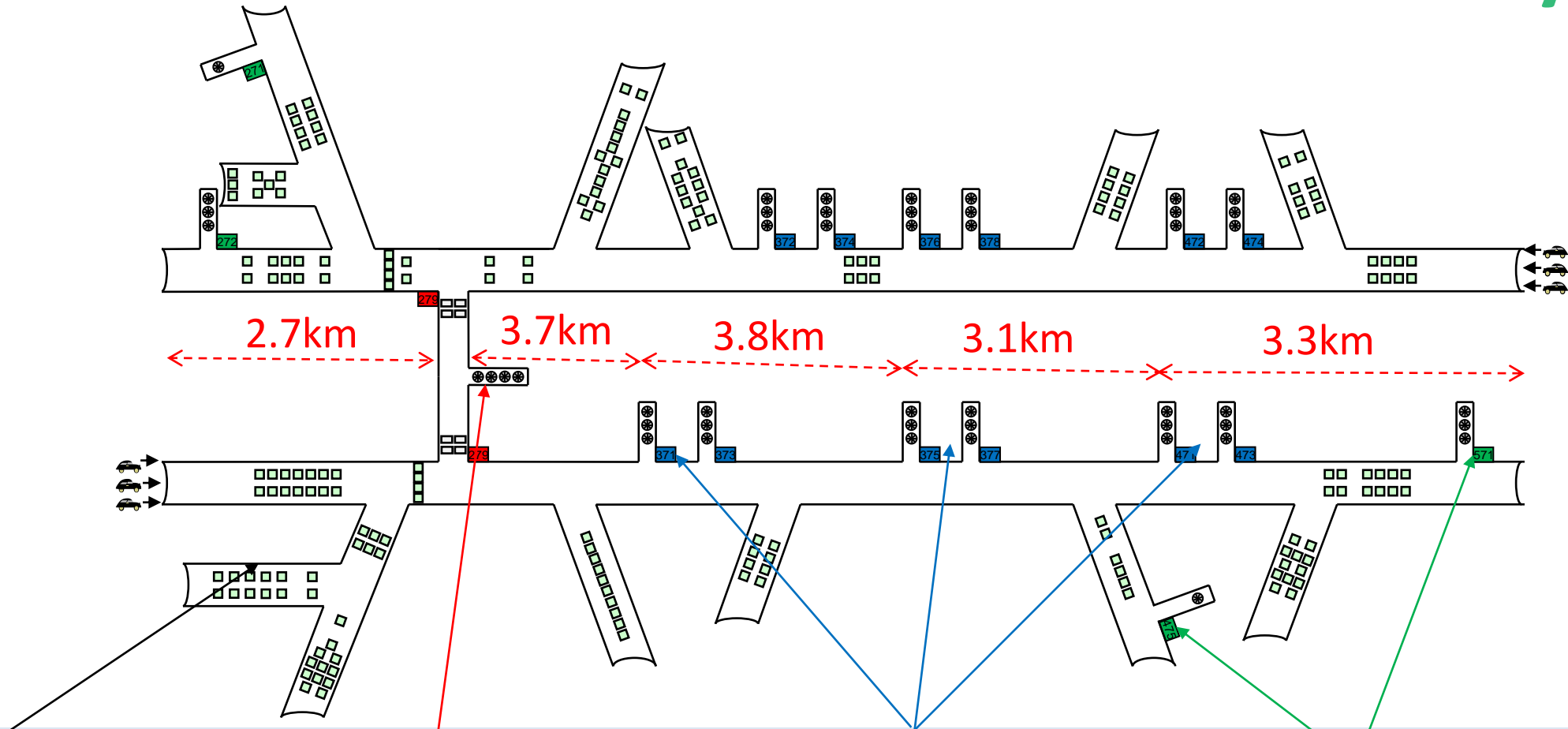
Sensors

- Air velocity sensors: 190
- Air quality sensors: 54
- Smoke detectors: 250
- Linear heat detector

Facts

- Length: 21 km
- Length of main tunnel: 17 km
- Total length of all tubes: 56 km
- Number of lanes in main tunnel: 3 lanes in each direction in two separate tunnel tubes
- Maximum speed: 80/100 km/h
- Estimated traffic: 140 000 vehicles/day (year 2035)
- Construction costs: 42 bn SEK (2021 prices)
- Opening: 2030

Schematic overview of tunnel-ventilation system

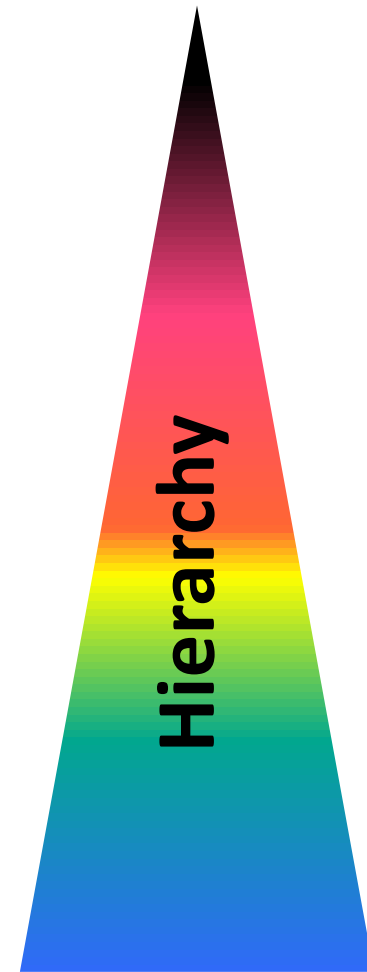


- Jet fans (250)
- Axial fans (47+1)
- Air velocity sensors (190)
- Smoke-extraction station**
(serves both tubes)
- Air-exchange stations (6)
- Portal-air extractions (4)
(none on 4 exits)
- Air quality sensors (54)
- Smoke detectors (250)
- Linear heat detection

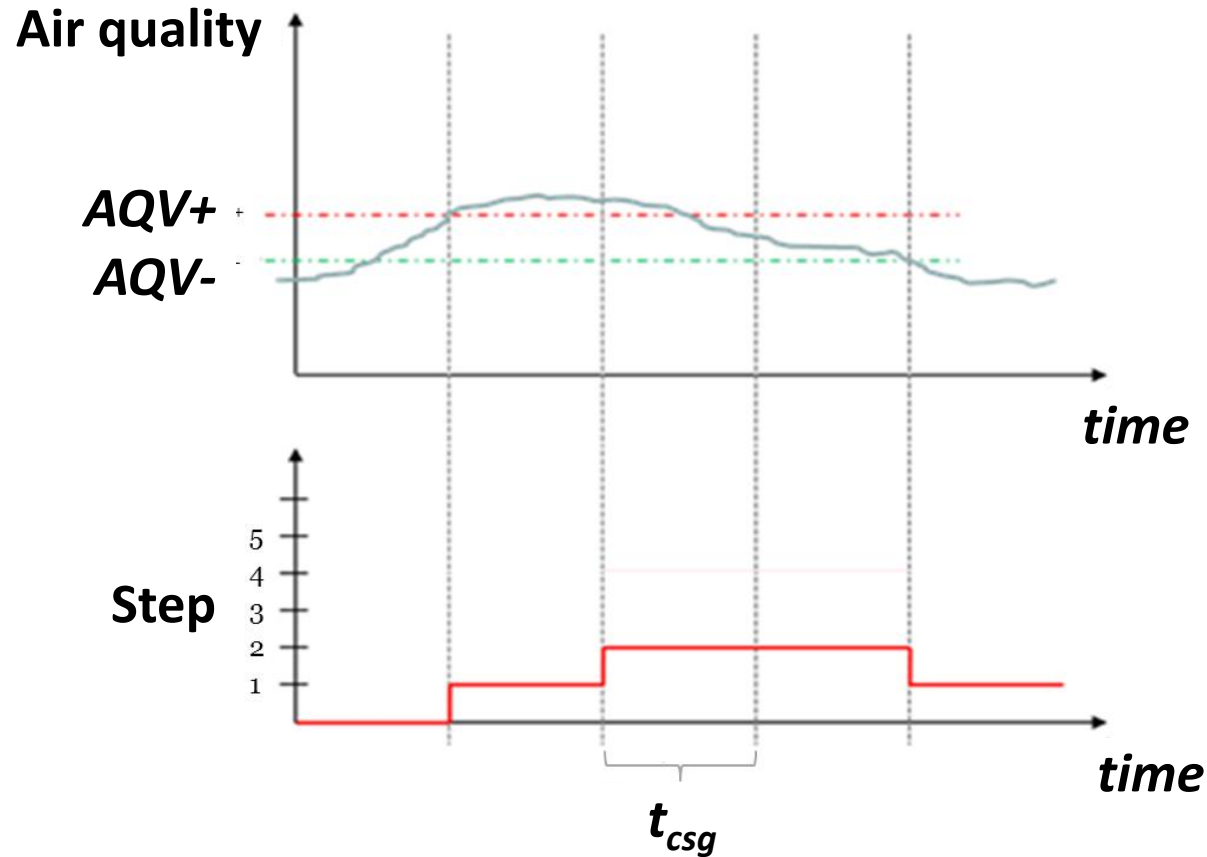
Ventilation modes

- **Stopped ventilation**
- **Fire ventilation**
 2. Fixed settings
 3. Variable settings (to enable modification by emergency services)
 4. Maximum (about 5 m/s towards fire)
 5. Minimal (about 1 m/s towards fire)
 6. Standard (about 3 m/s towards fire)

} same routines, different set points
- **Normal operation (internal and external air quality)**
 7. Maximum (all fans at full capacity)
 8. Normal (According to air-quality measurements)
 9. Time schedule (fan, time and day schedule)
 10. Maintenance according to air quality measurements (as 8, different set points)



Step-wise controller for in-tunnel air quality: principle

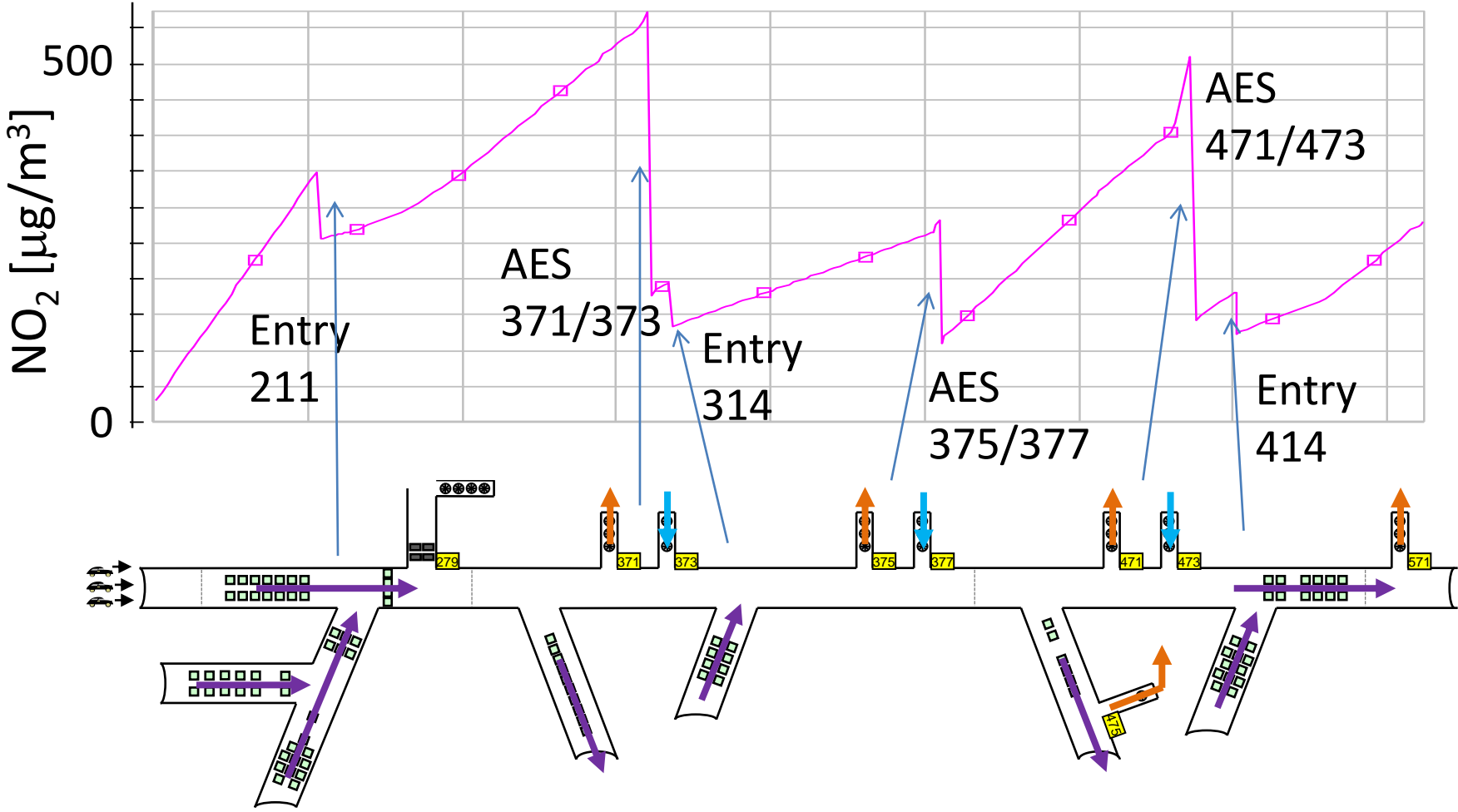


An air-quality target value (AQV) is specified, which is assessed for each sensor:

1) Air-quality level $> AQV+$:
=> Ventilation stepped up

2) Air-quality level $< AQV-$
and operation time $> t_{csg}$:
=> Ventilation stepped down

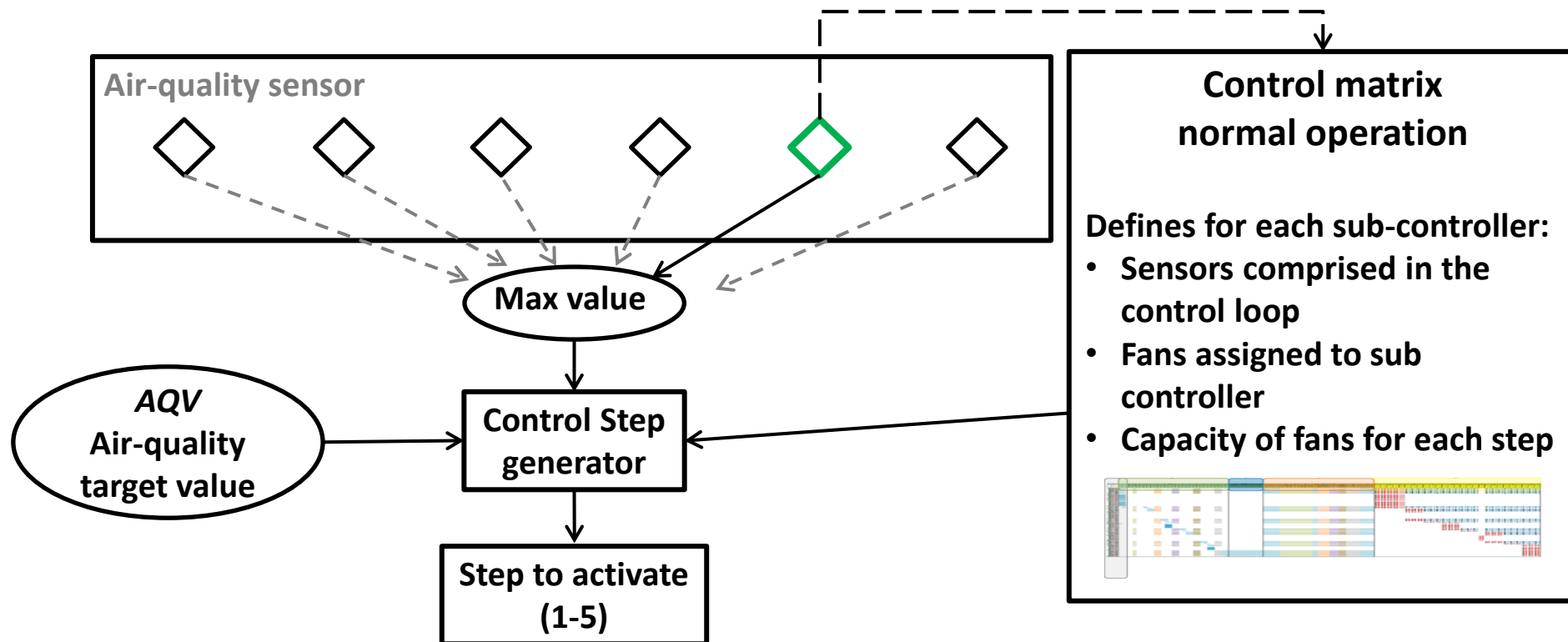
Normal ventilation at maximum capacity northbound tunnels



Step-wise controller for in-tunnel air quality: principle

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- 1) Air-quality level $> AQV+$: Ventilation stepped up
- 2) Air-quality level $< AQV-$ and operation time $> t_{csg}$: Ventilation stepped down

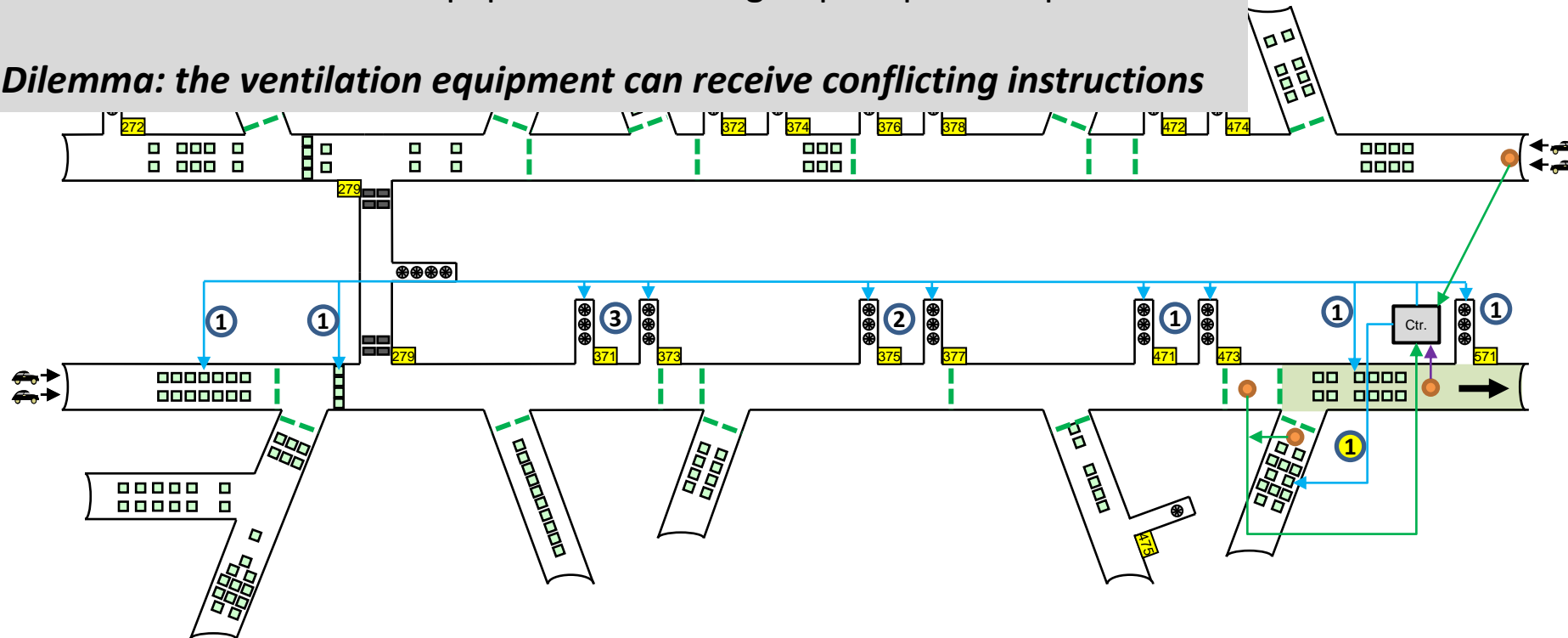


Step-wise controller for in-tunnel air quality: application

NOS (normal operation sections):

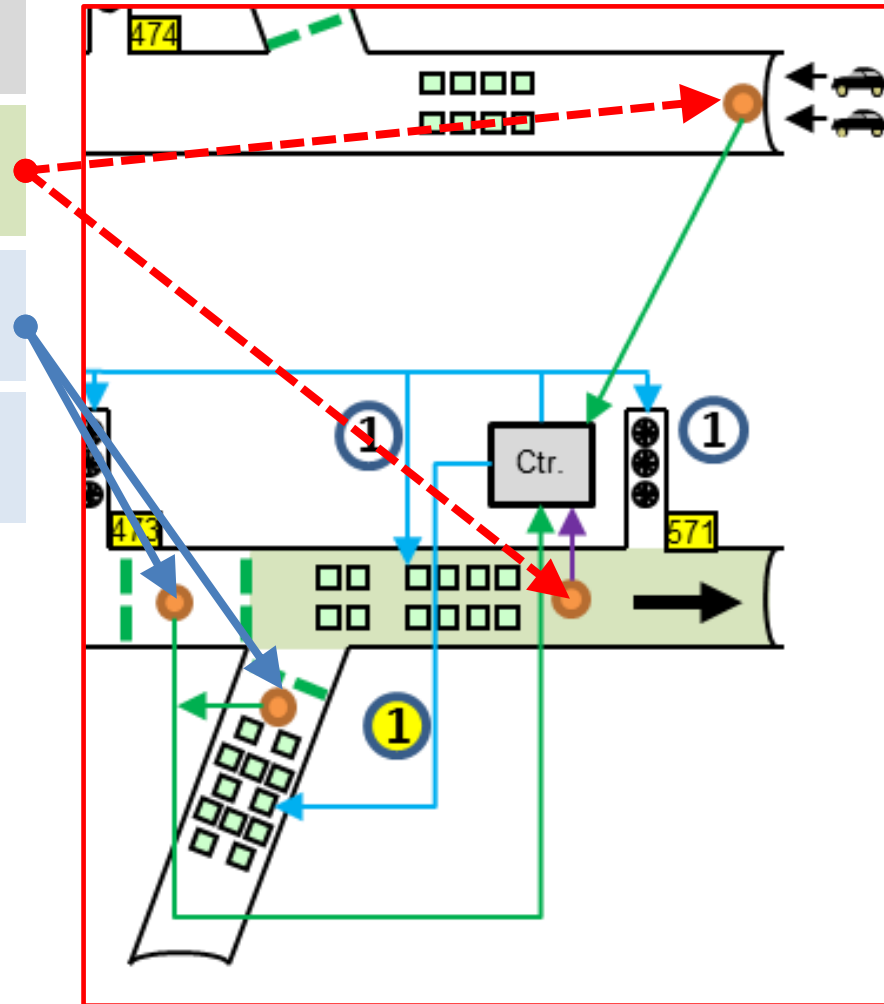
- at least one air-quality sensor
- Ventilation equipment also in other sections (NOS) at disposition
- Selection of ventilation equipment according to pre-specified priorities

Dilemma: the ventilation equipment can receive conflicting instructions

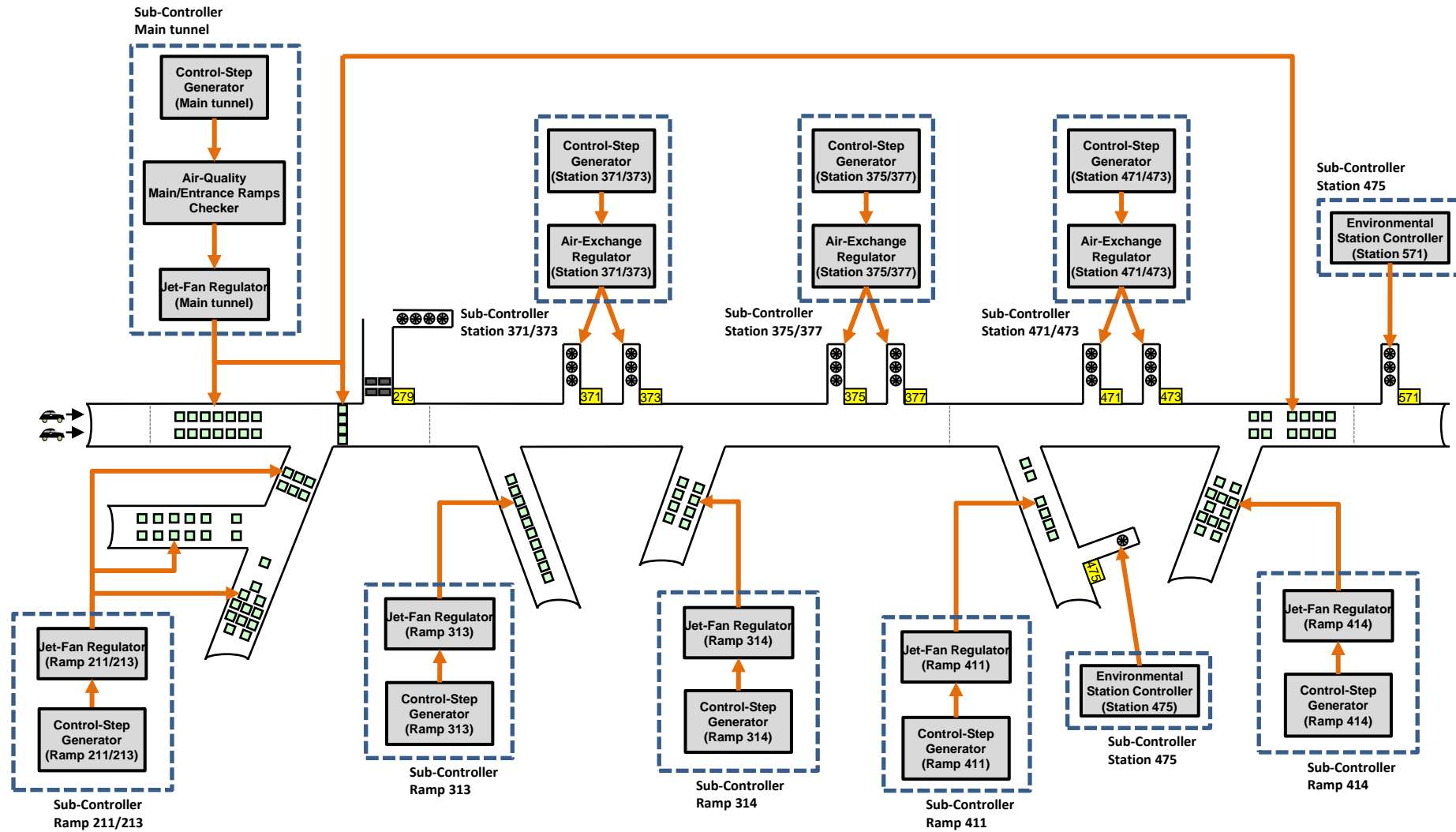


Step-wise controller for in-tunnel air quality: example

- *Several air-quality sensors devoted to one Normal Operation Section (NOS)*
- Only portal-air extraction if inside air quality is worse than ambient air quality*
- Increase air-exchange in main tunnel or flow in ramp according to analytic rules*
- ① *Ventilation equipment in several sections selected according priorities*



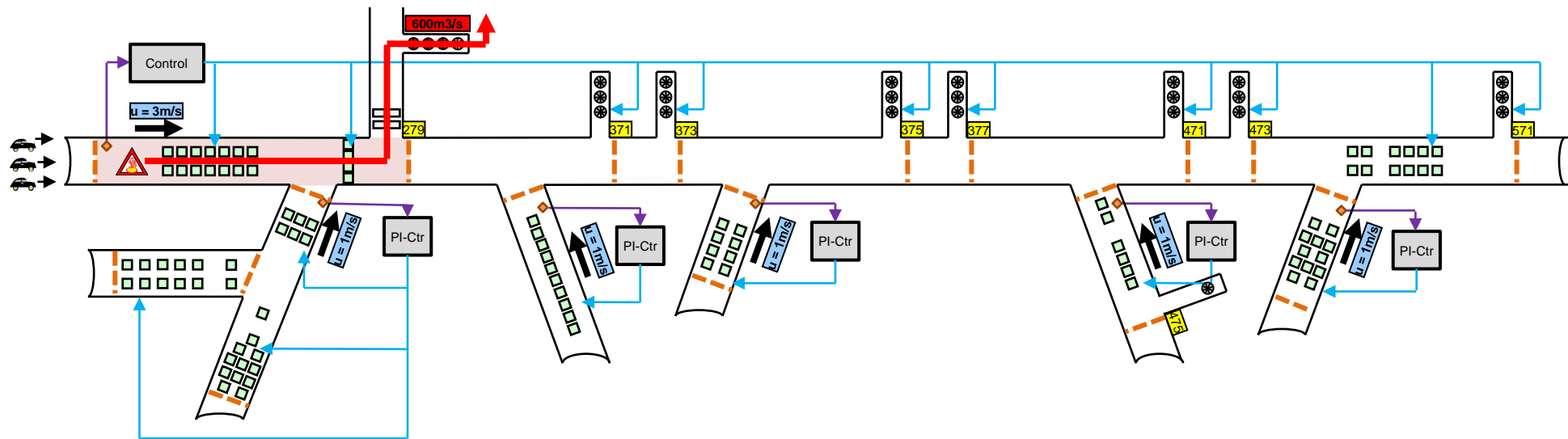
11 controllers for normal ventilation of northbound tunnels



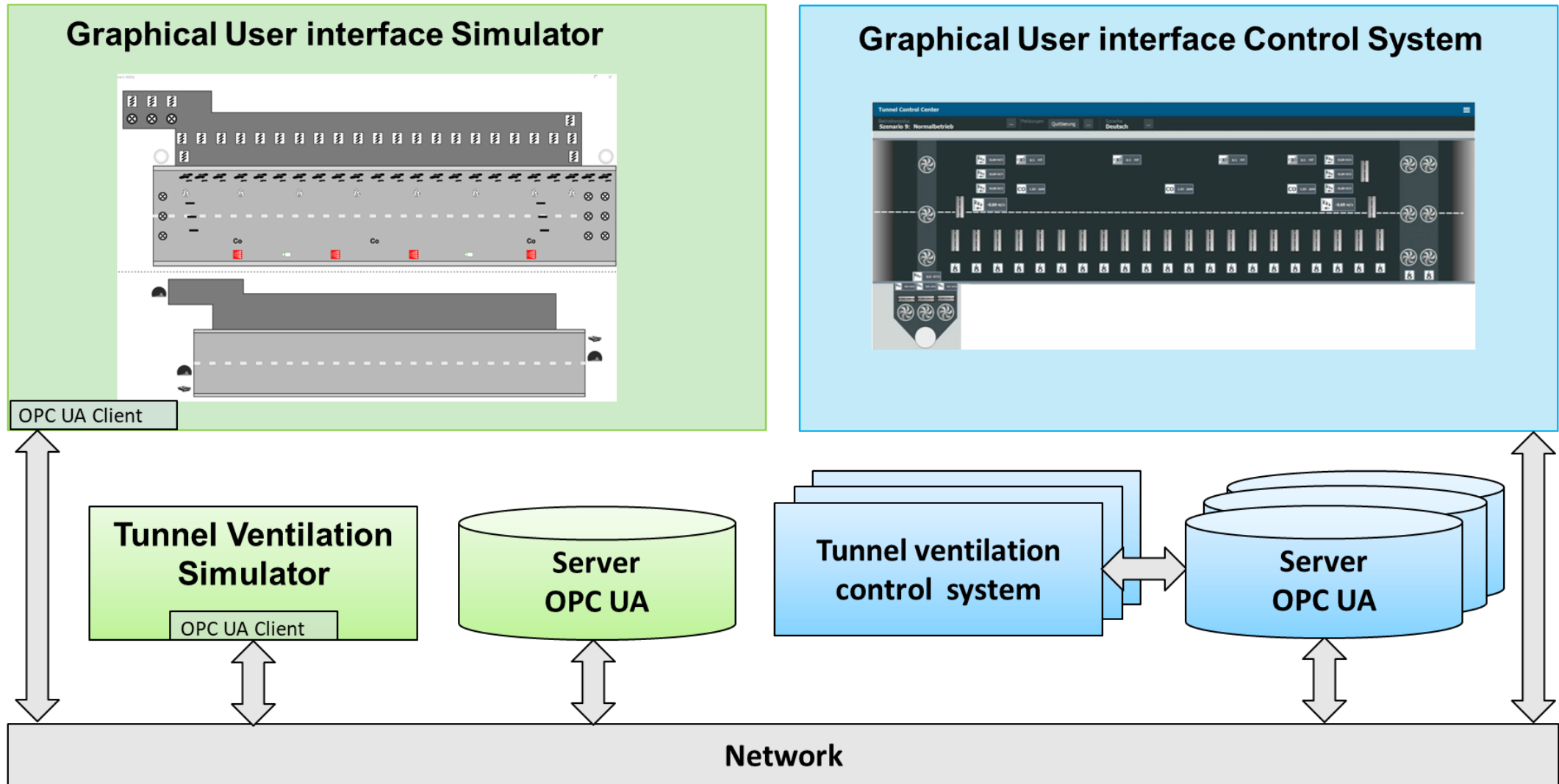
Smoke management with active ventilation control

- Longitudinal ventilation at specified velocity
 - 3m/s if FFFS functions
 - 1 m/s if FFFS doesn't function and there is traffic congestion (<10 km/h)
- Smoke extraction at ventilation stations except by low-pressure fan (GRP)

- 1 m/s at tunnel sections to protect
- => always active flow control
- Plausibility checks of air-velocity sensors (anemometers)
- Ventilation sections not the same as for normal operation
- Over-pressurisation of non-incident tube



Tunnel-ventilation simulator – digital twin



Tunnelventilation – E4 Förbifart Stockholm

Thank you for your attention

» E4 The Stockholm bypass

www.trafikverket.se/the-stockholmbypass

Further literature on:
<https://www.hbi.ch/en/publications>