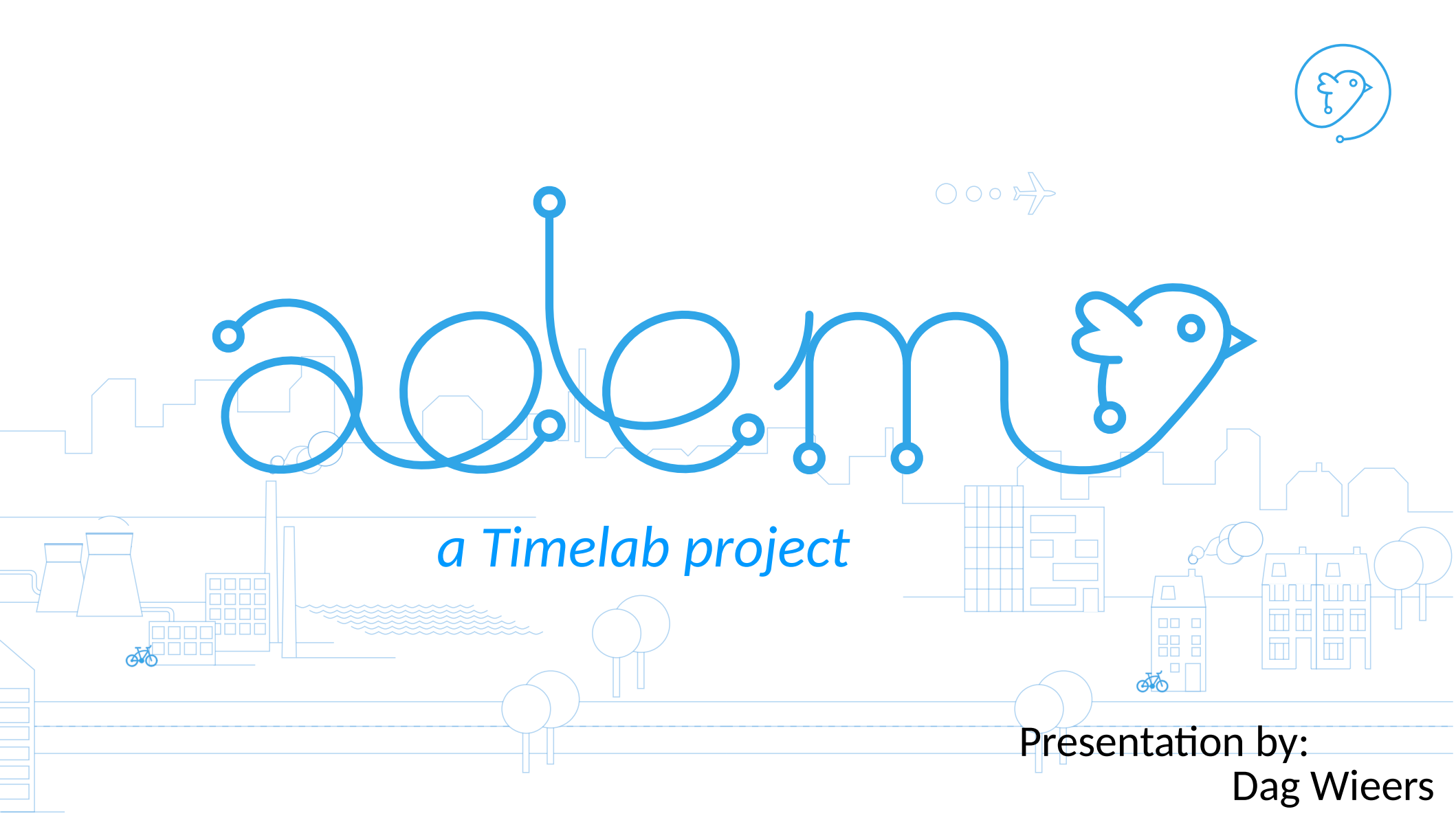
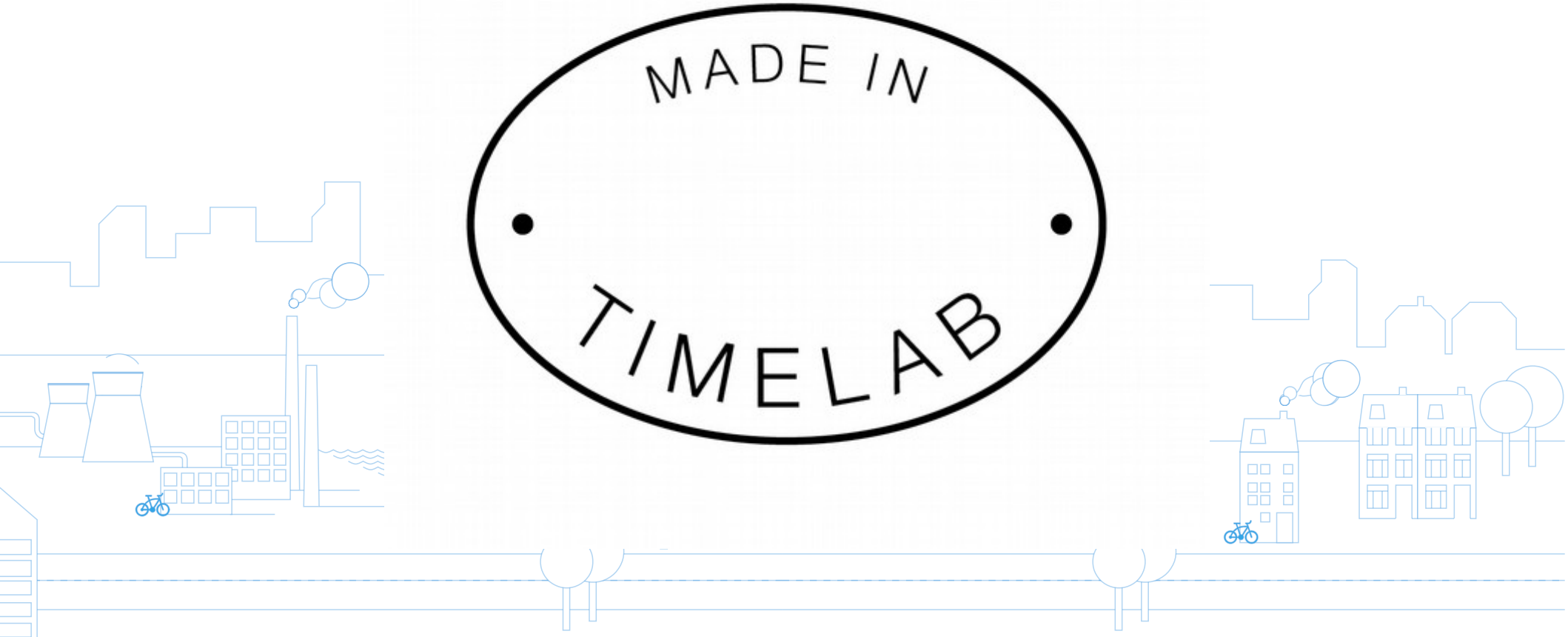


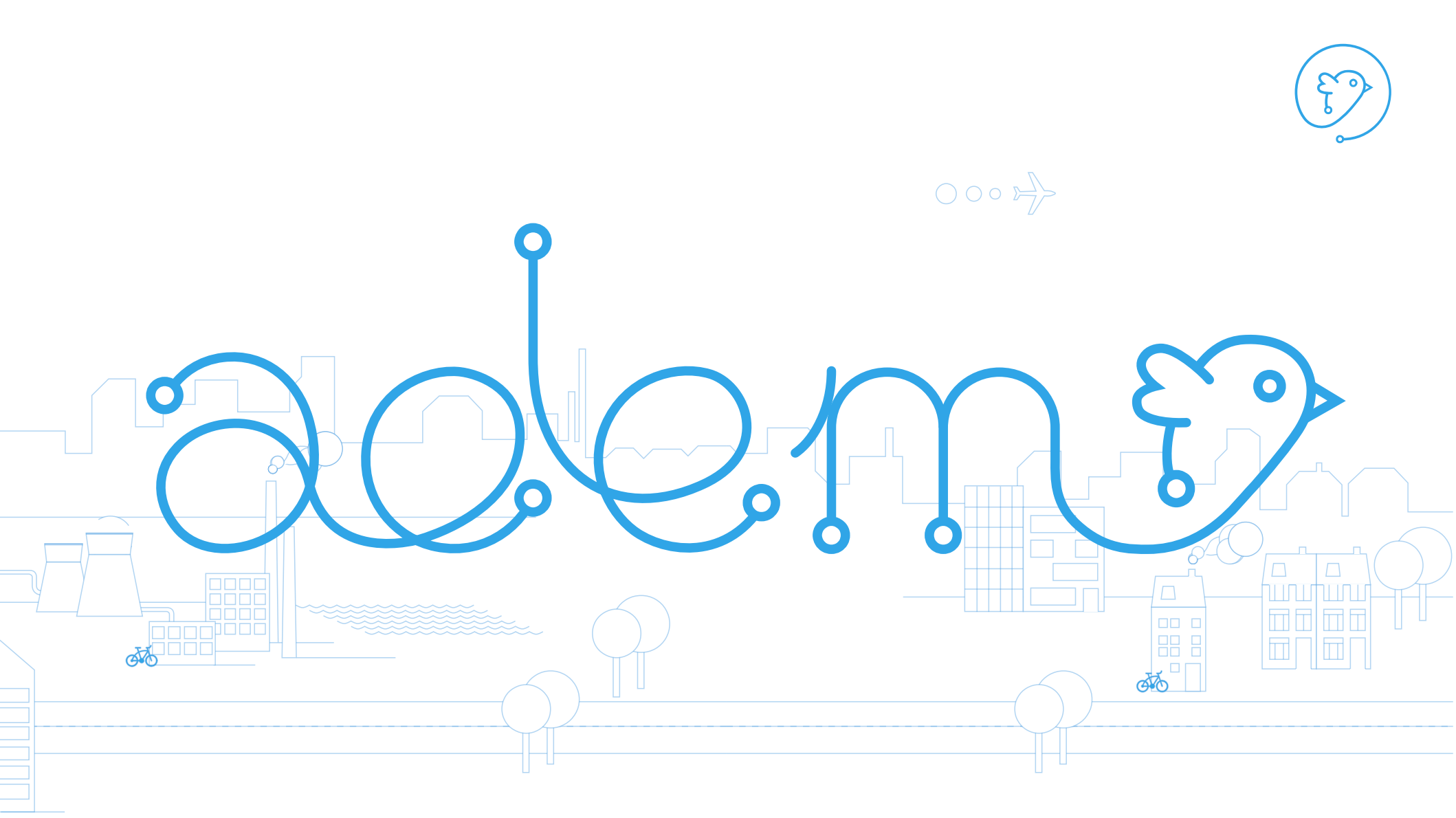
Presentation by:
Dag Wieers


MADE IN
TIMELAB


Before you leave,
please clean up!

What is Timelab ?

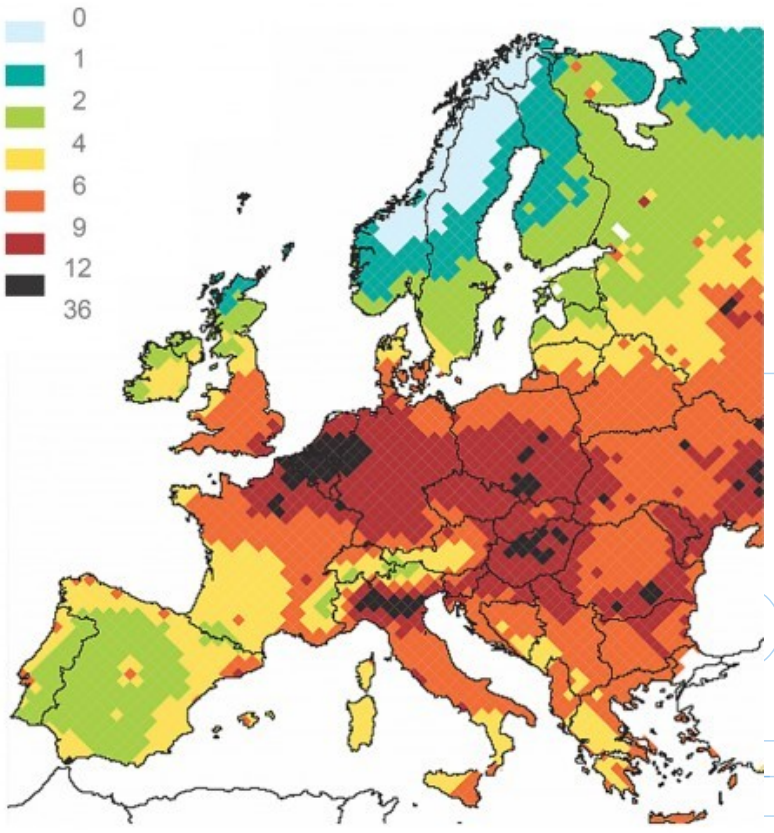
- A non-profit organization founded in 2010
- Located in the beautiful city of Ghent, Flanders
- A facilitator for “makers” to collaborate and share knowledge
- Offers:
  - CityLab; *incl. 3D printers, laser cutters, CNC wood router…*
  - Creation-projects; *incl. this ADEM project*
  - Workshops, boot-camps and (art) residencies
  - Co-working café and Friday lunches
- Supported by the city of Ghent *and* the Flemish government


adem

What is the ADEM project ?

- **Collect and share real-time air quality information**
- Technology
  - Create a device to collect particulate matter (fine dust) data
  - Create a web service to collect data and publish information
- Community
  - Community-driven project development
  - Public awareness of air pollution and risks (survey, campaign)
  - Open hardware, open software, open data
  - Fostering community around the project

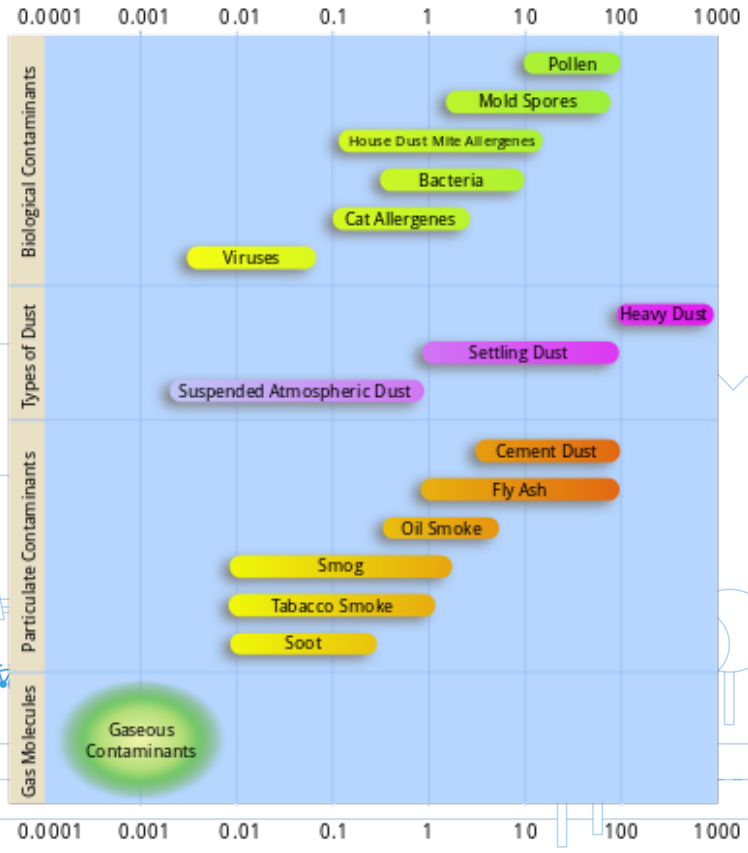
Loss of life expectancy



- Average loss of life expectancy in months
  - due to PM_{10} air pollution
  - $PM_{2.5}$ is more dangerous
- Belgium right in the center
  - detailed maps indicate East/West Flanders and Antwerp to be even worse
- Based on data from 2000

https://ec.europa.eu/research/quality-of-life/ka4/pdf/report_airnet_en.pdf

Type of pollutants



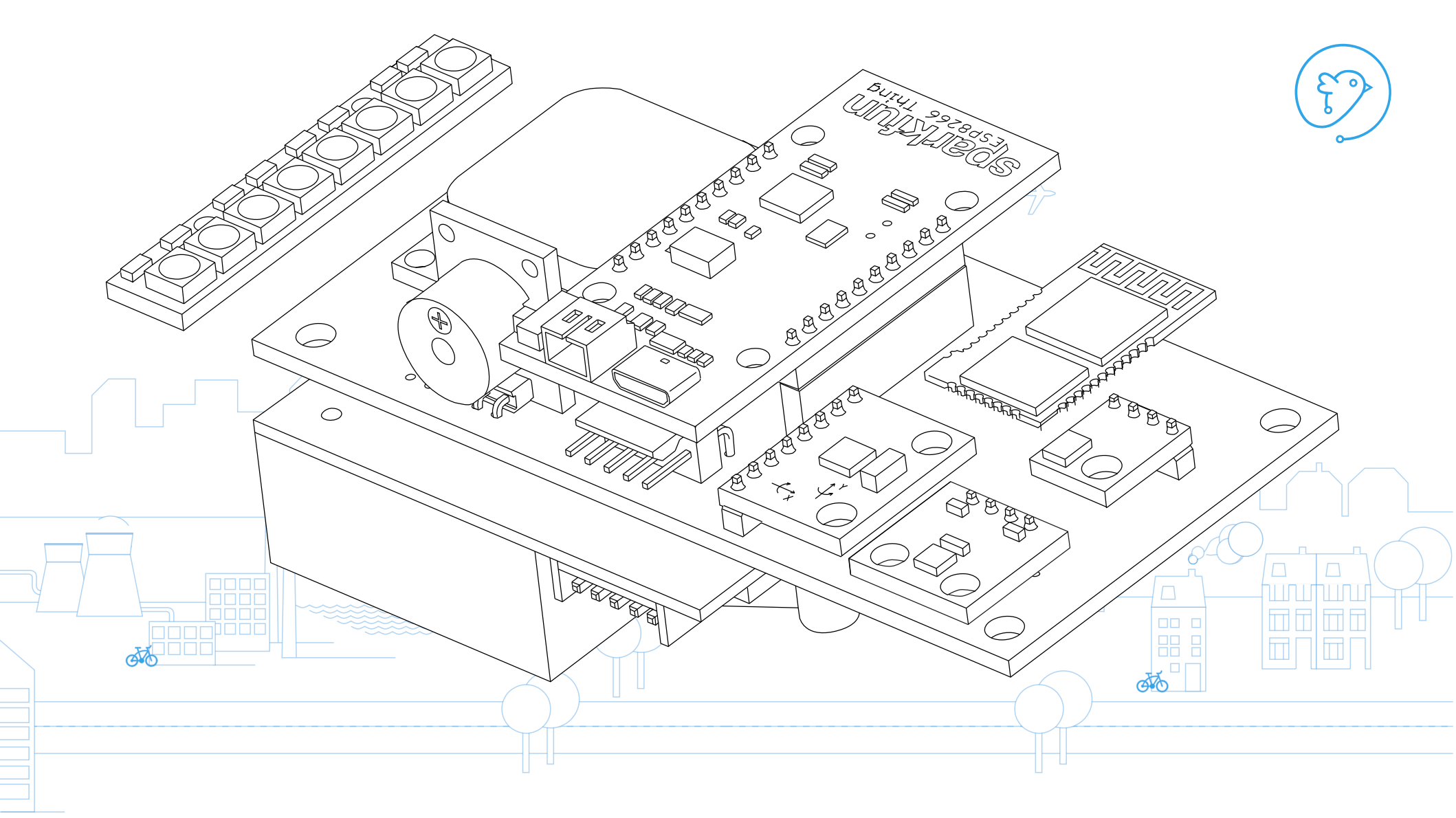
- Everything larger than PM_{10} gets trapped by the body early *(hurray for nasal hairs!)*
- **PM_{10} – Inhalable particles**
  - between 10µm and 2.5µm
  - settles in bronchi and lungs
  - airborne for hours
- **$PM_{2.5}$ – Respirable particles**
  - 2.5µm and smaller
  - settles in alveoli *(gas exchange)*
- **Ultrafine particles**
  - 0.1µm and smaller
  - can find its way to your blood stream
  - airborne for weeks *(hurray for rain!)*

https://en.wikipedia.org/wiki/Particulates


P
Zone
3

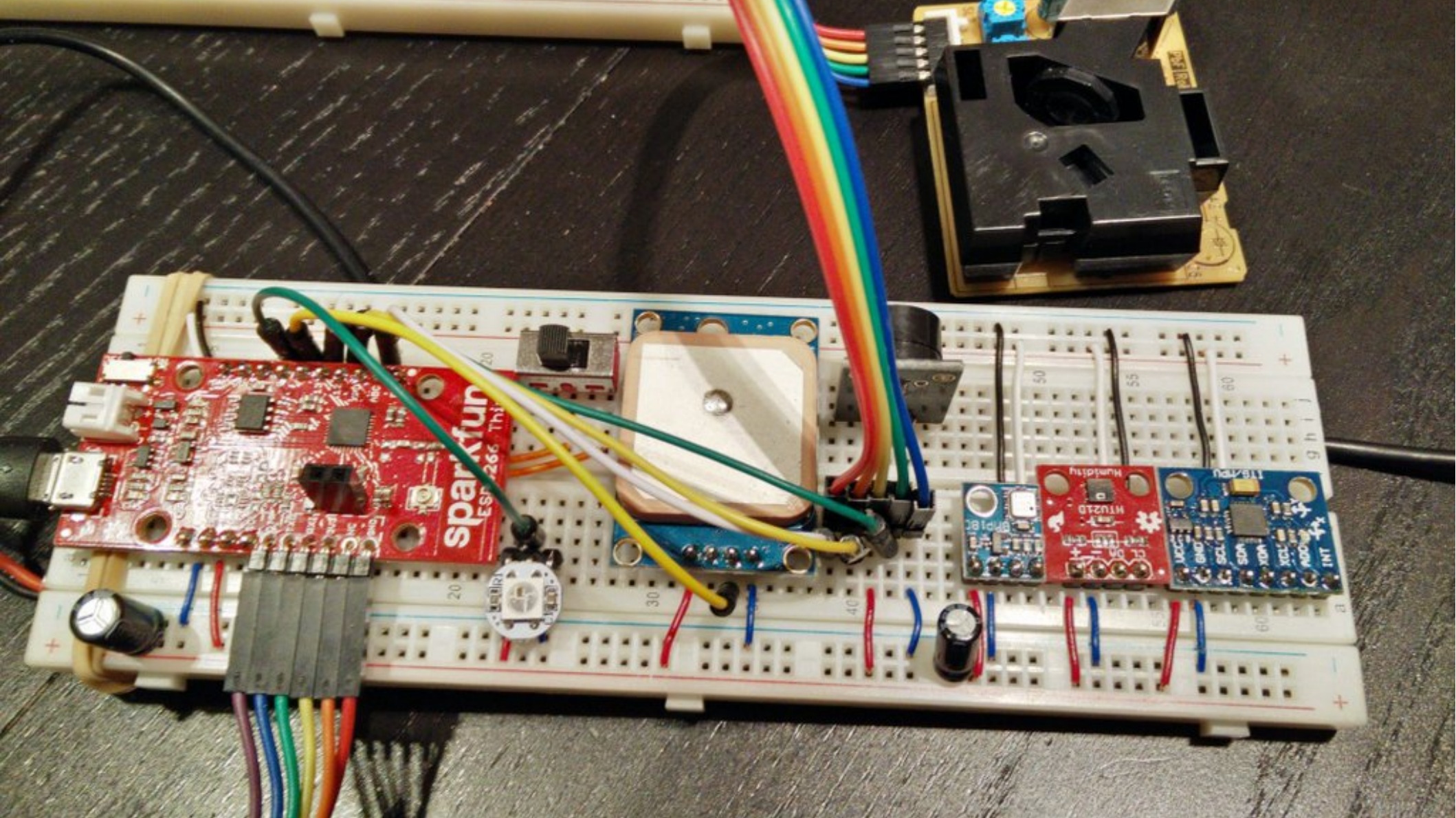
Air quality in Ghent

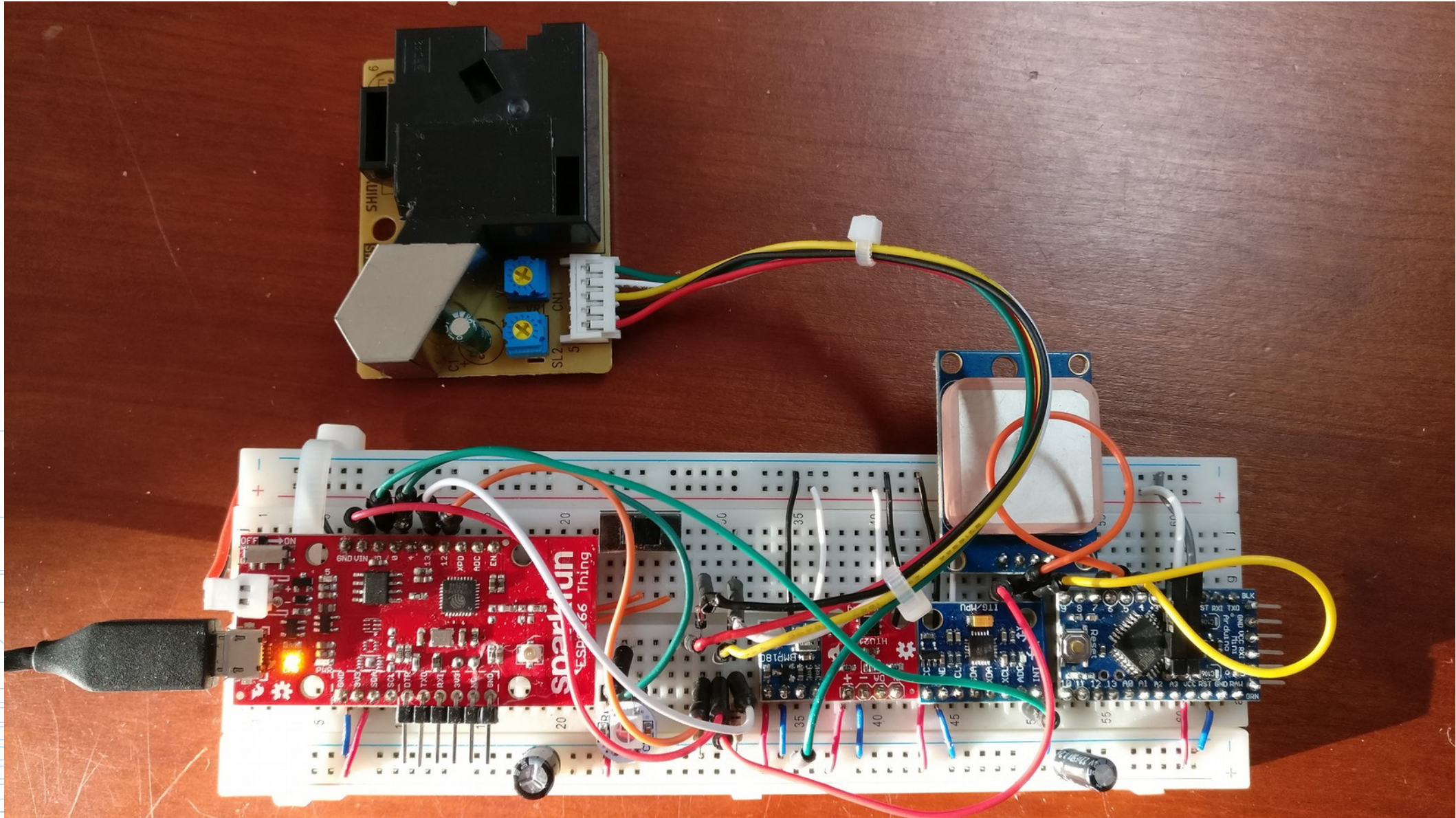
- Ghent is second largest city in Flanders
  - University city with population of 260.000 *and* 65.000 students
  - Lots of people use bicycles throughout the day
  - Port of Ghent and industry known source of air pollution
  - 2 highways close to city center (one stretching into center)
- Only 2 official air pollution stations with fine dust meters
  - Strategically placed to meet European levels
  - Yearly averages are useless, micro-measurement is key !
  - Air quality is not just PM, but PM is the least known variable today
- City council (incl. green party) is taking environment seriously !


SparkFun
ESP8266 Thing

Design goals

- Goal ?
  - Create an open device that can be locally built and repaired
- How ?
  - Affordable general purpose hardware components
  - Open hardware, open software and open data
  - Modular design that is easy to customize (sensors, drivers)
  - Reuse of existing Open Source libraries

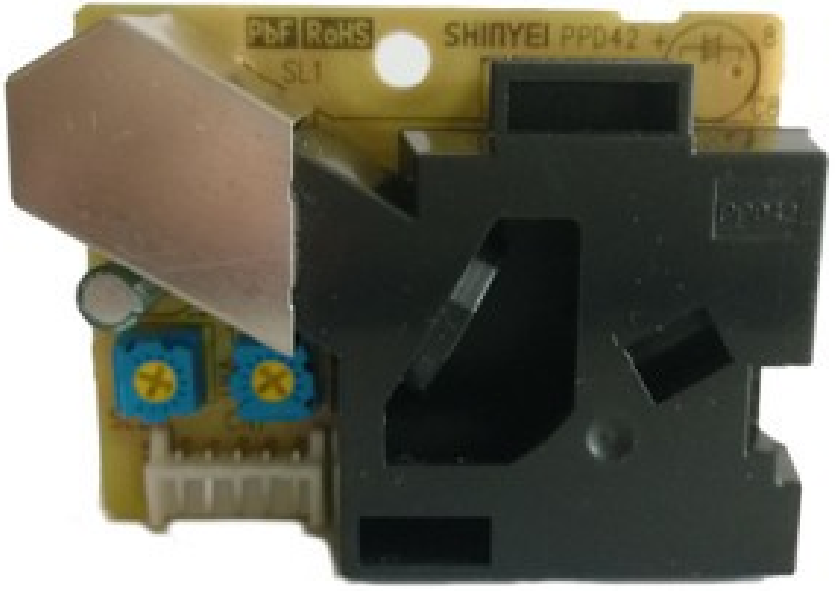


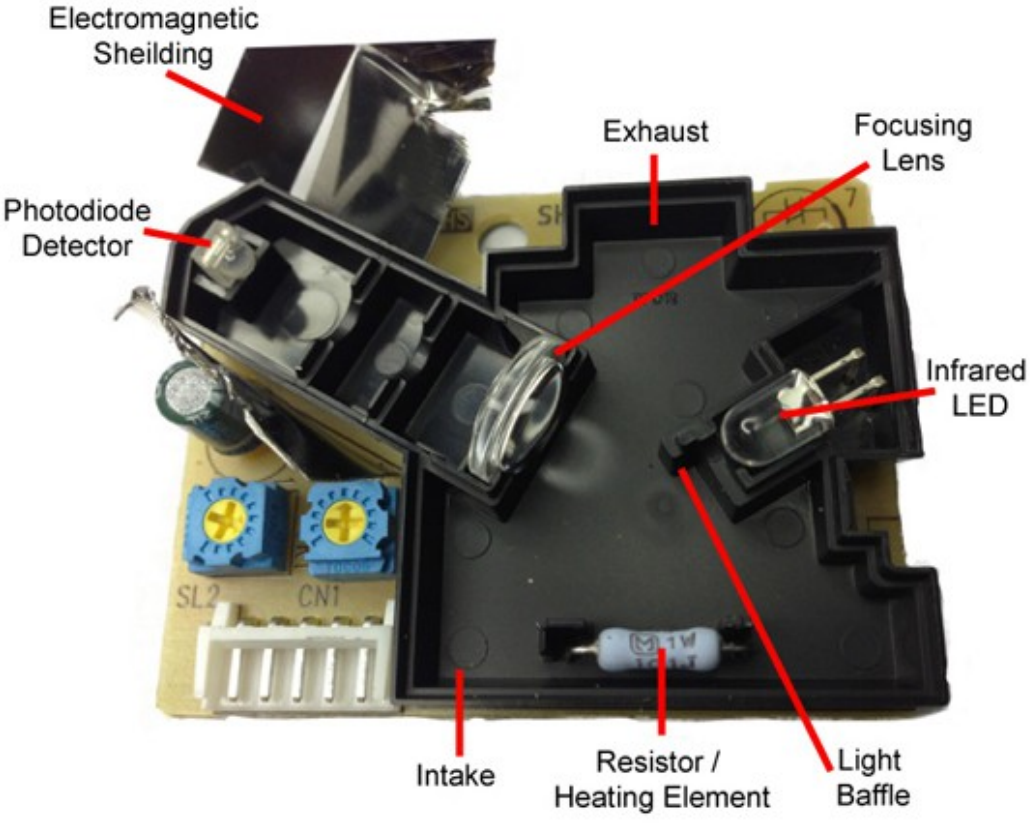

SL2
CN1
OFF
ON
GND VIN
XPD
ADC
EN
Thing
Reset

Hardware design

- Micro-controller / WIFI – *Sparkfun ESP8266 Thing*
- I²C Sensors
  - Fine dust meter – *PPD42NS*
  - Accelerometer – *MPU6050*
  - Humidity sensor – *HTU21D*
  - Air pressure sensor – *BMP180*
  - GPS – *GY-NEO6MV2**
    - UART to I²C conversion – *Arduino Pro Mini (ATMEGA328P)*
- RGB Led / Buzzer / LiPo Battery

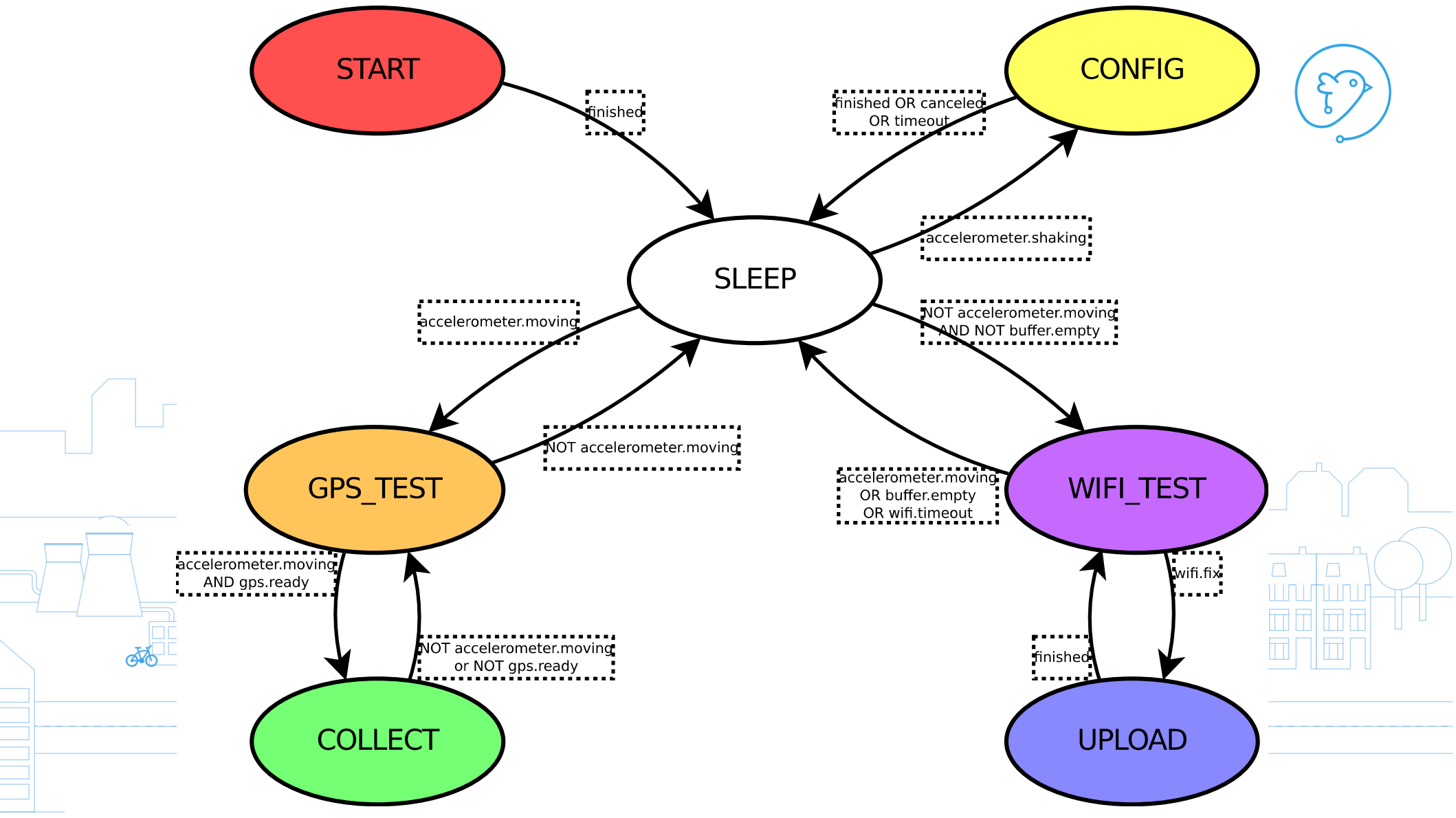
Shinyei PPD42NS





Firmware design

- Arduino-based framework (CI testing with platformio)
- Components can be swapped/added by alternatives
  - Possibly using I²C id bus scanning / driver selection
  - Accepting contributions through GitHub
- Small test-examples for individual drivers/libraries
- Code-readability is key !
  - Abstraction through device drivers and wrappers
  - Simple state-machine with state-transitions


START
CONFIG
SLEEP
GPS_TEST
WIFI_TEST
COLLECT
UPLOAD
finished
finished OR canceled
OR timeout
accelerometer.shaking
accelerometer.moving
NOT accelerometer.moving
AND NOT buffer.empty
NOT accelerometer.moving
accelerometer.moving
OR buffer.empty
OR wifi.timeout
accelerometer.moving
AND gps.ready
NOT accelerometer.moving
or NOT gps.ready
wifi.fix
finished

Current device status

- Hardware design
- Component evaluation and testing
- Initial PCB design + first casing design
- Prototype 1 (solder-less breadboard)
- Prototype 2 (solder-less breadboard); add Arduino Pro Mini
- Second PCB design + second casing design
- Prototype 3 (soldered breadboard); real-life testing
- …
- Profit !

Various issues in the process

- Too few I/O pins for all components
- Imperfect signal from PPD42NS
- Underpowered components
  - GPS and PPD42NS may need 5V
- Onboard I^2C of GPS was impossible to get working
- Various issues with ESP stability and timing sensitivity
  - Influences I^2C communication (protocol analyzer!)
  - WIFI troubles (mostly captive portal / disconnects)
  - Infrequent crashes

Possible future functionality

- Collection of bicycle road quality information (i.e. bumps)
- Include more air quality sensors (incl. NO_x, SO_2, CO, O_3, …)
- Support (outside and in-house) stationary devices
- Auto-calibration of devices when they pass each other
- Mobile app to guide runners/bikers to most healthy routes
- Correlate air quality to sources *and* weather conditions
- Billboards showing real-time air quality at “hot” spots

How can you help ?

If you are interested to…

- develop on embedded platforms (Arduino/C++)
- visualize real-time sensor data (environmental or data-scientists)
- help install the device and train users
- create awareness by helping with campaigns

You are welcome

- no prior knowledge required
- device team meets every wednesday-evening
- ADEM progress meetings every month
- just come by at Timelab and shape the future !

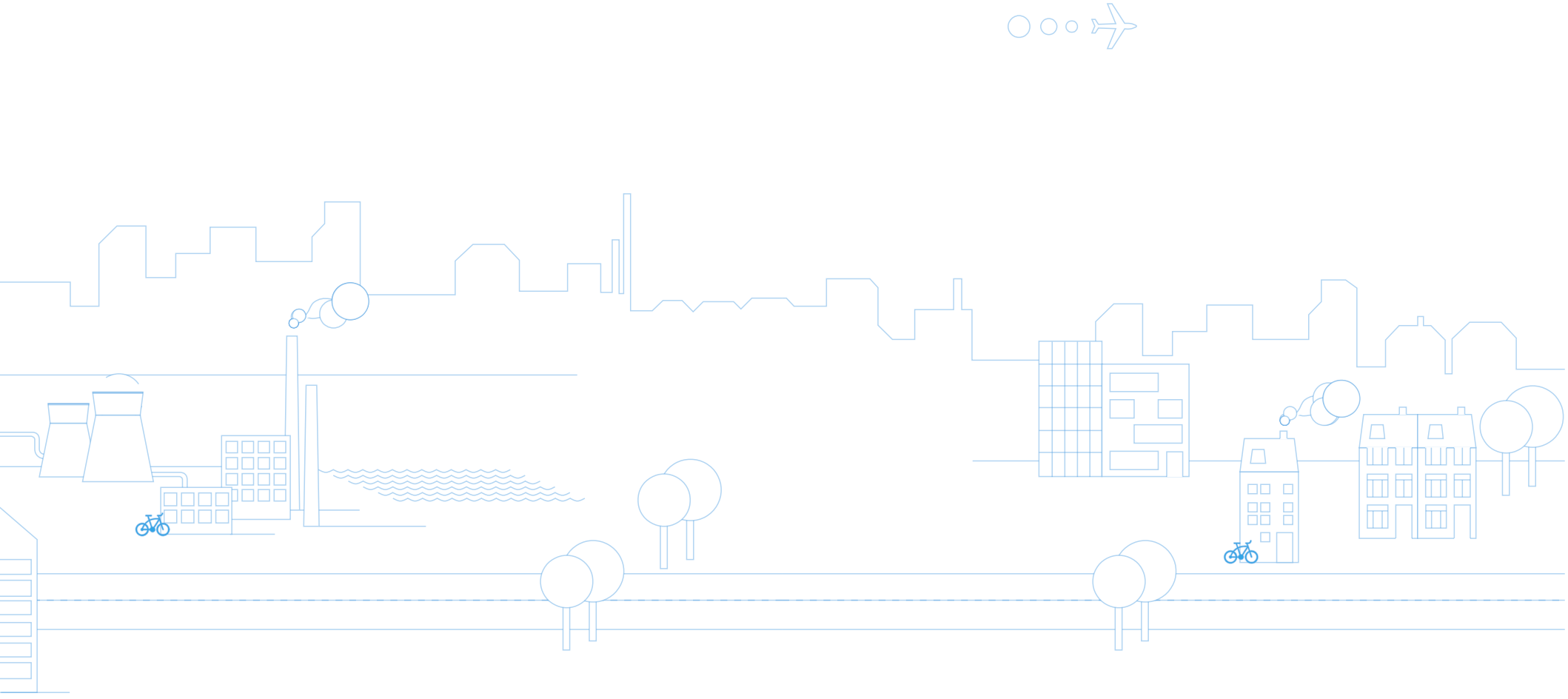
More information

- **ADEM project**
  - GitHub – http://github.com/timelab/ADEM/
  - Website – http://ik-adem.be/ (dutch)
  - Email – ja@ik-adem.be
  - Twitter - @ik_adem
- **Timelab vzw**
  - Website – http://timelab.org/ (mostly dutch)
  - Email – hello@timelab.org

Interesting links

- Real-time Air Quality Index maps
  - http://aqicn.org/map/europe/
- ETH Zurich OpenSense project
  - http://www.opensense.ethz.ch/trac/
- Ultrafijnstof en rochelroutes
  - http://www.rochelroutes.nl/
- MEP, it's time for cleaner air!
  - https://www.youtube.com/watch?v=JmdPbXW-BTw
- Wikipedia information
  - Particulate matter: https://en.wikipedia.org/wiki/Particulates
  - Ultrafine particles: https://en.wikipedia.org/wiki/Ultrafine_particle
  - Diesel exhaust: https://en.wikipedia.org/wiki/Diesel_exhaust

Questions ?

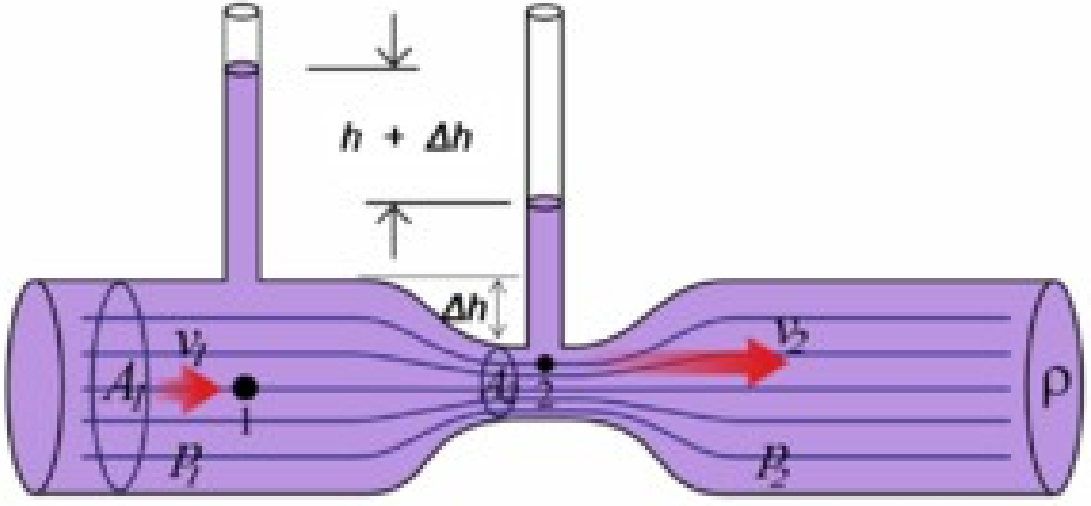


Bill of Materials

Component	Type	Non-bulk price
Microcontroller	Sparkfun ESP8266 Thing	€ 15,95
Accelerometer	MPU6050	€ 2,83
Barometer	BMP180	€ 2,04
Battery	LiPo 3,7V 500mAh	€ 2,00
Buzzer	KY-006	€ 1,44
Fine dust meter	PPD42NS	€ 15,90
GPS	GY-NEO6MV2	€ 11,66
Humidity sensor	HTU21D	€ 3,24
RGB Led	NeoPixel WS2812	€ 2,40
UART-to-I²C convertor	ATmega328P Pro Mini	€ 3,00
		€ 60,46

Venturi effect

- Ensuring airflow on moving devices
  - *so we can remove the resistor (heat pump) to save battery*
  - Large intake hole creates underpressure at bottleneck, sucking air into the device



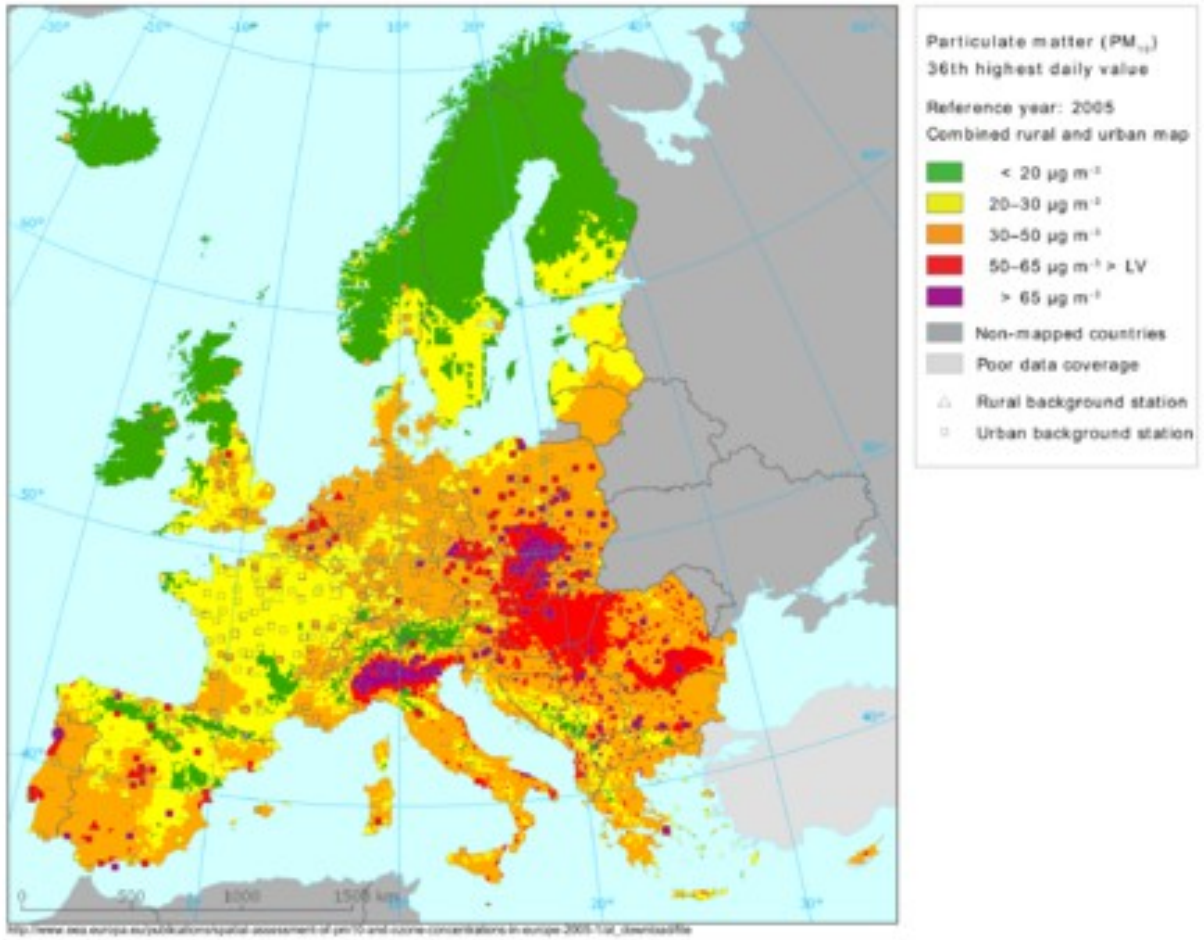
Usual suspects

- Air quality is affected by
  - Industry, power plants
  - Buses (diesel*), cars (incl. electrical cars), subway/trains, trams
  - Airplanes
  - Household heating
  - Agriculture
- But also
  - Weather conditions (wind, rain, air pressure)
  - Streets and buildings (air flow)
  - Indoor conditions (ventilation, candles, cooking*, smoking*)
  - Natural sources (wildfire, volcanoes, dust storms, …)

Air-quality awareness projects

- 2010: Air-quality monitoring on trams in Zurich (ETH Zurich)
  - Measuring O_3, CO, NO_2 and ultrafine particles
- 2014: AIRbezen in Antwerp (Universiteit Antwerpen)
  - 700 strawberry plants measuring ferromagnetic fractions
- 2015: Ivy-plants in Ghent (Universiteit Antwerpen)
  - 240 ivy-plants measuring finedust particles
- 2016: CurieuzeNeuzen in Antwerp (Vrije Universiteit Brussel)
  - Measuring NO_2 using small collection-tubes

Concentration of PM_{10} in Europe



http://www.eea.europa.eu/publications/spatial-assessment-of-pm10-and-ozone-concentrations-in-europe-2005-1/at_download/file

European air quality standards

Pollutant	Period	Europe AQ	Permitted exceedings
$PM_{2.5}$	1 year	25 µg/m³	
PM_{10}	24 h	200 µg/m³	35 / year
	1 year	40 µg/m³	
CO – Carbon monoxide	24h / $\overline{8h}$	10 mg/m³	
SO_2 – Sulphur dioxide	1h	350 µg/m³	24 / year
	24h / $\overline{8h}$	125 µg/m³	3 / year
NO_2 – Nitrogen dioxide	1h	200 µg/m³	18 / year
	1 year	40 µg/m³	
O_3 – Ozone	24h / $\overline{8h}$	120 µg/m³	
Benzene	1 year	5 µg/m³	
Pb – Lead	1 year	0.5 µg/m³	
As – Arsenic	1 year	6 ng/m³	
Cd – Cadmium	1 year	5 ng/m³	
Ni – Nickel	1 year	20 ng/m³	
Polycyclic Aromatic Hydrocarbons	1 year	1 ng/m³	

http://ec.europa.eu/environment/air/quality/standards.htm

WHO air quality guidelines

Particulate matter ($PM_{2.5}$) 24 h mean:	<25 µg/m^3	WHO Air Quality Guideline;
Particulate matter (PM_{10}) 24 h mean:	<50 µg/m^3	WHO Air Quality Guideline;
Carbon dioxide (CO_2):	< 1000 ppm	ASHRAE 62. 1-2013;
Sulphur dioxide (SO_2) 24 h mean:	< 20 µg/m^3	WHO Air Quality Guideline;
Nitrogen dioxide (NO_2) 1h mean;	< 200µg/m^3	WHO Air Quality Guideline;
Ozon (O_3) 8 h mean:	< 100 µg/m^3	WHO Air Quality Guideline;
Carbon monoxide (CO) 8 h mean:	< 75 ppm	ASHRAE 62 1-2013;
Formaldehyde:	< 0.1 mg/m^3	ASHRAE 62 1-2013;