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D2.7 Tutorial for air quality projects in high schools

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Abstract	This deliverable serves as a handbook for air quality projects in high schools. It contains information about the ACTION air quality pilot in high schools, tips and lessons learned as well as material that has been used and created within the high school projects.
Keywords	Citizen science in high schools; air quality project; Arduino based sensors; tutorial

How to quote this document

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EXECUTIVE SUMMARY

This deliverable contains a tutorial for air quality projects in high schools, based on the experience from the ACTION pilot in Norway. It is targeting primarily scientists that would like to carry out similar projects in (high) schools, but it can also be used by teachers and other interested persons (e.g., from grassroot organisations) to get inspiration on transdisciplinary school projects, combining natural science and technology. The materials in the Annex will be useful examples for designing own initiatives.

ACTION partner NILU was coordinating this pilot with the aim to give high-school students in Oslo and the larger Oslo area the opportunity to carry out their own air quality projects. For carrying out measurements and collecting data, the students used an Arduino-based air quality sensor platform, equipped with a Nova SDS011 sensor to measure pollutant levels of particulate matter ($PM_{2.5}$ and PM_{10}) in the air. They could add additional components for measuring e.g., relative humidity, temperature, noise or CO_2. The students worked in groups of 3-5 persons who were in charge of the technical part of mounting and programming the Arduino based sensor, as well as the scientific part of defining the research question, methodology, data analysis and conclusions. Each group presented a scientific poster with the results at a joint student conference.

Based on our experiences, we can provide the following lessons learned:

- Dedicate enough time for preparations so that the activities fit into the teachers' curriculum and they have enough time to buy equipment, prepare their teaching and the way they want to consider the project outcomes in their exams
- Expectation management is important. Communicate early to the teachers what you expect from them and what they can expect from you. At the same time, give the teachers as much room as they need to implement the activities into their curriculum.
- Be available for both teachers and students. Establish a communication forum where questions can get answered quickly and in an informal way and where participants can communicate between themselves and share good and bad practices (e.g., Facebook group).
- A public event like a student conference is a nice way to bring students in contact with other students to open their mind to the "bigger picture". It is also a good opportunity for the students to present their activities and results to a larger audience and have direct contact with the scientists.
- Evaluation of the activities is as important as in any other project.

This deliverable provides both a report about the pilot activities in Norwegian high schools, and a step-by-step tutorial for those readers interested in carrying out air quality projects in high schools themselves.

1 INTRODUCTION

A key element of the ACTION project is drawing on the experiences of pollution-based citizen science initiatives to understand the diversity of the design space, refine the project's research and innovation goals and offer solutions that meet real needs. To do so, the project has set up a citizen science accelerator that includes funding, mentoring, training, technology, tools, promotion and networking opportunities to help the citizen science initiatives to reach their goals effectively and sustainably. The accelerator started with a set of five citizen science pilots, one of them being "Air quality measurements in high schools", the project that this deliverable is about.

Although air quality is generally good in Norway, $PM_{2.5}$ and PM_{10} pollution often exceeds limit values during wintertime, due to wood burning, use of studded tires, road sanding, salting and during springtime due to road cleaning activities. This is why the pilot activities focused on particulate matter levels during winter/spring time.

ACTION partner NILU was coordinating this pilot, giving high-school students in Oslo and the larger Oslo area the opportunity to carry out their own air quality projects. For carrying out measurements and collecting data, the students used an Arduino-based air quality sensor platform, equipped with a Nova SDS011 sensor to measure $PM_{2.5}$ and PM_{10} pollution levels. They could add additional components for measuring e.g., relative humidity, temperature, noise or CO_2. The results were presented by the students themselves at a joint student conference.

This deliverable serves as a tutorial for air quality projects in high schools, based on lessons learned in the Oslo pilot. It serves as a field report, providing insight into the preparation process, the actual project phase, the student conference and the evaluation. All materials are attached in the Annex and they will also be made available for download at https://actionproject.eu/. However, since the material has been prepared for Norwegian high schools, most of it is only available in Norwegian. The material is available in open source and can be freely modified and used.

2 PREPARATION PHASE

The pilot for air quality in high schools was planned for winter/spring 2019, but the preparations started as early as October 2018, when NILU contacted 23 high schools in Oslo and the larger Oslo area, informing them about the possibility to carry out air quality projects in their high school as part of the European ACTION project (letter - Annex 1). Many high schools in Norway have a special focus, such as on media and design, theater or natural sciences. We targeted those high schools with a special focus on technology and research, of which seven schools participated with in total more than 100 students. The students were in the age between 17 and 18.

Through contacting the schools that early, we wanted to ensure that the project could be implemented into the curriculum of the school for 2019. We invited the interested teachers to a meeting at NILU in November 2018, introducing the ACTION project, describing the pilot idea and discussing the timeline, expectations and requirements for the execution of the pilot. At that meeting, we agreed on the following timeline (Fig. 1):

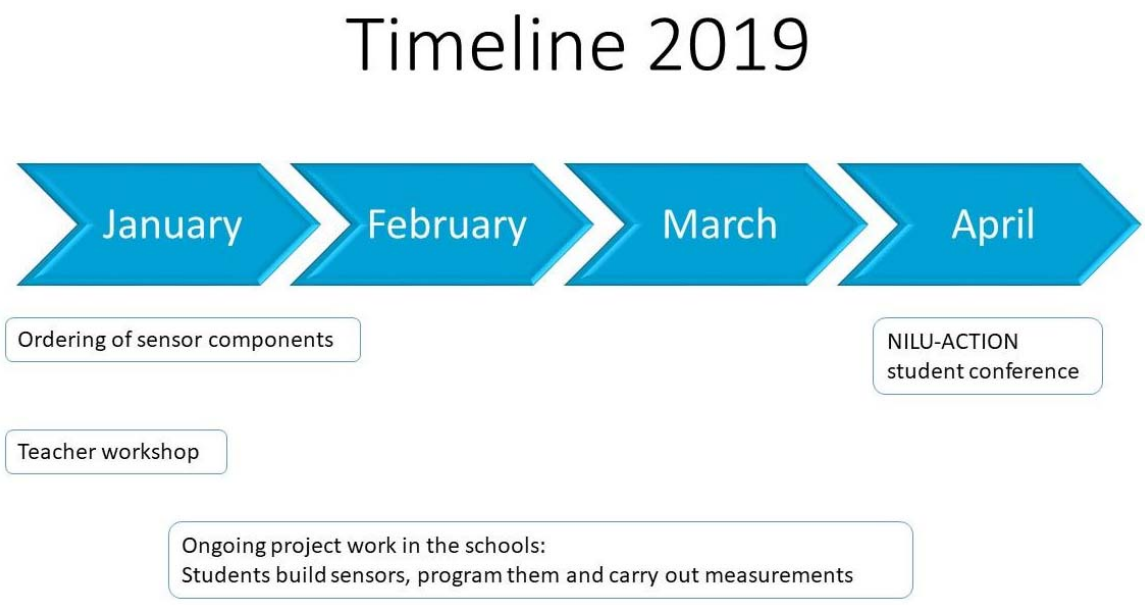


Figure 1. Timeline of the school pilot for 2019

The first event on our timeline was the teacher workshop in January 2019. We met with 11 teachers at one of the participating high schools. First, we provided basic information about air pollution, its effects on health, pollution sources, legal aspects, measurement of air quality and possibilities and challenges connected with the low-cost sensor platforms that we were planning to use in the pilot. The presentation is attached as Annex 2. During this session, we were able to answer many questions of the teachers. Not all of them felt the need to stay to the second part of the workshop, where a participating teacher offered a hands-on session about assembling the sensor(s) to the Arduino board, attaching an SD-card component and other parts, such as display, temperature sensor, GPS, etc. In addition, he introduced Arduino coding which is required to get the sensor measuring.

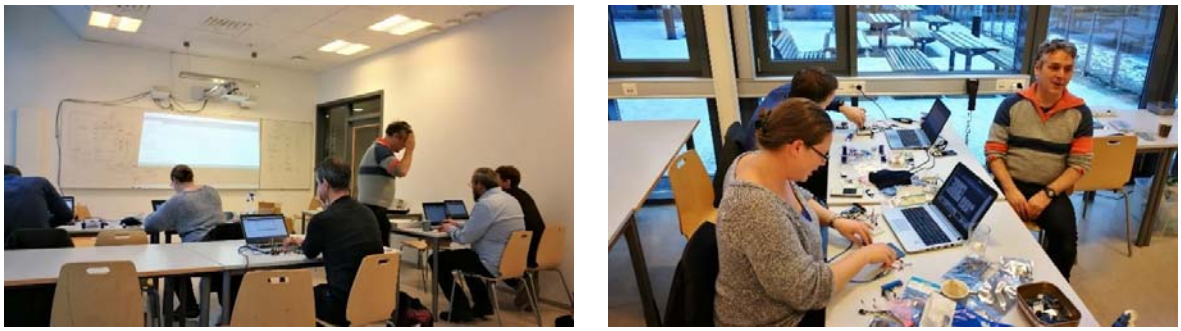


Figure 2. Teacher workshop

At the workshop, we agreed upon the following: (1) The teachers have freedom to introduce the topic to the students as they wish and to give also the students as much freedom as possible to design and carry out their air quality measurement project. They were also free to choose the time when they would carry out the projects with their students so that it would fit with their curriculum. (2) NILU would be helping the teachers/students if necessary, in different ways – with the technology, scientific background, information material or a physical visit. (3) The teachers ordered the required equipment themselves, each teacher for their own school/class. The costs could be reimbursed through the ACTION project after the student conference. (4) A student conference for all participating students was planned for April at one of the participating schools. There, the students should present their results by help of a scientific poster. (5) A NILU-ACTION Facebook group has been created by the teachers, to communicate with each other during the project phase and to exchange problems and questions they would come across. NILU-ACTION scientists were also invited.

ACTION Tips: Preparation phase is crucial, start as early as possible. If you have to order equipment, do this as soon as possible, there will always be some delay in delivery. Allow for open dialogue between teachers and scientists, including expectation management. Plan time to train the teachers and involve them in as many activities as possible. Allow for as much freedom as possible (also within the schools) to promote ownership.

3 PROJECT PHASE

Each teacher was free to start the actual project work with their students whenever this fitted best into their semester plan. Some teachers started as early as January, whereas other teachers waited until March. Regardless of the point of time when they carried out the project work, the projects were integral part of the curriculum and the students would receive grades from the teachers on this.

In order to comply with the GDPR requirements, we prepared a consent form that the participating students (or their legal guardians in case they had not filled 18 yet) had to sign and return to us. By signing the students agreed that participation in the ACTION project was voluntarily, that they could resign any time that we would not collect their personal data and they could indicate if they agreed that pictures were being taken from them. The form (in Norwegian) is attached as Annex 3.

During the actual project phase, the teachers applied different approaches. Several teachers used the presentation we gave at the teacher workshop for their teaching. One teacher asked NILU for additional information on health effects caused by air pollution (Annex 4). A NILU scientist has been invited to one high school to give an introductory presentation about air quality and measuring methods (Annex 5). Another high school teacher invited a NILU scientist to discuss the plans his students had for measuring air pollution. E.g., some students wanted to measure indoor air pollution in classrooms and compare the results with noise and temperature measurements. Other students wanted to measure air pollution from the metro in town and another group planned to measure air pollution along a very busy ring road at different times of the day and the week. Other teachers were very keen on visiting the NILU laboratories with his students, so that they would learn more about air quality and scientific work. Thus, they came to the NILU laboratories for a guided tour.

Working on the scientific posters was a new experience for the students. One teacher invited a PhD student from the University of Oslo to introduce scientific thinking and designing scientific posters to the students. A group of that school later won the prize for the best poster at the student conference.

Apart from the activities described here, the teachers worked very independently on the projects.

ACTION Tips: Make sure all certificates/agreements are in place to be signed at the start of the project phase. This includes also an agreement on what type of data should be delivered by the citizen scientists and to whom, by when and in which format. Be transparent and provide updates on project activities and on what happens with the data. Create suitable ways for communication, e.g. a Facebook or What's app group.

4 STUDENT CONFERENCE

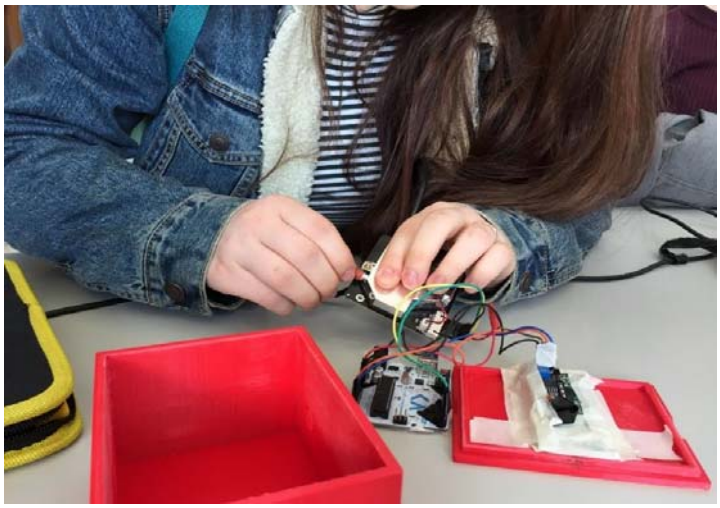
The NILU-ACTION Student Conference was held on 08. April 2019 with more than 80 students participating. One of the participating high schools (“Kuben”) offered their new auditorium as meeting venue. It was centrally located in Oslo, with public transportation access close by and thus easily accessible for the students and the teachers.

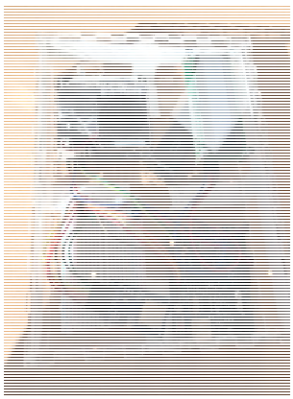
The final agenda looked as follows:

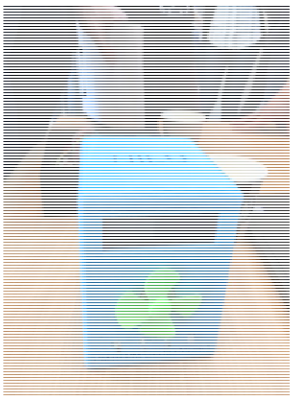
10.00-10.30	Show-up at Kuben high school, poster installation
10.30-10:40	Welcome by NILU and Kuben
10:40-11:00	Presentation by NILU scientist Chris Lunder about NILU’s work in the Arctic and Antarctic
11.00-11.45	Presentation by Cautus Geo about sensing technologies
11.45-12.30	Lunch and finalising poster preparation
12.30-14.00	Poster presentations, jury is going from poster to poster, listening to the students’ presentations.
14.00-14.15	Distribution of diplomas and finish by NILU and Kuben

The students had to bring their scientific posters that described their work, results and conclusions. Some students also brought the sensors they had built, some of them even built sensor casings for easy and safe transport and measurements. The pictures below provide some insight into the conference (Fig. 3 and 4).

Figure 3. Impressions from the student conference







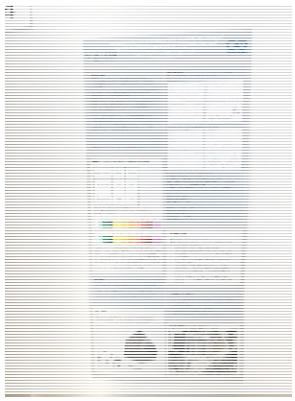


Figure 4. Examples of sensor platforms and scientific poster made by the students

As mentioned in the agenda, a jury had been formed to judge the posters (for example of the posters developed by the students, see Annex 6). The jury was divided into two groups to make sure that in the relative short amount of time all posters could be judged. Each jury group consisted of three members: a NILU scientist, a teacher and the headmaster of Kuben high school and the second speaker of the sensor company respectively. The students' work was judged based on criteria for the categories "Best research project – researcher award" and "Best poster – poster award". In addition, the whole audience could vote for their favorite poster in the category "Audience award". The winner groups received their diplomas from the "Kuben" headmaster in a ceremony at the end of the student conference (Fig.5).

Figure 5. The proud winners with their diplomas

ACTION Tips: The student conference has been appreciated by both teachers and students. A public event like this can motivate students to perform better since the result of their work/project will be made public. It is a nice way to bring citizen scientists in contact with other citizen scientists, opening their mind to the "bigger picture".

5 EVALUATION

Together with T6 ECO/WP6, we have designed an evaluation form both for the teachers and the students. They completed the form after the student conference and the teachers sent the forms to NILU. We translated the open replies to English and sent an overview of the replies to T6 who are working on the interpretation. Annex 7 contains the English version of the questionnaire for the teachers and the students. Deliverable D2.8 is dedicated to the evaluation of the activities around air quality projects in high schools. It will include evaluation results from the pilot activities in 2019 and 2020. Thus, the chapter at hand provides only a short summary of the evaluation results from 2019 without any deeper (statistical) analysis. The evaluation that will be carried out in 2020 will be based on the ACTION impact assessment methodology that is currently under development. This first evaluation focused on the following aspects:

- What was perceived as positive in the project and what was perceived as difficult or to be improved?
- Knowledge and skills acquired
- Results in terms of awareness raising on air quality-related issues
- Impact on pro-environmental behaviours
- Changes in class/school social relationships thanks to the performed activities
- Chances in the perception of science

Most of the students claim that they have learned something new about air pollution, technology and scientific work. However, the majority indicates that they will not change their habits based on what they learned about the topic. Almost half of the respondents claim that they feel that they can do more and better at school after working with air quality projects, especially in science-related topics. Asked about what they liked most, the students mentioned that they enjoyed the freedom they had within the projects, that they learned something new and useful and that it was fun working in groups. Asked about what should be improved next time, many students complained that they did not have enough time for the project and some also felt that more knowledge on the Arduino programming and the introduction to the topic has been missing and that the activities would benefit from better communication/more involvement of the scientists.

In general, also the teachers seemed to be content about the project. Beforehand, they told us that they were very excited about this kind of project, since it brings together different topics (technology, programming, natural sciences, effects on society) and would be an interdisciplinary experience for the students. The technology part seemed to not work properly in several cases, that might be due to the fact that the quality of the measuring devices is not comparable to standardized monitoring equipment commonly used in science. The teachers claimed that the project increased their awareness about air pollution and they also see increased awareness in their students. Asked about new skills and competences, the teachers claim that they have gained new skills in dealing with Arduinos and sensors, whereas for the students they claim that they now have a better understanding about air pollution, science/scientific work and the technology used in the project. The teachers claim they have a more pro-environmental behavior after the project, but that this does not apply to the students.

ACTION Tips: Evaluation is a crucial part of your project. Even more important is to improve your activities based on the obtained feedback and provide feedback to your participants.

6 DATA REPOSITORY

The sensors built by the students is the Nova SDS011 for measuring particles in the fraction of $PM_{2.5}$ and PM_{10}. During the measuring activities, the students will take measurements at different locations. A file will be generated in the SD card of each sensor. The format of this file is:

- Date
- Time (in local time)
- GPS location (if the module is connected to the sensor)
- PM2.5
- PM10

More details on data management can be found in D1.1 Data Management Plan.

Once the activity is ended, the files generated are sent to the NILU coordinator by the teachers. The teachers attach other relevant information to the dataset such as the identifier and the location of the sensor.

With this information, NILU will upload the dataset to our future data portal, together with the metadata. From there, it will be deposited at our community at Zenodo.

The diagram below shows the process followed by data (Fig. 6).

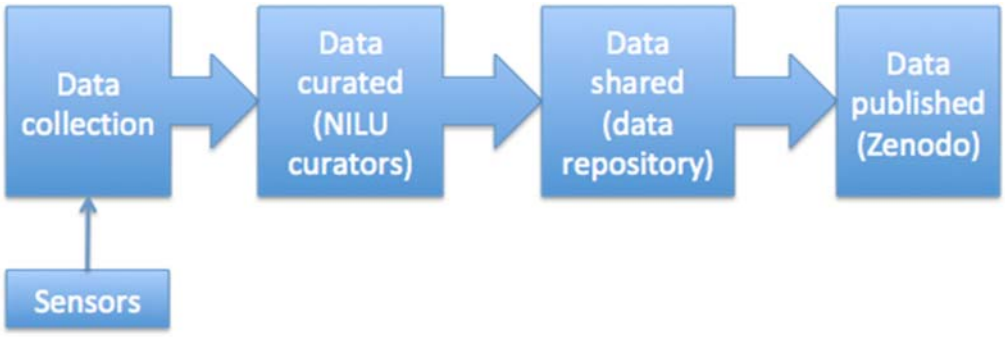


Figure 6. Data flow for the Norwegian pilot

ACTION Tips: Make as much data openly accessible and available in formats that can be read and used by other potential citizen scientists. They will benefit a lot!

7 TUTORIAL

This chapter provides practical guidance for scientists, teachers and other interested people to carry out air quality projects in high schools. It is written in form of a tutorial, but **these are only suggestions**. You may feel free to adjust the activities accordingly.

7.1 Invitations and information meeting

In order to carry out a CS project in high schools, you have to approach the teachers. If you do not have any direct contact with any of the teachers from before, send an email to the principal, asking to distribute the invitation to the teachers that could be potentially interested. Remember to send this invitation early, as the teachers have to plan their semesters ahead, based on the respective curricula. It is smart to do some research in advance, to know for the curriculum of which class your activities match best. In the ACTION project, we approached high schools with a focus on science and technology since we had worked with some of them previously and we knew that these schools would most likely be very interested in joining our activities.
Arrange for an initial meeting between the participating teachers and the project lead. At this meeting, plans for the project can be outlined and discussed, and any questions answered. We used this meeting also to agree on dates for a teachers' workshop and the student conference. We also created a Facebook group for the teachers and the involved NILU scientists to provide a platform for informal exchange of information and to post questions. This meeting could also be merged with the teachers' workshop; however, we found it useful to have a separate meeting in advance.

7.2 Teachers' workshop

This workshop is for the participating teachers to provide them with an introduction into the topic of air quality (AQ) in form of a PowerPoint presentation. In the ACTION project, the NILU scientist covered the following topics:

- Introduction into the topics air quality and air pollution
- Health effects of air pollution
- Air pollution sources
- Legal aspects
- Measuring and monitoring of air pollution
- How to use micro sensors?

The PowerPoint will be sent to the teachers after the workshop so that they can use it for their own teaching. It is attached as Annex 2 (in Norwegian).
The second part of the workshop should be dedicated to the micro sensors. Give the participating teachers the opportunity to build a sensor themselves and code them, this will help them in their planning of activities. In our case, a teacher that already had some experience with the sensors and Arduino boards from before, volunteered to lead that part.
Remember to have electronic tools (including soldering tools) and sensor components available. Teachers have to bring their laptops for the coding.

7.3 Introduction to the students

This part should be left to the teachers. Some teachers invited the NILU scientist to give an introductory presentation to the students, similar to the one from the teachers' workshop. Some

teachers used the material provided by NILU at the teachers' workshop and introduced the topic to their students themselves.

Sensor building and coding activities have been carried out in the classes without involvement of NILU staff. Also other aspects, such as scientific working, how to write a scientific report or create a scientific poster, have been handled by the teachers individually. However, you should be able to help out in these parts as well if required.

The experimental project is based on an Arduino microcontroller programmed from a Windows platform. Microcontroller programming is notoriously complex, but the Arduino project has come very far towards making this accessible to inexperienced users. Arduino code is actually written in the C language, but most of the intricacies of coding, compiling, library version handling, linking and uploading to the target have been hidden. There are still snags, though, and setting up the Arduino environment can be tricky if you are out of luck. Also, the Windows handling of USB devices can be very unstable.

We try to describe the mainstream Arduino way below. We have also created a sketch directory in a ZIP file, already containing two extra libraries, to help bring inexperienced users to a quick, positive result. This ZIP file is available at our Zenodo community.

Also note that all sensors, and all measurements always will have inaccuracies or even large errors. The low-cost micro-sensors used in this project are less accurate than professional measurement devices. The keen student may notice, for example, that particle sensors do have a large range of error sources, that humidity sensors may be unreliable at high relative humidity, and that temperature sensors may suffer from self-heating. Beyond the reach of this project, serious measurement and monitoring projects MUST also include calibration against reference sensors or at accurately known conditions.

7.4 Shopping list and how to assemble the sensor

The following parts are required to build a sensor that can measure $PM_{2.5}$ and PM_{10}, temperature and relative humidity. Data is transferred to a SD-card.

- Arduino UNO board rev. 3
- Adafruit shield with real time clock (RTC) and SD-card reader for rev.3
- An SD card (or a micro-SD card with a full-size adapter), 2 - 32 GB
- LEDs (different colors, e.g., green, orange and red) - optional
- USB A – B cable
- Power bank or wall wart (7-9 VDC)
- CR1220 back-up battery for the RTC
- Nova SDS011 sensor for measuring PM
- DHT-22 Sensor for measuring temperature and relative humidity
- Soldering equipment (soldering iron and soldering wire)

Furthermore, the students have to use a laptop where they install the Arduino IDE software from www.arduino.cc, a USB driver, and some sensor libraries. Windows administrator permissions may be required.

If problems are encountered with the Adafruit shield after following the simple instructions below, please refer to the very detailed tutorial from Adafruit https://learn.adafruit.com/adafruit-data-logger-shield .

Detailed information on the temperature and humidity sensor is found in https://learn.adafruit.com/dht . Adafruit recommends its own libraries (https://learn.adafruit.com/dht and https://github.com/adafruit/DHT-sensor-library). However, we have used the Cactus-IO library http://cactus.io/sensors/temperature-humidity/dht22-humidity-sensor .

Additional gadgets can be added as preferred (e.g., display, GPS, …). The user will need to adjust the code accordingly.

Assembling the sensor parts consists of the following steps:

1. The Arduino board has all connectors pre-soldered – no work required. Note that the latest revision 3 has the USB controller built into the ATMEGA chip, while earlier versions have an FTDI USB chip that needs a separate USB driver installed in the PC.
2. The shield card needs pins to be soldered. Cut the supplied pin rows to the correct lengths and insert the short ends into the shield from the bottom side. Insert the long pin ends into the sockets on top of the Arduino. Then solder the pins on the top side of the shield.
3. We recommend soldering additional pins to the shield, to allow plugging simple patch cables between the shield and the sensor pins.
4. The SPI interface to the SD card are internally connected in the shield (pins 10, 11, 12, 13), no action is needed.
5. The I2C interface is internally connected to the RTC on the shield (pins A4 and A5), no action is needed
6. The DHT22 will operate on +5V, but this results in some degrees of self-heating. Connect GND and +3.3V. The DATA pin should be connected to D2 (digital pin 2) on the Arduino shield, with a 10kOhm pull-up resistor to the +3.3V line. Some versions of the DHT22 are mounted on a small circuit board with an internal pull-up resistor. If the resistor is omitted, the sensor may appear to work initially, but results may be unreliable over time.
7. The SDS011 particle sensor needs connections to GND and +5V. Furthermore, its TX pin should be connected to pin D8 on the Arduino shield, and its RX pin connected to pin D9. These are controlled by the sketch to operate as Software Serial port SerialTwo.
8. An SD-card and a CR1220 battery must be inserted into the shield.

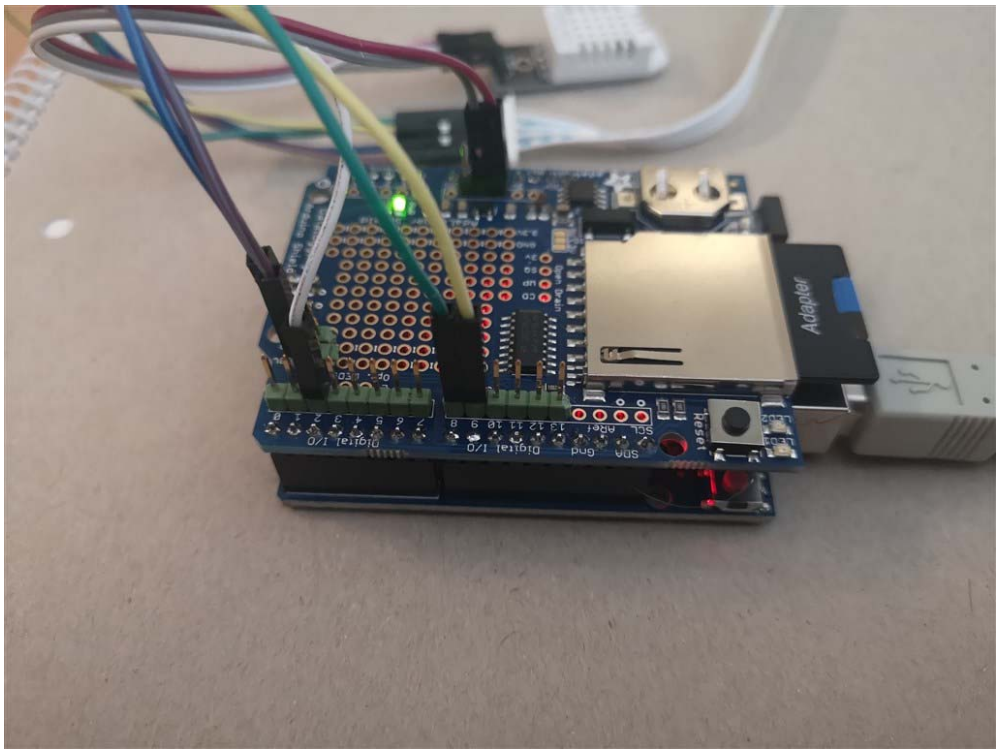


Figure 7: The shield with SD card holder and RTC battery. Pins soldered on the top are inserted into the Arduino. Pins soldered beneath point upwards and allow for connecting sensor cables. Cables and/or sensor pins may alternatively be soldered directly into the shield prototyping area.

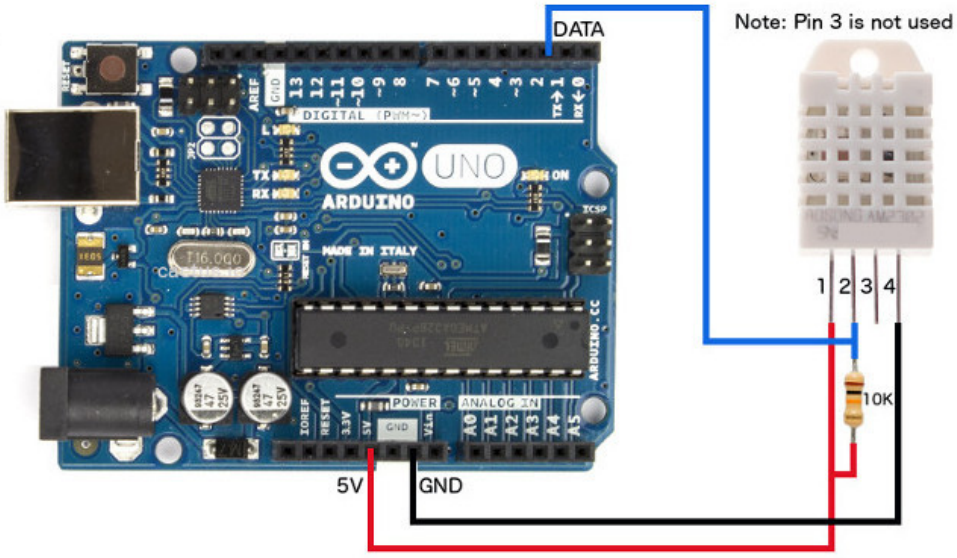


Figure 8: Recommended connections for the DHT22. We have used pin 2 for data, as shown. Different power pins may be used (GND, and +5V or +3.3V). The 10kOhm pull-up resistor is important, but not shown in our demo. It may already be included on a small break-out circuit board that the DHT22 may be delivered with.

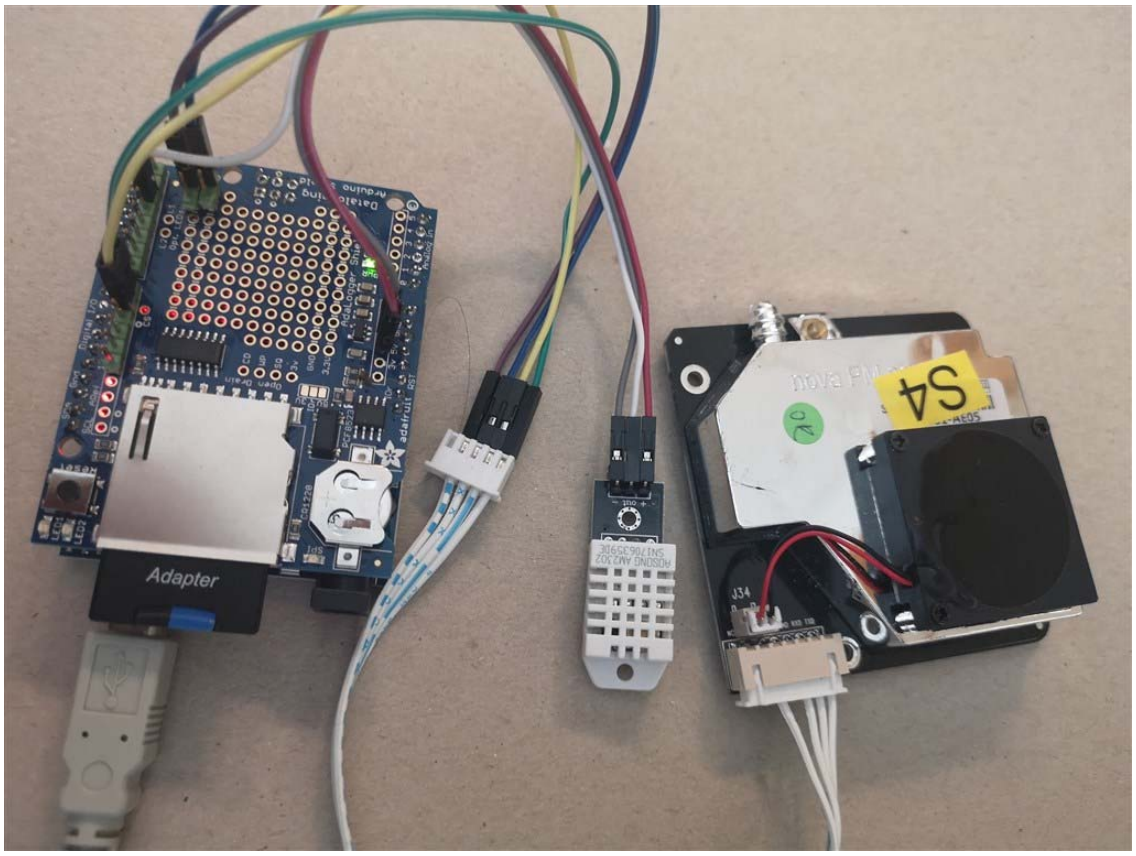


Figure 9: The Arduino with shield on top to the left, the DHT22 temperature/humidity sensor, middle, and the Nova SDS011 particle sensor to the right. The SDS011 pins are numbered 1 to 7 from left to right. Pin 7 is named TXD (transmit), and is connected to the green wire, running to the Arduino pin D8 (RX – receive). In a serial port the transmit pin of one unit must be connected to the receive pin of the other unit. The SDS011 pin 6 is RXD, connected through the yellow wire to the Arduino pin D9 (TX). SDS011 pins 5 and 3 are connected through blue and violet wires to GND and +5V, respectively.

The sensors and electronics should be mounted in a box for weather protection during measuring. The students can design the box themselves. The material should be water resistant and enable air flow to the sensors (through one or more downward facing holes shielded from direct rain and from water running down the side of the enclosure). Here the students can be creative (see figure 10).

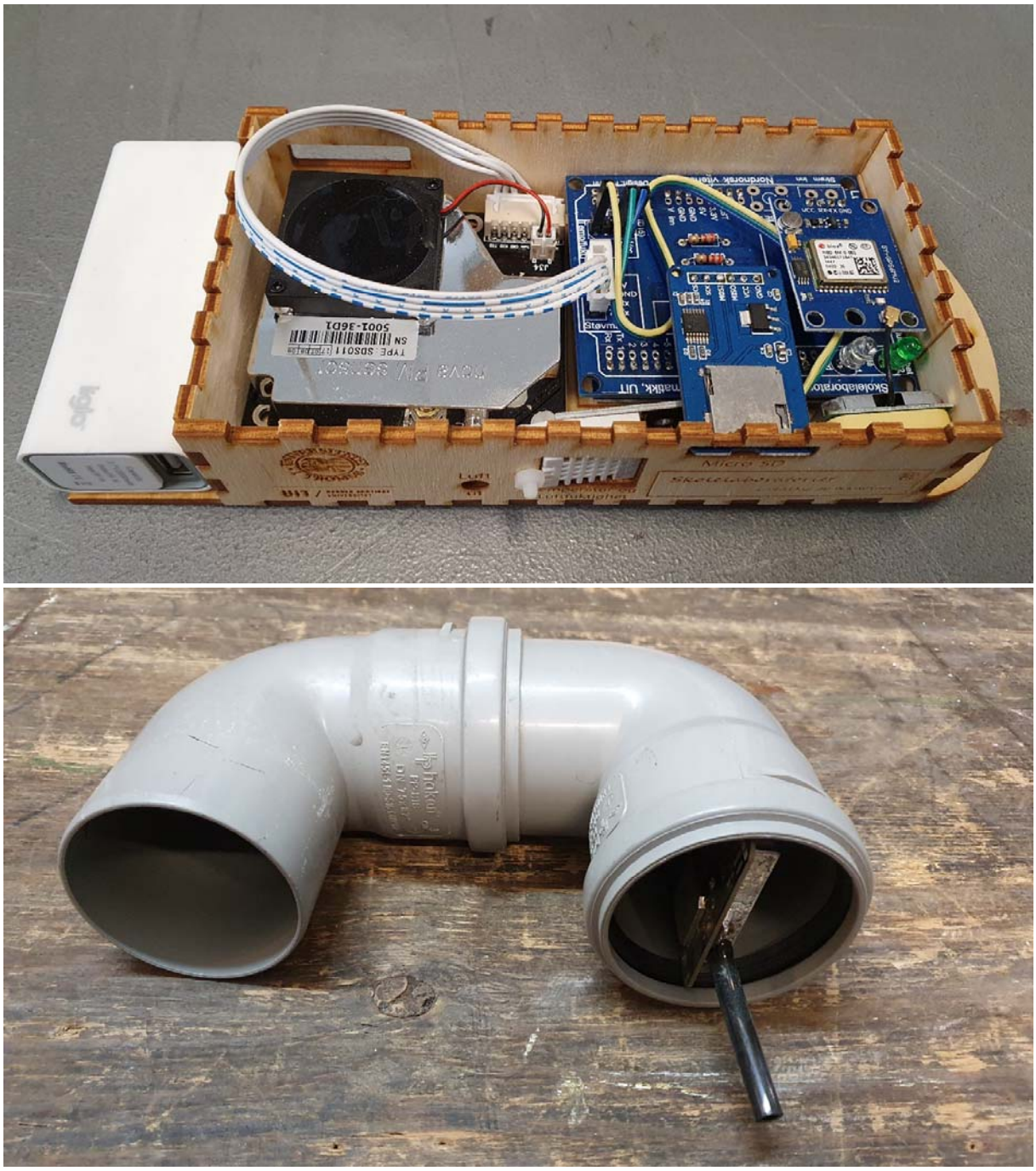


Figure 10: Examples of casings for the sensor

7.5 Arduino code

First establish the Arduino IDE (Integrated Development Environment) and the required libraries on the PC. Then:

1. Download and install Arduino IDE (Windows installer, currently version 1.8.13, tested with older version 1.8.5) from https://www.arduino.cc/en/Main/Software

2. Connect the Arduino UNO, open the Arduino IDE, and select the correct board (Tools / Board: Arduino/Genuino UNO). Make sure the board is located and a USB port is assigned.
3. For a simplified project setup, unzip the supplied SDcard_Arduino_demo.zip into the users Documents/Arduino folder. This should create a directory named SDcard_Arduino_demo, containing the sketch itself and a subdirectory named src (which contains two required libraries). The sketch is set up to use the local versions of these libraries.
4. *Alternatively, for the standard Arduino configuration, install RTC library from https://github.com/adafruit/RTClib . Use the Download ZIP option. Then open this ZIP from the Sketch menu in the Arduino IDE (Sketch / Include Library / Add .ZIP library, navigate to the downloaded ZIP file and open this). Install the Cactus_IO DHT_22 library from http://static.cactus.io/downloads/library/dht22/cactus_io_DHT22.zip using the same method. The sketch may need a small change to find the libraries in the default location.*
5. The example code will include standard header files that are normally available in the Arduino IDE. These are SPI.h, SD.h, Wire.h, and SoftwareSerial.h. If error messages mention any of these, download and install appropriate libraries.
6. The Nova SDS011 particle sensor does not require a specific library. The example code will access this sensor directly via the software serial port Serial2, and format and log the returned values.
7. Open the supplied demo sketch in the Arduino IDE. The IDE may ask permission to create a directory for the sketch, accept this. If you copied the contents of the demo zip file into the Arduino sketch directory, this directory already exists, and also contains the two libraries under the src subdirectory.
8. Try to compile and upload the sketch, and check for any error messages.
9. Open the Serial monitor to see data returning every 10 seconds.
10. Note that the timestamps are now not correct. The RTC must be initialized. Find the rtc.adjust command (line 103) in the sketch, edit for the current date and a time approximately 20 seconds forward in time, uncomment this line to activate it, then compile and upload the sketch again. The RTC will now be set.
11. To avoid resetting the RTC every time the sketch is recompiled, immediately comment out the same code line, and compile and upload the sketch again. The RTC will continue running, and the battery will keep it operating for years even without any external power to the Arduino.
12. To check results, let the sensors run for a minute (see the results arriving in the Serial Monitor), then power down the Arduino. Extract the SD card, insert it into a PC, and check the file DATALOG.TXT. The file itself may have a default timestamp 01.01.2000, but every record should contain a correct timestamp and monitoring results.
13. Re-insert the SD card into the shield. Start monitoring simply by powering up the Arduino, either by connecting the USB port to a PC, or by connecting a power bank or a wall-wart (7-9VDC) to the barrel plug. If only a 5V power supply is available (USB charger), this may be connected to the Arduino USB socket (even if no PC is present). Results should still get logged automatically to the SD card.

This is a demo code for the Arduino board used in connection with a Nova PM SDS011 and a DHT-22 sensor. Data is transferred to an SD card. The code can be amended as required.
An example code is available as Annex 8.

7.6 AQ project

The students are now supposed to carry out their own AQ project, based on scientific working methods. They shall formulate a research question which their AQ project shall deliver the answer to. They can work with the obtained data as follows:

- Comparison of measurements from different sensors (Correlation)
- Comparison with data from monitoring sites (Correlation)
- Looking at bias, precision
- Measuring different parameters at the same time, e.g., temperature, relative humidity, noise
- Looking at additional data, e.g., weather data
- Looking at additional air quality data, e.g., from official monitoring networks, or from NASA

Their research shall result in a report that has to be delivered to the teachers. The report consists of the following elements: Background, research question, methods, results, discussion, conclusion. The students shall also create scientific posters, following the same structure as the report.

7.7 Student conference

The student conference gathers all participating school classes. All students/student groups shall present their results by help of a scientific poster. Either one of the participating schools or any other location can serve as meeting place.
It lasts around four hours and has the following agenda:

- Welcome
- 30-45 min presentations from scientists or technology experts about topics related to the AQ project
- At least two teams of evaluators go from poster to poster. The respective students shall provide a very short summary of their activities and results and answer any questions the evaluators might have.
- The evaluators meet to discuss the results while the students have lunch.
- The winners are announced, and diplomas distributed.

The evaluation teams can consist of the lecturers, teachers or the principal of the school that provides its facilities. Evaluation criteria have to be prepared together in advance. We suggest three categories:

- Best research project:
    - Does the work reflect good scientific background knowledge?
    - Did the group apply good research methods?
    - Have the results/solutions been tested and assessed and good documented?
    - Have the students found an answer to the research question?
    - Is the conclusion aligned with results and hypothesis?
    - Quality of the interview with the evaluators
- Best poster:
    - Does the poster clearly reflect hypothesis, methods, results and conclusion in a scientifically correct way?
    - Does the title and overall impression attract interest?
    - Is the information presented in a logical order? Are problem framing, results and conclusion integrated in a logical way?
    - Is there a clear «take home-message"?
    - Is the project appealing (design, quality of pictures, ect)?

In addition, we also had an “audience award”.

7.8 Evaluation

As for any other project, an evaluation is crucial to improve the activities in the next round.
It is important to ask both teachers and students separately and anonymously. The following information could be useful to receive from the students:

- Age
- Gender
- Questions with options for different answers (Likert scale: Strongly disagree – disagree – neutral – agree – strongly agree):
    - Thanks to this activity I learned something new about air pollution
    - I learned something new on technology
    - I improved my understanding on how scientific research processes work
    - I'm thinking to change my habits (reducing impact on environment)
    - I feel I can do more and better at school, esp. in scientific related topics
- Questions with open answers:
    - What did you like about this activity?
    - What should be improved and how?
    - Anything else you would like to share with us

This could be questions for the teachers' questionnaire:

- How did you hear about this citizen science project?
- How were the activities organised?
- What were your expectations?
- How many students participated in the activities? (number, gender, age)
- Did the project meet your expectations?
- What surprised you?
- Did this project increase your own awareness about AQ issues? (yes/no; if yes, how)
- Did this project increase your students' awareness about AQ issues? (yes/no; how/why not)
- Did this project provide you with new skills and competences? (yes/no; how)
- Did this project provide your students with new skills and competences? (yes/no; how)
- Do you think you will show more pro-environmental behaviour thanks to the knowledge you gained with this project? (yes/no; how/why not)
- Do you think your students will show more pro-environmental behaviour thanks to the knowledge they gained with this project? (yes/no; how/why not)
- Do you think the project has influences the way of how your students view and value science? (yes/no; how)
- What did you like most with this project?
- What do you think your students liked best with the project?
- Do you think this project will change the relationships among your students and the way they interact on a daily base? (yes/no; how)
- Do you think this project increased the motivation and self-esteem of your students? (yes/no; how)

7.9 Ethics

If you are an external person/institution that wants to carry out AQ projects with schools, please remember that issues might arise around data protection and GDPR. Ensure you provide informed consents for both teachers and students or their legal representatives to sign for whatever kind of data you will collect (including evaluation). Ensure that information you collect cannot be traced back

to any individual person. If your activity is part of a research project, compile a data management plan and ensure you have all relevant documentation and consent forms in place.

8 CONCLUSIONS

8.1 The pilot in relation to the ACTION objectives

This deliverable provides an overview of the activities within the ACTION pilot “air quality projects in high schools”. It describes the preparation, execution and evaluation phases. In this chapter, we would like to share our lessons learned and position the pilot in the context of the ACTION project as a whole.

The pilot on air quality measurement by high school students has been carried out in different schools, in different ways, depending on the teachers and the curriculum. However, the evaluation sheets seem to show that the pilot has been a good way to raise awareness about the topic of air pollution amongst Norwegian high school students. The results also show that the students have learned something new, not only about pollution, but also about technology and its importance for society. A more in-depth evaluation analysis of the activities will be available in deliverable D2.8.

The pilot on air quality has been contributing positively to the objectives of WP2 – Citizen Science Accelerator through providing real world experiences and giving feedback from both students and teachers. This will contribute to shaping and validating the infrastructure, toolkit, training and other resources delivered by WPs 4-7.

The pilot on air quality has further contributed to the ACTION project’s main objectives by:

- contributing to methodologies, tools and guidelines to understand requirements of different stakeholder groups in CS;
- contributing to a digital infrastructure to help citizen scientists easily set up and manage projects in all their online and offline manifestations, manage and share their data openly, and comply with RRI;
- contributing to the socio-technical toolkit;
- partnering with researchers and stakeholders from education to establish a multi-stakeholder ecosystem for responsible citizen science and innovation and promote ACTION and our pilots in this ecosystem to receive valuable feedback and have broad impact.

The high school pilot has further contributed to expanding the canvas of more “traditional” citizen science projects, providing an example of CS on air pollution in education. This kind of project is very beneficial for the students from several perspectives:

1. transdisciplinary learning – natural sciences, technology, human health
2. practical application – building and coding sensors
3. benefit for society – where does pollution come from? What are the effects? How can society be protected from these effects?
4. working in groups – working with other students, distribution of tasks, mutual learning
5. learning how to work scientifically – hypothesis, study design, data collection and analysis, discussion of results and conclusion.

This pilot is contributing to the ACTION infrastructure and toolkit with examples of information material, Arduino codes and measurement data obtained from different student projects. Together with our lessons learned, this “information package” provides useful insight and information for people interested in carrying out similar projects with students.

8.2 Lessons learned

Although NILU has carried out similar activities previously, the school activities related to the ACTION project where quite challenging at times. Here are our lessons learned.

Preparation phase:

- Start with your preparations as early as possible. Teachers have to adapt the activities to the frame of their curriculum.
- Plan as detailed as possible and at the same time leave the teachers as much freedom as possible. They are the experts when it comes to pedagogic skills.
- Continuously offer your help with science and technology. It's useful to establish an uncomplicated forum with quick communication routes (in our case it was a facebook group for the teachers and NILU scientists).
- Prepare all documentation in advance (information sheets, agreement forms, evaluation forms, etc).
- Expectation management: explain the teachers from the beginning what is required from them, when and why. E.g., you will need the collected data after the projects are finished, you will ask both teachers and students to sign an agreement form in the beginning and complete an evaluation form at the end of the project activities; you will pay equipment for all schools up to a certain amount, etc.

Project phase:

- Keep in contact with the teachers and offer your help. We visited some schools to give an introduction about air pollution, help supervising the students and offered visits to NILU so that the students could get insight into the bigger picture of the project work they were doing.

Student conference:

- Include the teachers in the preparation work. In our case, one high school offered their school to be the venue for the student conference
- Arrange for some interesting programme for the students and allow for enough time for the students to present their posters. They have spent several weeks on this and want not only one minute to present it. Arrange for a jury, food and diplomas/awards.

Evaluation:

- An absolutely necessary tool to assess your activities and the outcome
- Important if you plan for another project to learn from the mistakes made

Annex

Annex 1 - Invitation letter for the teachers (in Norwegian)

Annex 2 - Presentation at the teachers' workshop (in Norwegian & English)

Annex 3 - Consent form (in Norwegian)

Annex 4 - Information material about health effects of air pollution (in Norwegian)

Annex 5 - Example presentation for high schools (in Norwegian)

Annex 6 - Examples of scientific posters at the student conference (in Norwegian)

Annex 7 - Evaluation forms for both teachers and students (in Norwegian)

Annex 8 – Example of an Arduino code for Nova SDS011

Annex 1 - Invitation letter for the teachers

Forskningsprosjekt luftforurensning i videregående skoler

Sammendrag

Vi ønsker å involvere elever i måling av lokal luftforurensning ved bruk av Nova PM SDS011-sensorer. Elevene bygger sine egne luftmålesensorer, koder dem og gjennomfører deretter sitt eget forskningsprosjekt med sensorene. Resultatene presenteres bl.a. på Urban Future Global Conference i mai 2019, som arrangeres i forbindelse med at Oslo er kåret til Europas Miljøhovedstad i 2019.

Bakgrunn

NILU – Norsk institutt for luftforskning er partner i det Europeiske forskningsprosjektet ACTION (P**A**rticipatory s**C**ience **T**oolk**I**t against p**O**llutio**N**). I den forbindelse ønsker vi å involvere elever i måling av lokal luftforurensning i sitt nærmiljø. NILU har hatt samarbeid med flere videregående skoler tidligere og har gode erfaringer med å samarbeide med skolene om å lage et opplegg som passer inn i TOF-undervisningen (Elever og forskning i samarbeid om inneklima).

De siste årene har det skjedd en rivende utvikling innenfor mikrosensorer – rimelige sensorer som er små og enkle å håndtere. Vi vet at kvaliteten på disse sensorene er svært varierende og har lavere kvalitet enn referanseinstrumentene som benyttes i den regulære miljøovervåkningen. Som del av EU-prosjektet hackAIR (www.hackair.eu) har NILU testet noen «do it yourself»-luftmålesensorer av type Nova PM SDS011. Resultatene var positive, og derfor ønsker vi å bruke disse sensorene i ACTION-prosjektet.

Vi har pågående prosjekter med to videregående skoler i Oslo/Akershus der elevene bygger Nova PM SDS011-sensorer, koder dem og gjennomfører egne målinger. De ser ut til å være prosjekter som er meget godt egnet til undervisning innen TOF.

Prosjektmål og beskrivelse

Målet er å bevisstgjøre elevene om luftforurensning og sette dem i stand til å endre adferd og gjennomføre egne målinger.

Planen er å organisere en workshop for lærerne der vi informerer om luftforurensning og målemetoder, og viser hvordan man bygger sensorene og koder dem. Materialet brukes deretter i lærernes egen undervisning der elevene bygger sine egne luftmålesensorer, koder dem og deretter gjennomfører sitt eget forskningsprosjekt innen «luftkvalitet». Forskere og teknikere fra NILU vil bistå med nødvendig veiledning og informasjon.

Elevene vil få muligheten til å presentere resultatene på Urban Future Global Conference i mai 2019. Dette er en konferanse som arrangeres i forbindelse med at Oslo er kåret til Europas Miljøhovedstad i 2019.

Tidslinje og tidsbruk (skisse)

Januar	Bestilling av sensordeler
Februar	Workshop for lærere (1-2 dager)
Mars	Besøk på/fra NILU; oppdragsbrev e.l. (1/2 dag per skole)
Mars-April	Elevene bygger/koder sensorene og gjennomfører målinger
Mai	Presentasjoner av resultater (format kan diskuteres – for eksempel UFGC, «student conference», e.l.) (1-2 dager)

Kontakt

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Seniorforsker Nuria Castell

Annex 2 - Presentation at the teachers' workshop

NILU-ACTION lærerworkshop

Sonja Grossberndt
Nuria Castell

NILU-Norsk institutt for luftforskning

10.1.2019

Innhold

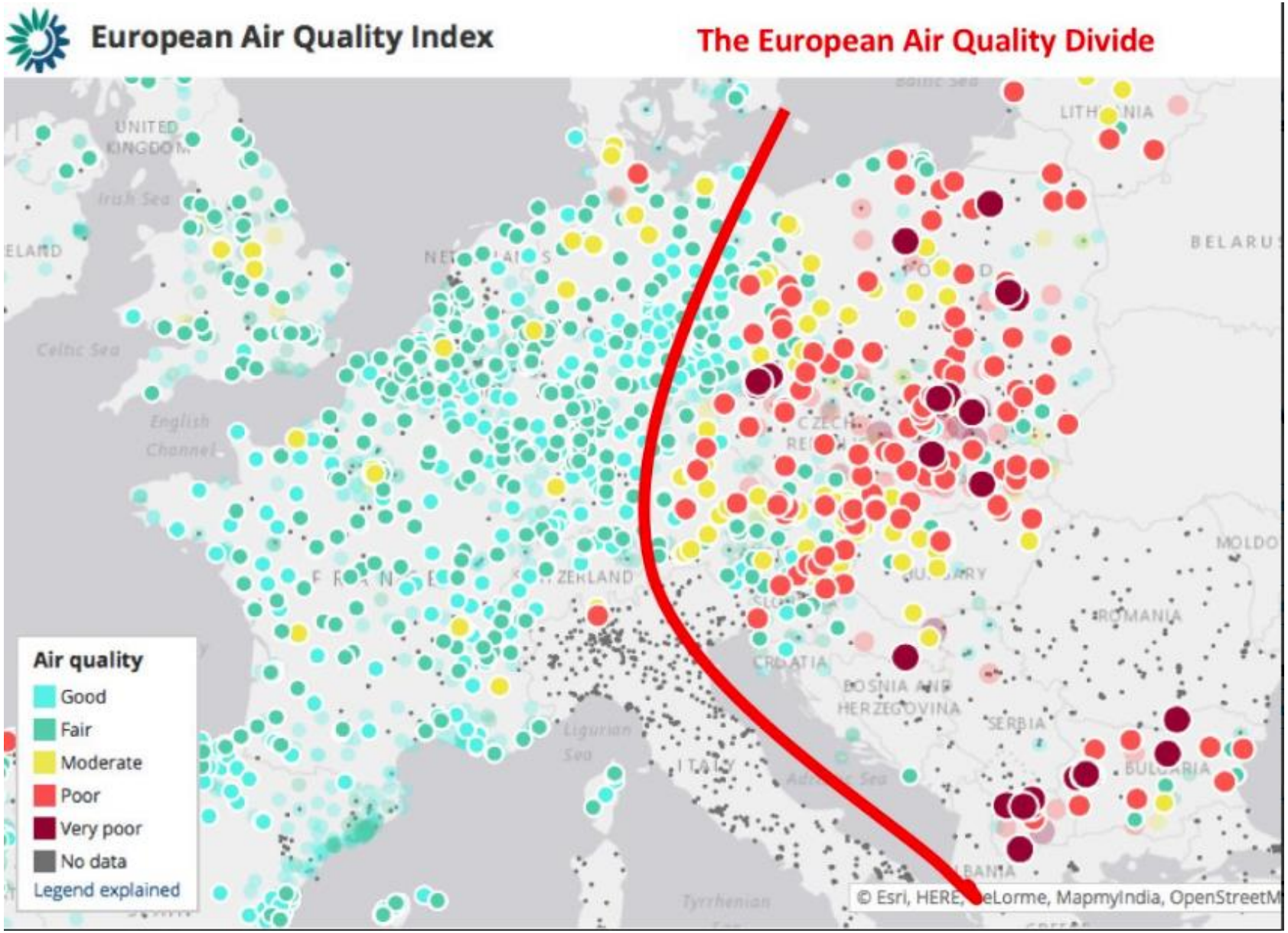
- Luftkvalitet og luftforurensning
- Helseeffekter
- Forurensningskilder
- Hva sier loven?
- Måling og overvåkning av luftkvaliteten
- Hvordan skal man bruke mikrosensorer?

Luften vi puster

Vi puster ca. 10.000 liter luft/døgn → stor betydning for vår helse

Luftforurensning har den største andel sykdomsbyrde fra miljøet, både globalt og I Europa
(Lim et al., 2012; WHO, 2014a)

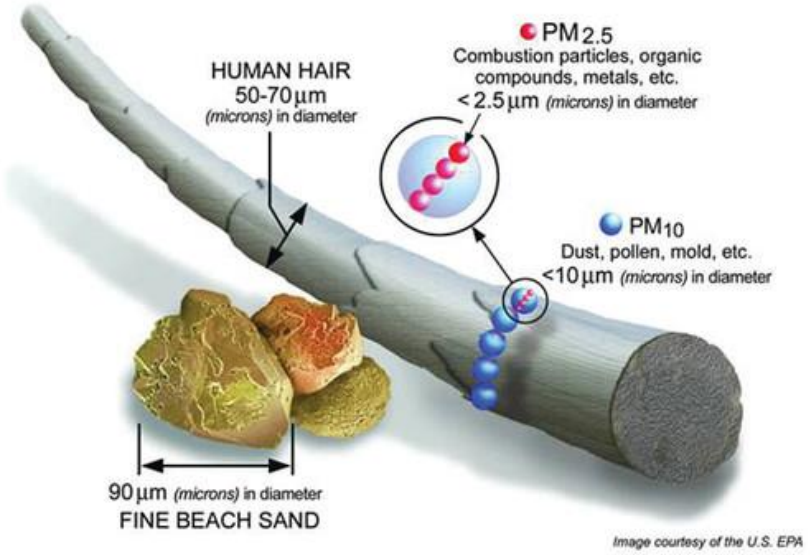
Luftkvalitet i Europa



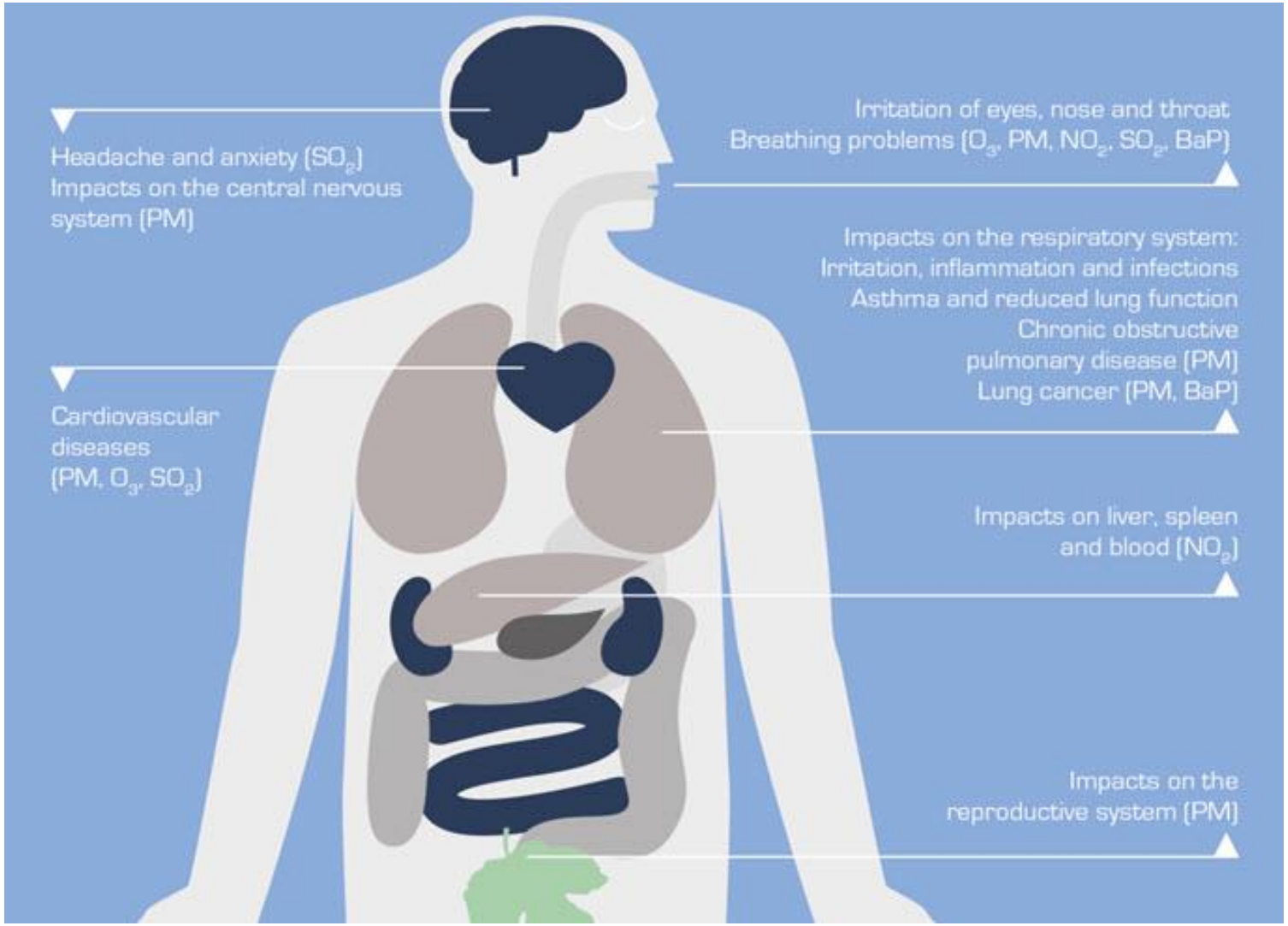
Luftforurensning

- Luftforurensning er en kompleks blanding av partikler og gasser
- Viktigste lokale luftforurensningskomponenter:
  - Svevestøv (PM_{10}, $PM_{2,5}$)
  - Nitrogenoksider (NO_x = NO + NO_2)

Luftforurensning er helseskadelig.



Helseeffekter av luftforurensning



Kilde: European Environment Agency, 2013

NILU

Viktigste forurensningskilder i Norge

Veitrafikk

Industri

Vedfyring

Skipstrafikk

Partikler (svevestøv)	Nitrogenoksider
PM_{10}, $PM_{2.5}$ Ultrafine partikler	$NO_x = NO + NO_2$ NO = nitrogenmonoksid NO_2 = nitrogendioksid
Trafikk, veislitasje, fyring, byggearbeid, industri	Utslipp fra dieselkjøretøy er hovedkilde
Flere kilder – flere muligheter å redusere utslipp	Mindre trafikk og/eller lavutslippskjøretøy

NILU

Aftenposten A-magasinet Osloby Sport Meninger Bli abonnent | Meny

Osloby Restaurantguiden Sulten Byliv

annonse

EFTA COURT

JUDGMENT OF THE COURT
2 October 2015

(Failure by an EFTA State to fulfil its obligations – Directive 2008/50/EC on ambient air quality and cleaner air for Europe – Limit values for certain pollutants in ambient air – Air quality plan)

ULOVLIG: Norge gjør ikke nok for å bekjempe luftforurensning, ifølge den ferske EFTA-dommen. FOTO: ARKIV

Norge felt for dårlig luftkvalitet

Luftkvaliteten i flere områder av Norge er så dårlig at den bryter med EØS-reglene, konkluderer EFTA-domstolen.

Les hele saken med abonnement på Bergens Tidende

Allerede abonnent? Logg inn

NILU

Styringsmål for lokal luftkvalitet i Norge

Grenseverdier

- Minimumsnivå for luftkvalitet som skal overholdes
- Utløser tiltak; juridisk bindende grenseverdier

Nasjonale mål

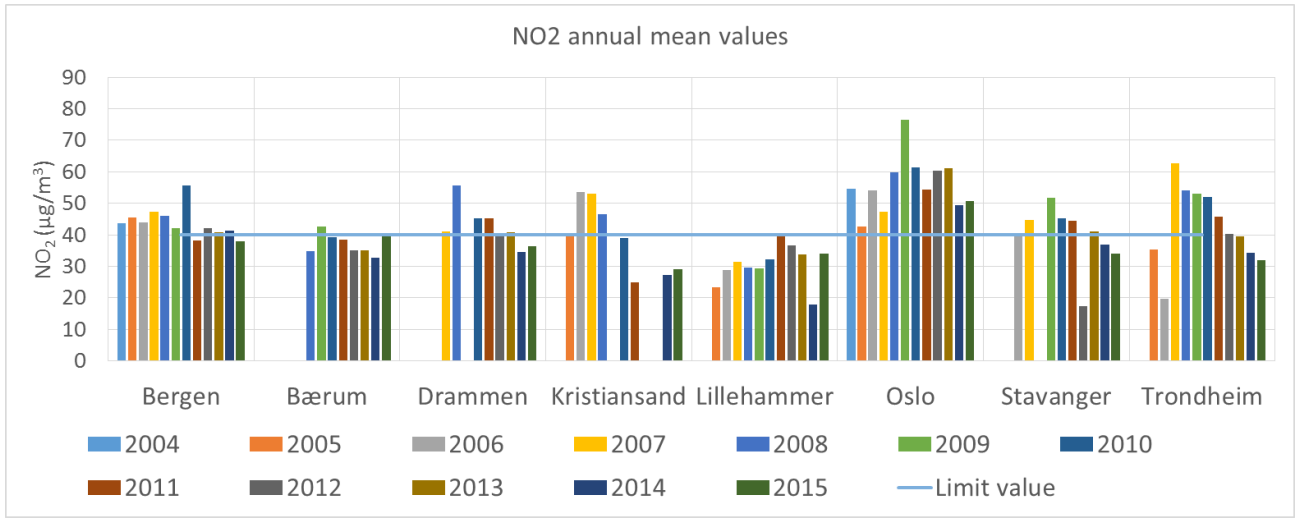
- Regjeringens ambisjonsmål der de fleste befolkningsgruppene beskyttes mot helseeffekter

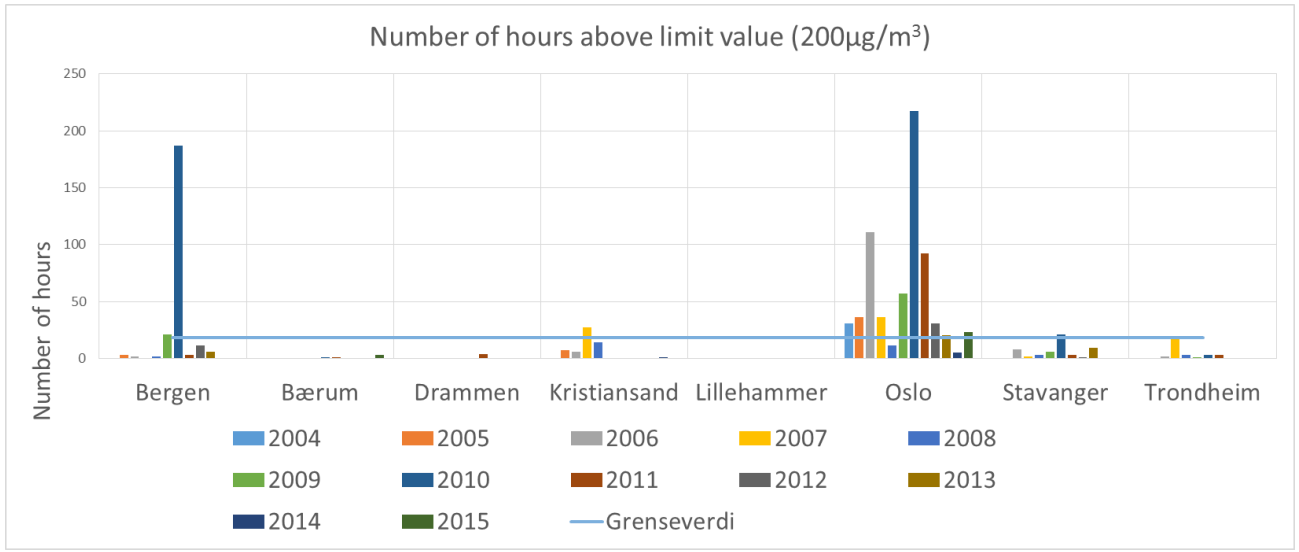
Luftkvalitetskriterier

- Trygt nivå for alle befolkningsgrupper, rene helsemessige vurderinger av luftkvaliteten

NILU

Luftforurensning i norske byer – NO_2





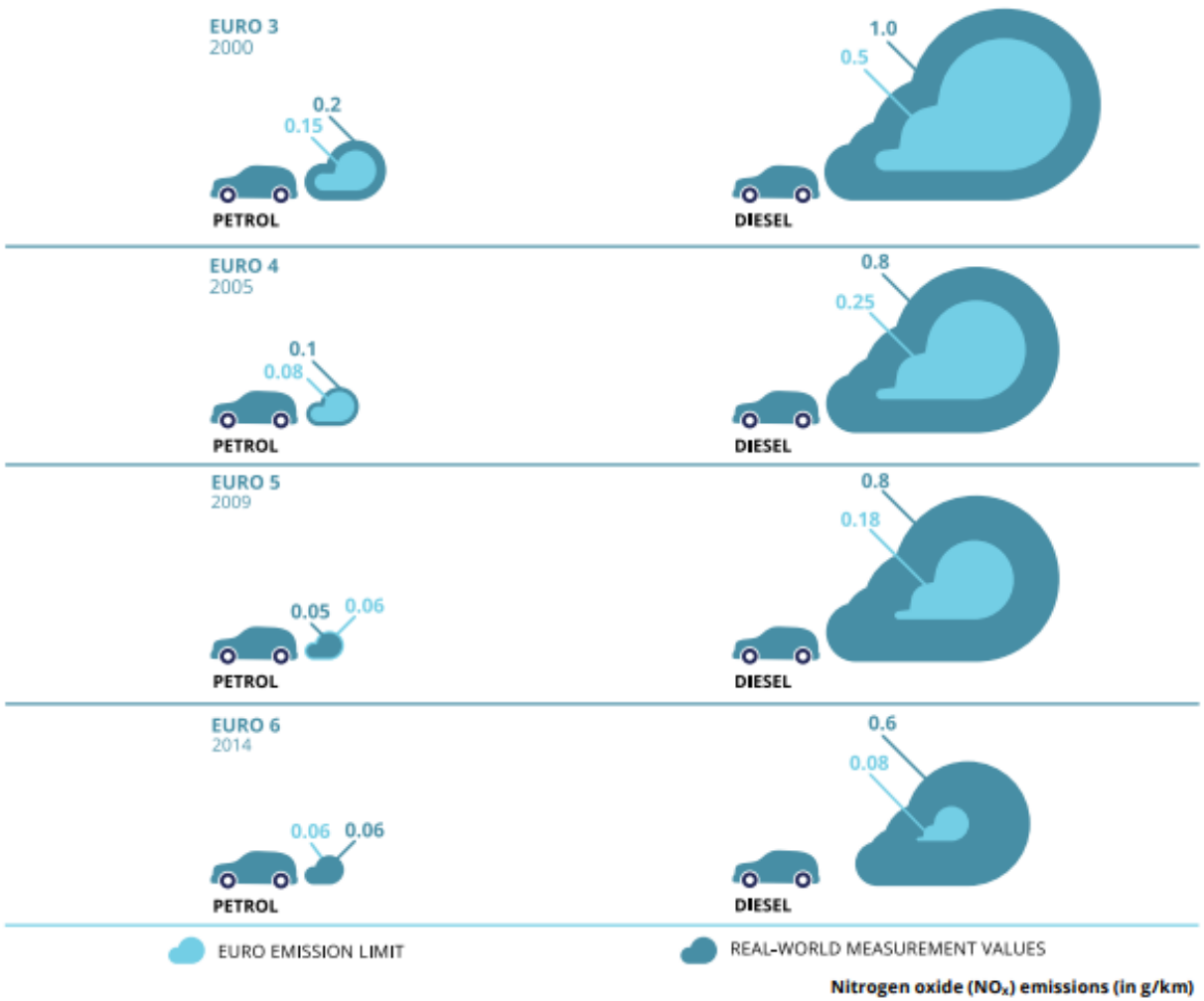
- NO_2 årsgjennomsnitt overstiger grenseverdiene i mange byer

- Antall timer som overskrider grenseverdier for NO_2

Hovedkilde: utslipp fra dieselbiler

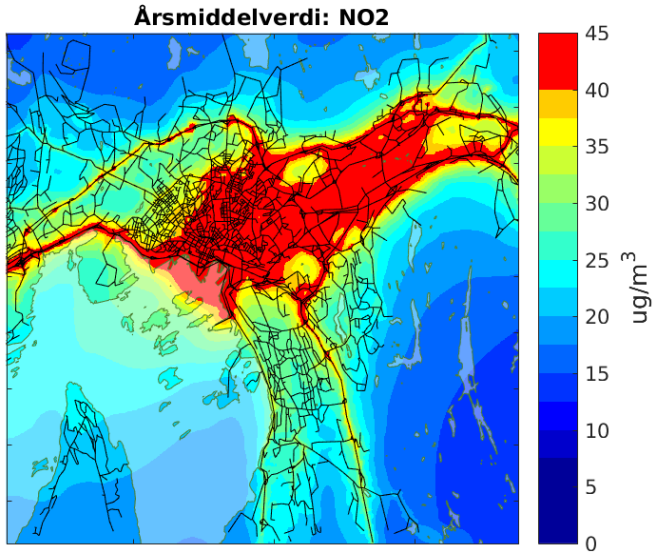
Hvorfor har vi et NO_2-problem?

Figure 6.3 **Comparison of NO_x standards and emissions for different Euro classes**

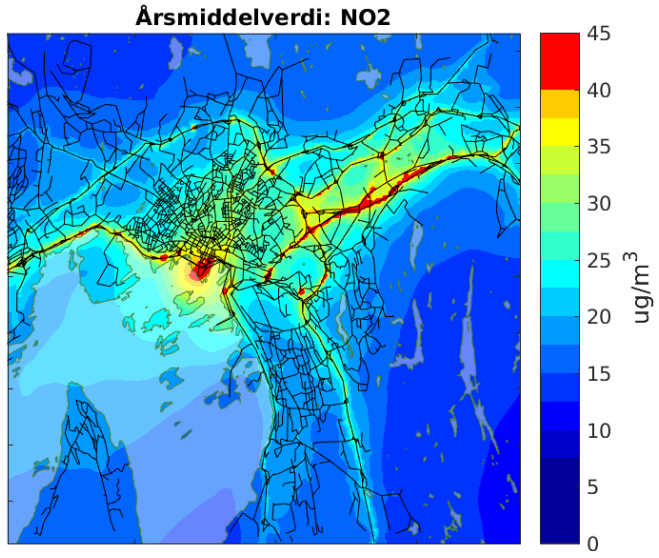


Hvordan blir situasjonen i 2020?

2014



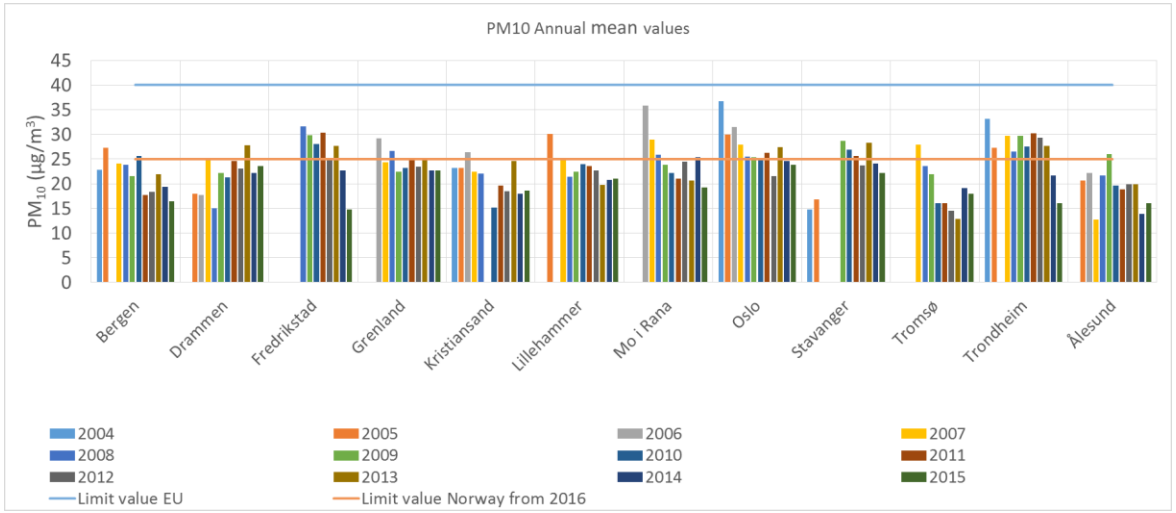
2020

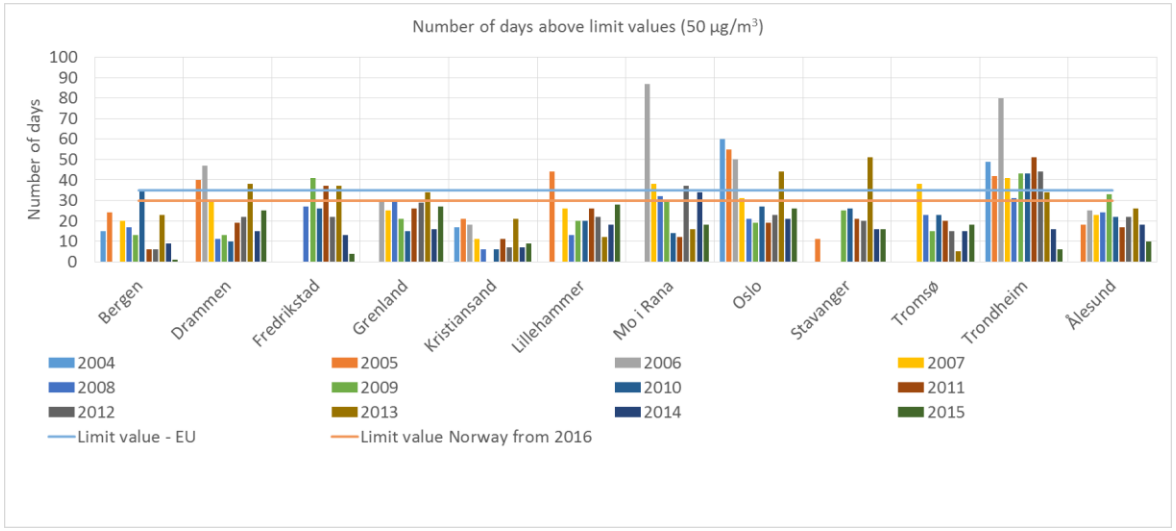


Vi forventer en nedgang av NO_2-konsentrasjoner:

- Euro VI tunge kjøretøy har velidg lav NO_x-utslipp
- Flere elbiler og hybridbiler

Luftforurensning i norske byer – PM_{10}



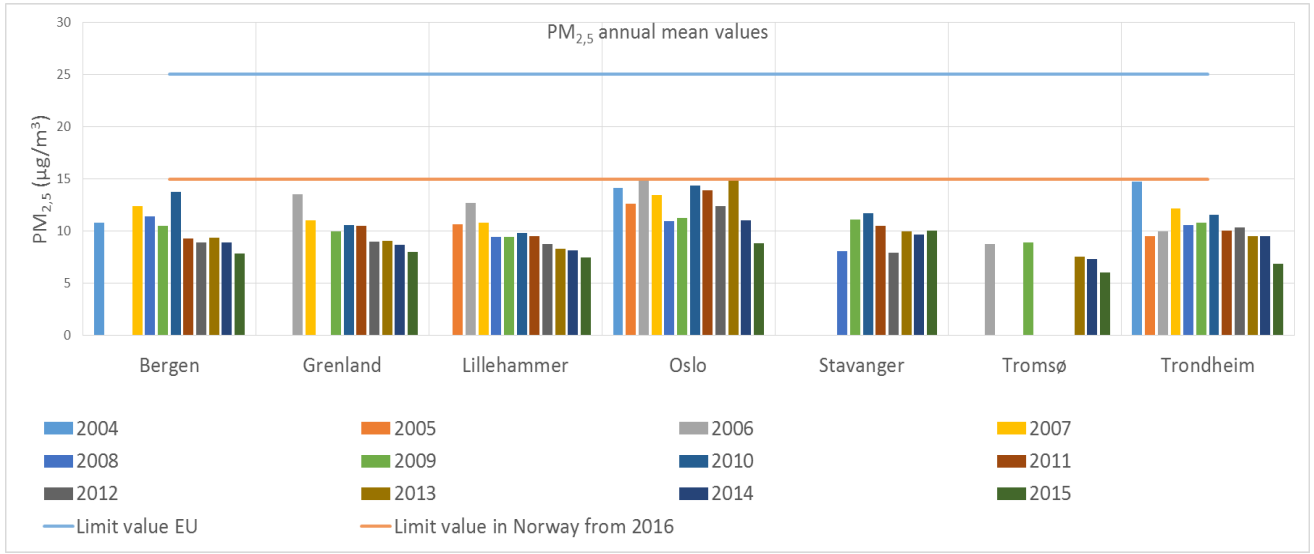


- PM_{10} årsgjennomsnitt i nærheten av/over nye grenseverdiene i norske byer

- Antall dager med overskridelser av grenseverdiene for PM_{10}

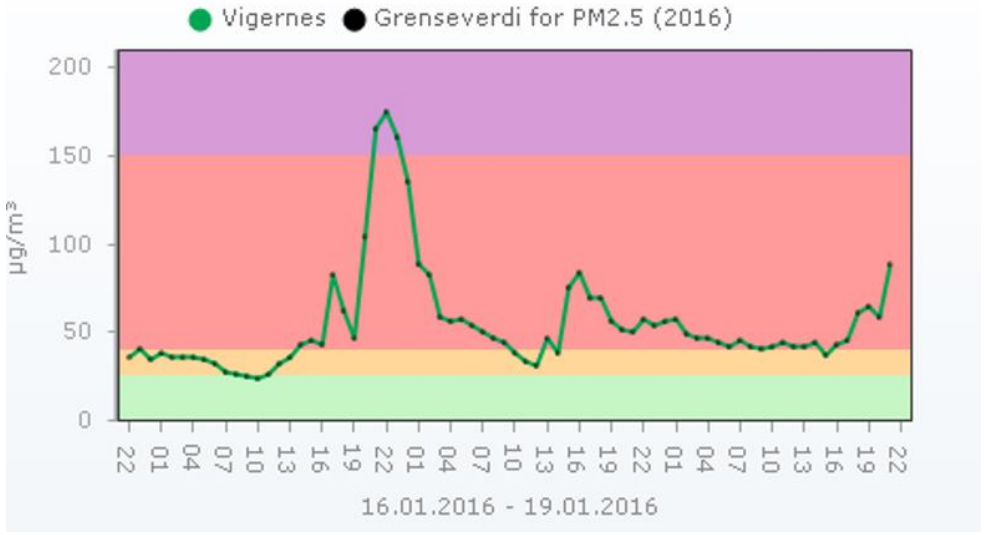
Hovedkilde: Veislitasje

Luftforurensning i norske byer – $PM_{2.5}$



- Årlig gjennomsnittsverdier for $PM_{2.5}$ er lav for alle byer
- Men – under inversjon kan $PM_{2.5}$ verdier være veldig høye

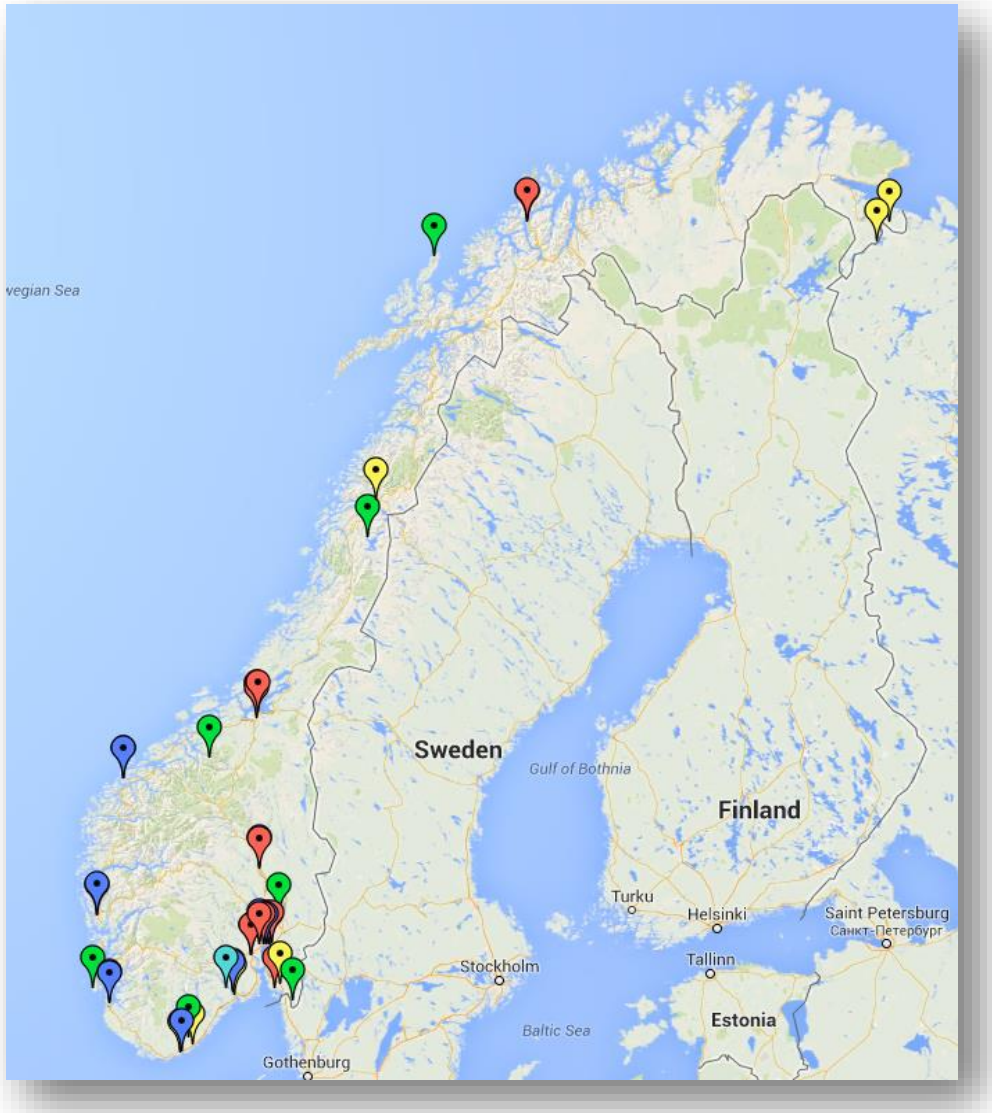
Hovedkilde: Vedfyring



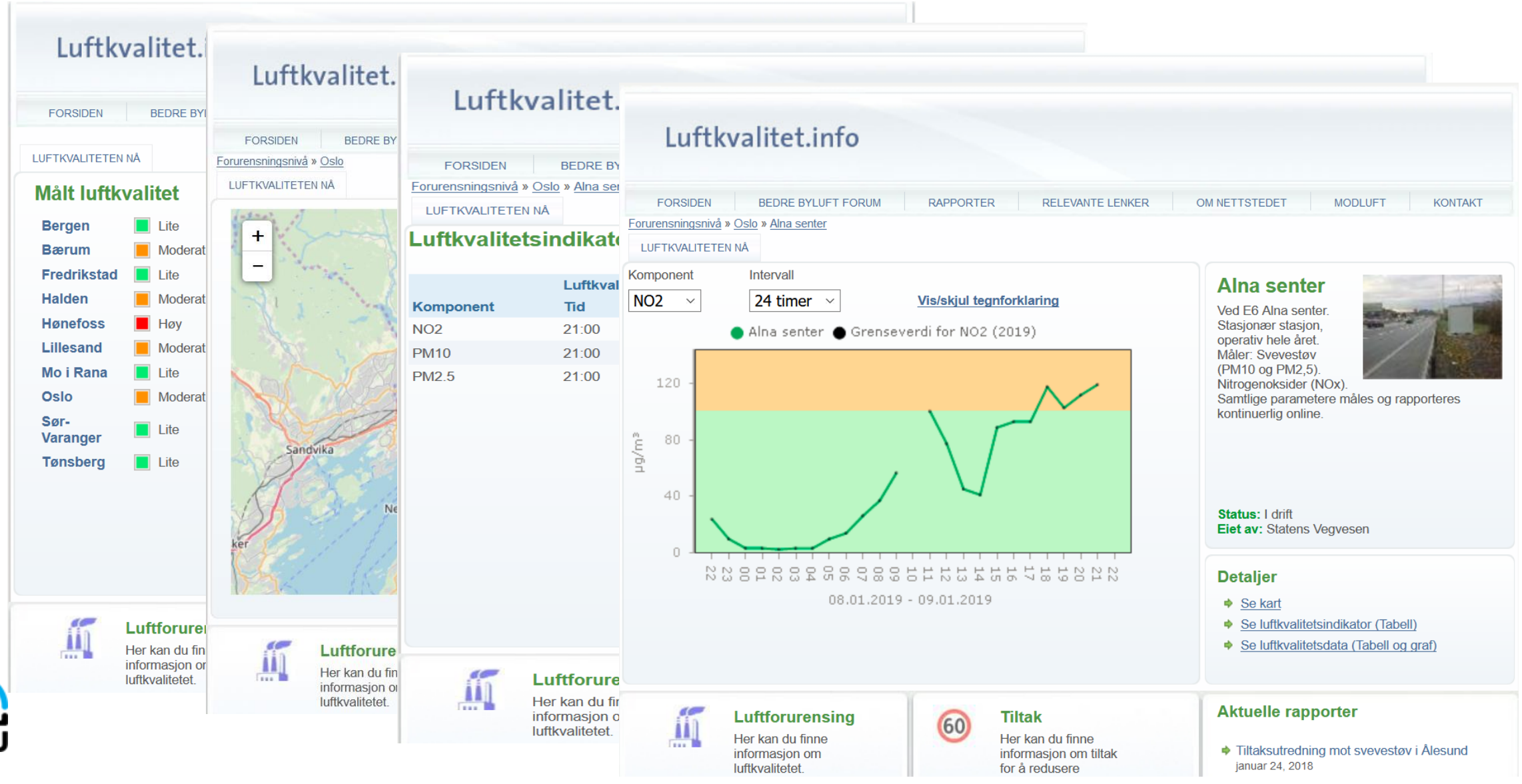
Hvordan måler vi luftkvaliteten?

- Målestasjoner opereres av Statens vegvesen, kommunene og NILU
- 59 målestasjoner over hele Norge:
  - 29 trafikk
  - 13 urban bakgrunn
  - 3 «bynær» bakgrunn
  - 6 industri
  - 8 regional bakgrunn

→ Data fra målestasjonene rapporteres til EU



www.luftkvalitet.info



Tradisjonell luftovervåkning

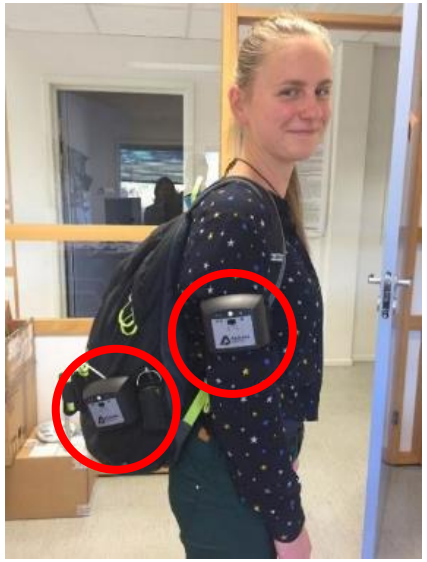
+

- Veldig nøyaktig
- Konsistente dataserier
- Sporbare (kvalitetssikring)
- Arkiv med flere tiårs data fra hele verden

–

- Store, komplekse stasjoner
- Dyrt vedlikehold (?)
- Begrenset antall

Alternative: mikrosensorer



Hvordan fungerer mikrosensorer?

Elektrokjemiske

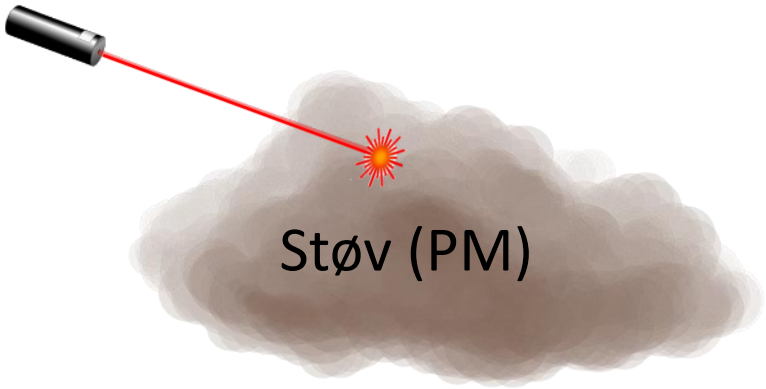
Også:

MOx (Metal Oxide)

-NDIR (CO_2)

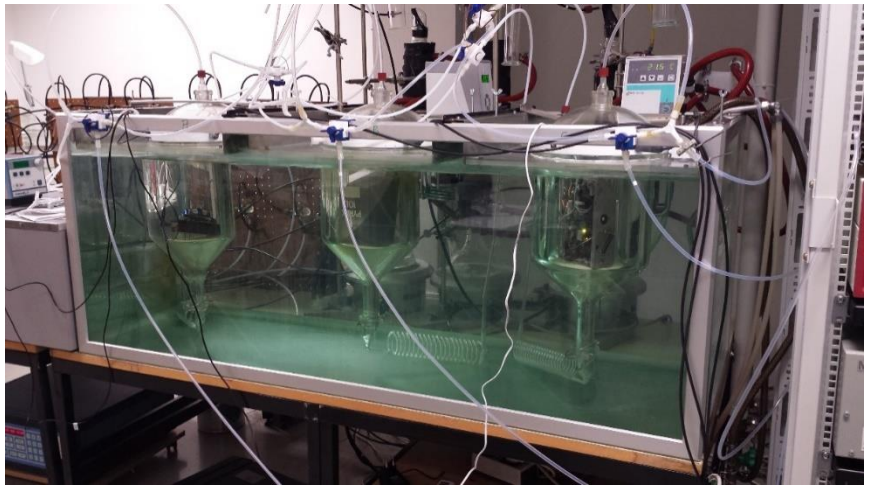
-PID (Flyktige organiske komp.)

Optiske metoder
(lysspredning,
Mie teori)



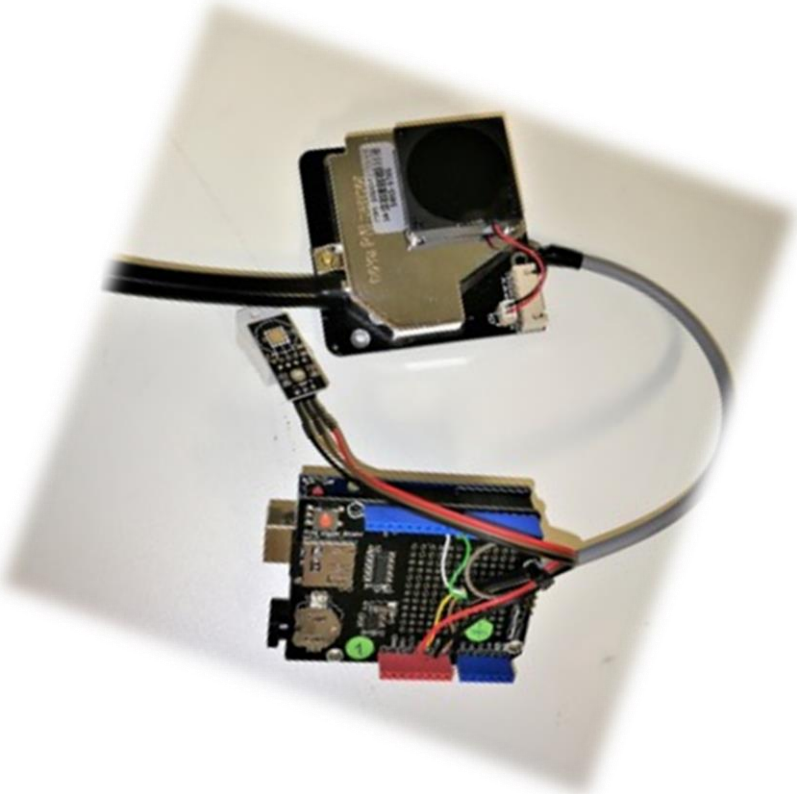
Testing på lab og i felt

- NILU har testet flere mikrosensorer på lab og i felt
- Betydelig lavere korrelasjon i felt enn på lab
- Stor variasjon fra sensorenhet til sensorenhet
- Helt nødvendig å kalibrere hver enkelt sensor i felt
- Sensorene kan endre seg i løpet av den tiden de er samlokalisert som følge av variasjon i meteorologiske forhold og konsentrasjonsnivåer
- Dette kan føre til økt usikkerhet i målingene og avvik som kan være vanskelig å oppdage



Dermed …

- Mikrosensor-teknologien er fremdeles umoden
  - Høy usikkerhet
  - Krever kompleks dataanalyse og expertise
  - Enorme datamengder som må håndteres
- Ikke bare plug-and-play
- Men har stort brukspotensial!
- Viktig å engasjere folk og øke bevissthet
- Like viktig å håndtere forventninger

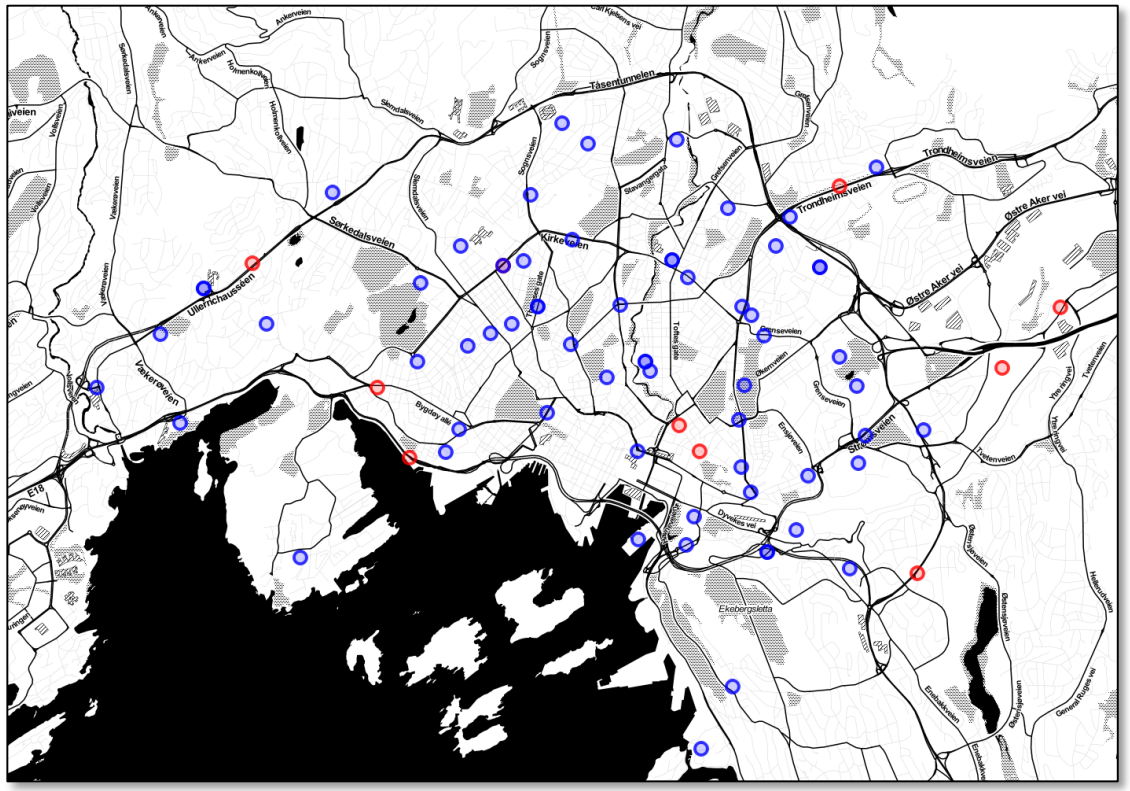


Videre på engelsk …

How to use low-cost sensor systems?

Background

- The low cost and portability of these sensors makes it possible to measure air quality in more locations.
- Many of these sensors can report measurements at a frequency on the order of minutes, or even seconds, making it possible to learn about changes in air quality throughout the day.



Red markers: Locations of Air Quality Monitoring stations for NO_2
Blue markers: Deployment sites of low-cost microsensors

Low-cost sensors may be used to locate pollution hotspots, identify sources of pollution, supplement fixed-site monitoring data, measure personal exposure to pollutants, educate, and enhance air quality awareness.

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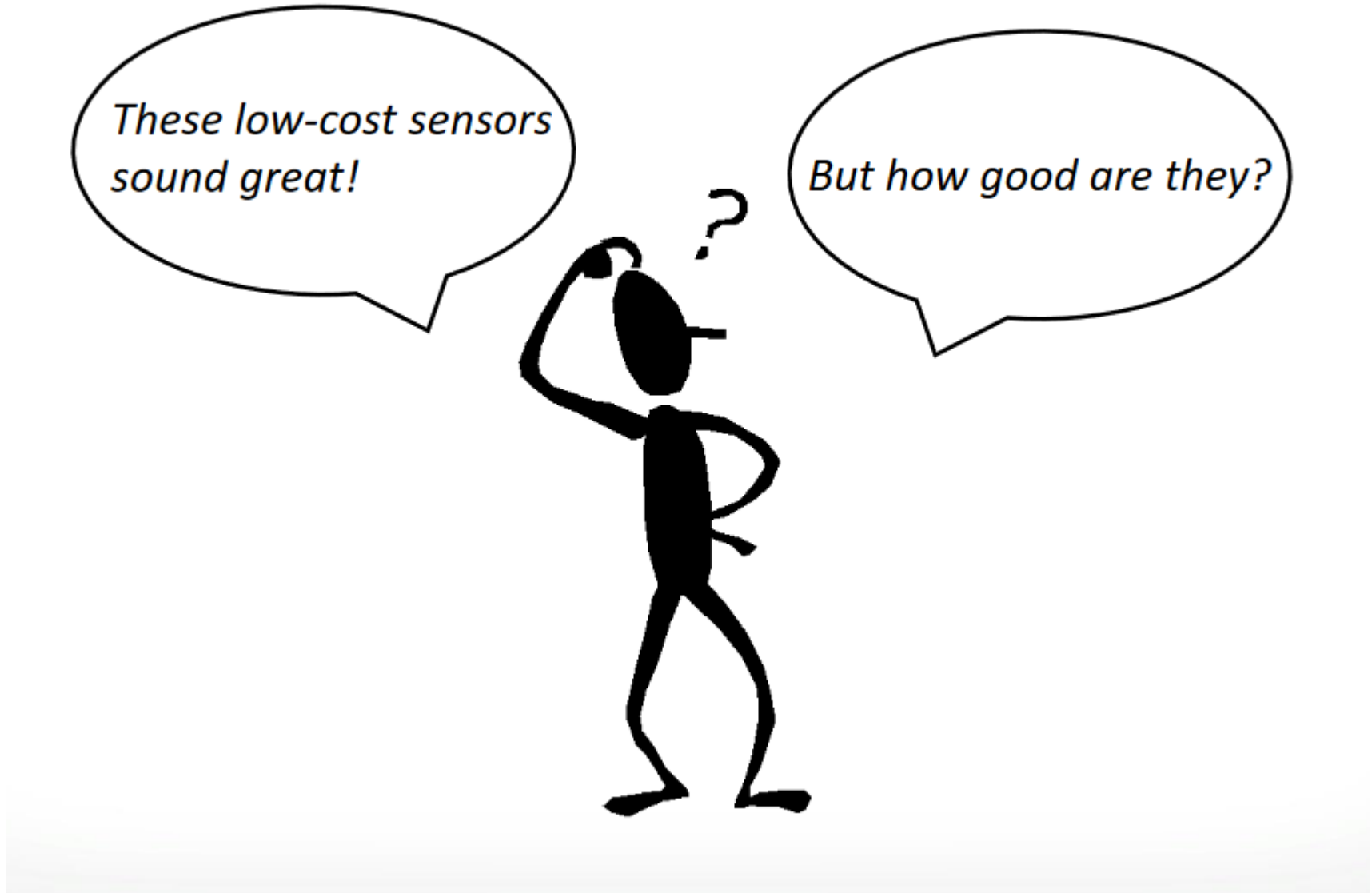
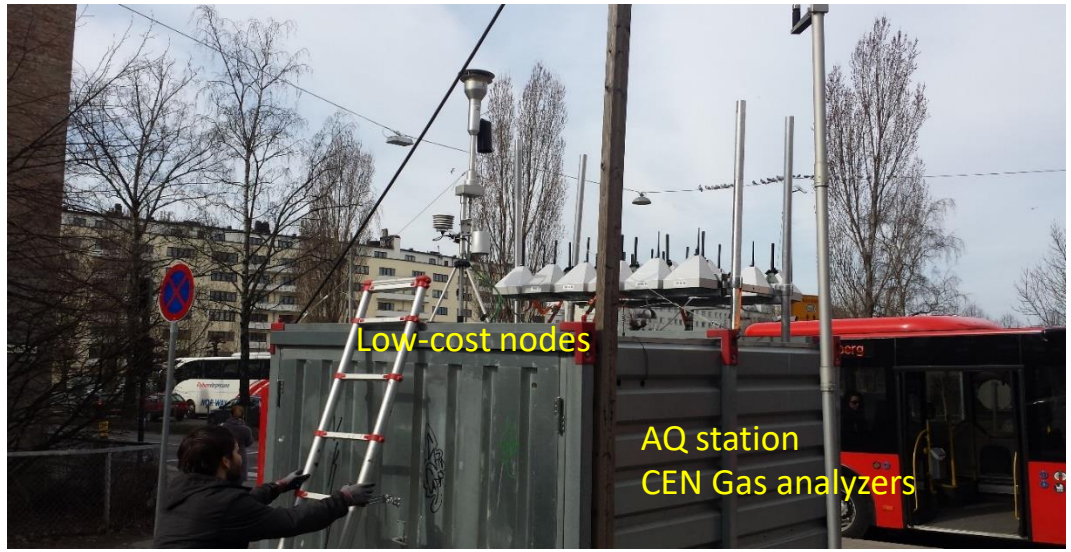

These low-cost sensors sound great!
But how good are they?
?

Evaluating low-cost sensors: collocation

What is collocation?

- Collocation is the process by which a reference monitor and non-reference monitor (sensor) are operated at the same time and place under real world conditions for a defined evaluation period.
- Sensor performance can be evaluated and data accuracy improved by comparing sensor data with reference monitor data.



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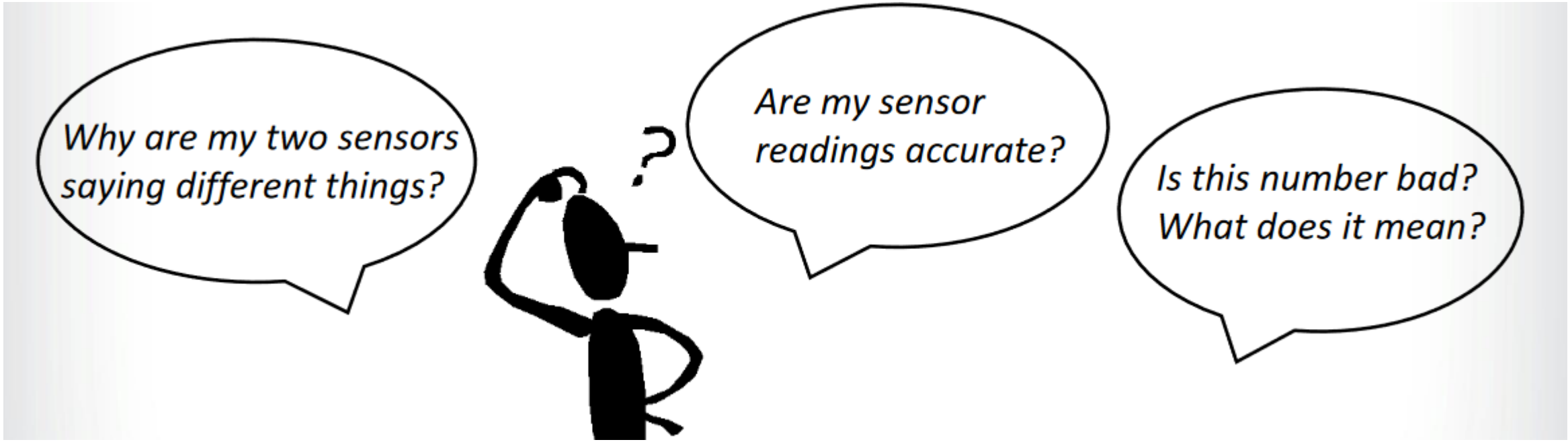

Overview of Quality Assurance for Citizen Science: Ron Williams, EPA

https://www.youtube.com/watch?v=2wCSkaF0sDo&feature=youtu.be

https://www.epa.gov/sites/production/files/2018-01/documents/collocation_instruction_guide.pdf

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Step 3: Data Recovery and Review

Now that I have data, what should I do?

- Once you have data, it's important to review it to evaluate quality and identify problems.
- It's a good idea to review your data during the collection phase to identify problems that may affect your data and correct them, as well as at the end of your data collection to evaluate the whole data set.
- Things to look for when reviewing your data:
  - Abnormally high or low values (outliers)
  - Expected Patterns
  - Interferences
  - Drift or Shift

These features are defined, with examples, on the following slides. Use information and observations recorded in your field notebook to help you understand any problems you find in the data, and to help you decide how to handle them (e.g., exclude certain data points.)

Outliers – data points that look out of place – much lower or higher than nearby data points

	A	B
1	Timestamp	PM 2.5 (ug/m^3)
2	12/7/2016 18:15	33.57
3	12/7/2016 18:20	35.91
4	12/7/2016 18:25	105.69
5	12/7/2016 18:30	110.24
6	12/7/2016 18:35	37.44
7	12/7/2016 18:40	38.16
8	12/7/2016 18:45	38.51
9	12/7/2016 18:50	39.18
10	12/7/2016 18:55	37.32
11	12/7/2016 19:00	38.16
12	12/7/2016 19:05	37.72
13	12/7/2016 19:10	38.14
14	12/7/2016 19:15	0.00
15	12/7/2016 19:20	37.55
16	12/7/2016 19:25	36.57

Field notes confirm I was visiting the sensor and left my car idling. That likely explains these high values.

This zero value is unusual. I wonder if this is a problem with the sensor or maybe data communication. I will keep an eye on the data to see if it happens again.

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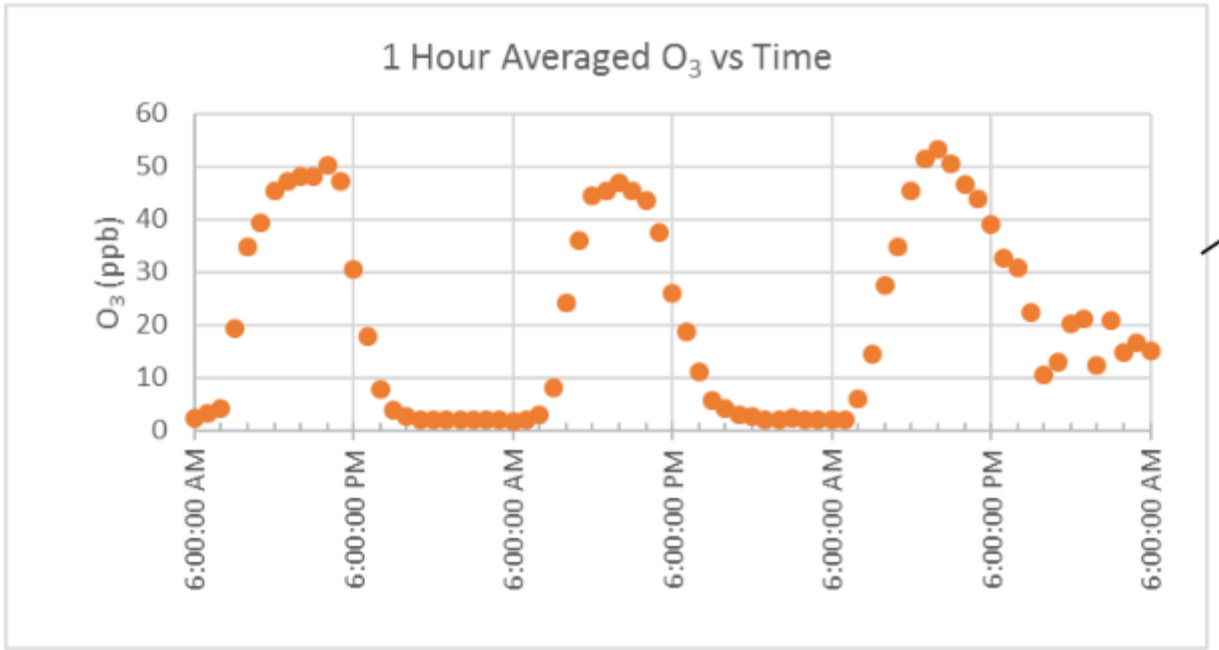
Expected Patterns – could be seasonal, day/night, or weekday/weekend patterns - absence of expected patterns may indicate a problem with your sensor or with your measurement approach



Ozone concentrations peak in late afternoon, as expected.

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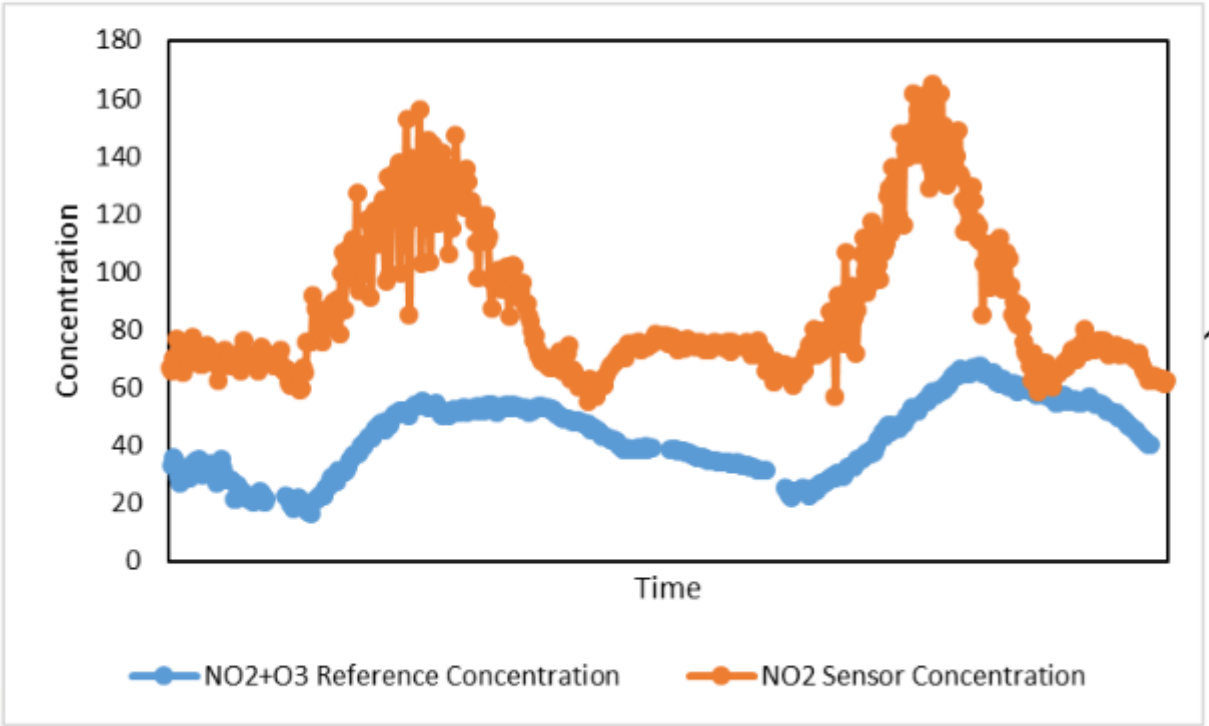
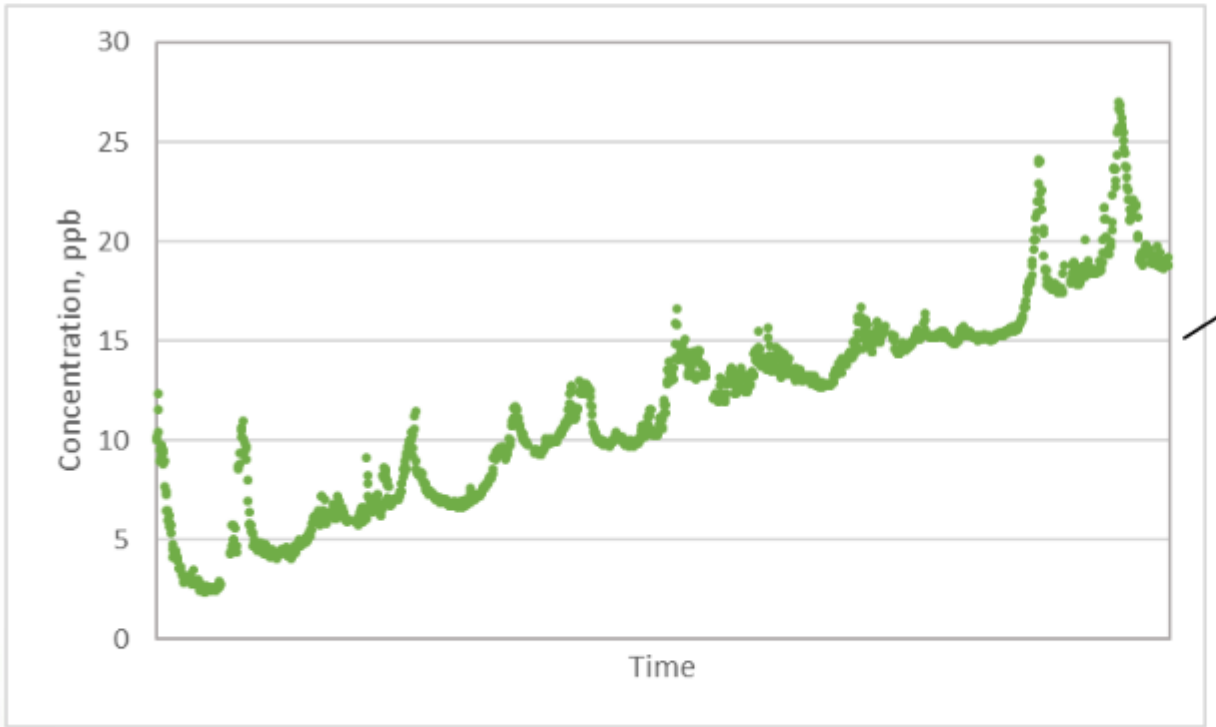
Interferences - may have a positive or negative effect on sensor response - can include pollutants or other chemical compounds that are not of interest, weather conditions, dirt/dust/insects.



The sensor is supposed to be measuring NO_2, but it's reporting concentrations higher than the combined reference NO_2 and O_3 concentrations. Could be a measurement interference.

Drift or Shift - a gradual (drift) or sudden (shift) change in a sensor's response characteristics over time – can be positive or negative - may lead you to wrongly conclude that concentrations have increased or decreased over time



Concentrations reported by the sensor are increasing gradually over time. Looks like the sensors response is drifting.

Click here to go back to the Approach steps slide.

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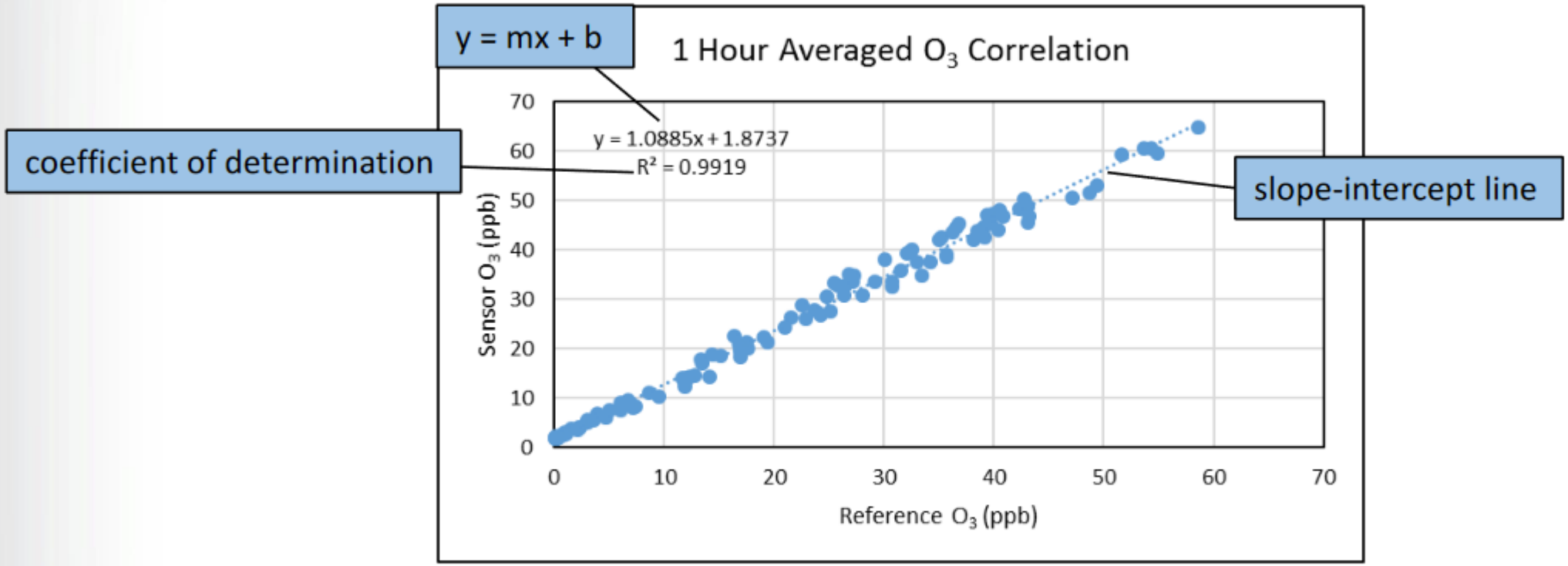
One way to compare the sensor data with the reference data is to plot the data in a correlation graph, as shown here:



The line going through the data is called the "slope-intercept" line and is represented by the equation **y = mx + b**. This equation is a statistical means of comparing the sensor data with the reference data. The **coefficient of determination**, represented by **R^2**, is a measure of how close the data are to the slope-intercept line.

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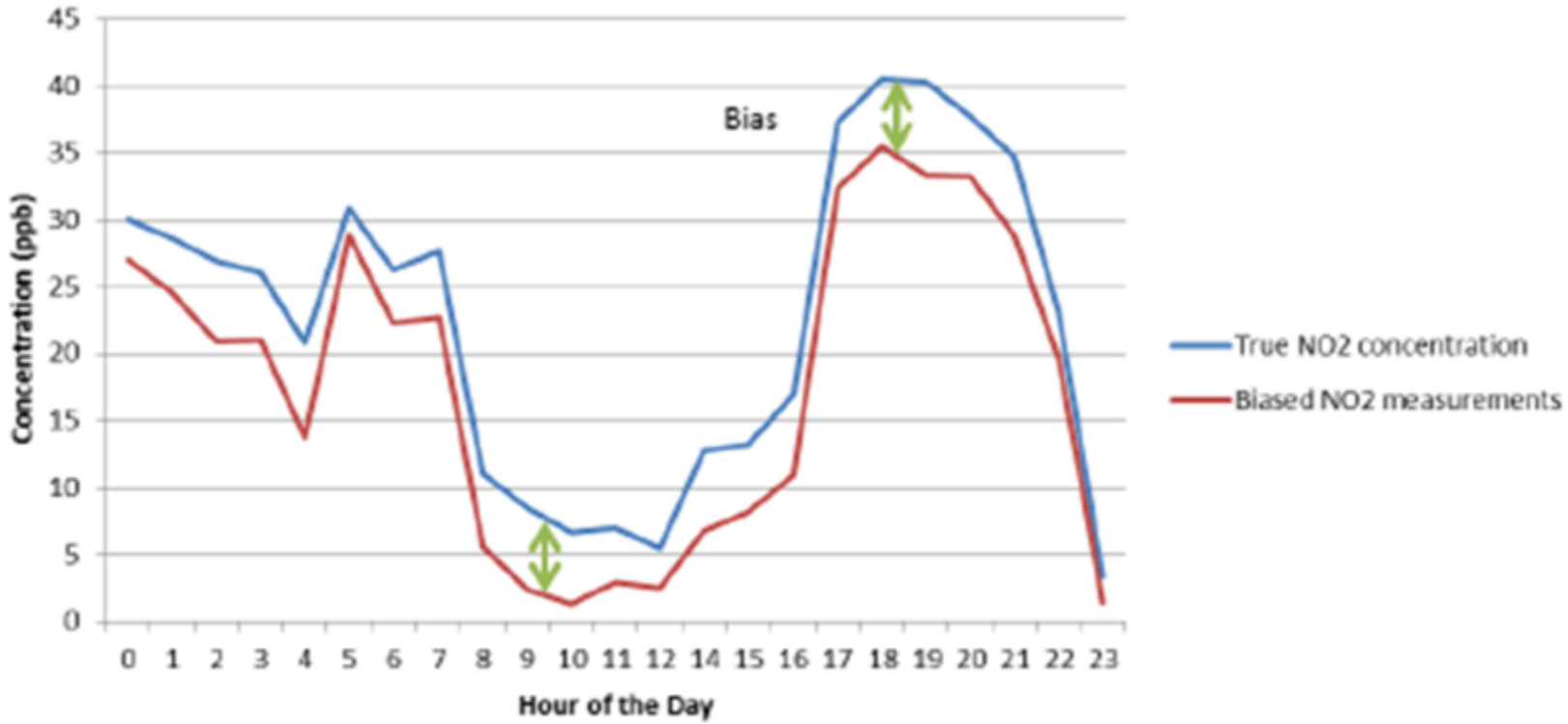
More about bias

Bias is a persistent error in a measurement process that causes all measured values to be too high or too low by a certain amount, compared to the true (reference) value. This is the *intercept* value in the slope-intercept equation y = mx + b.



Comparison of a true value of NO2 and biased measurements of NO2.

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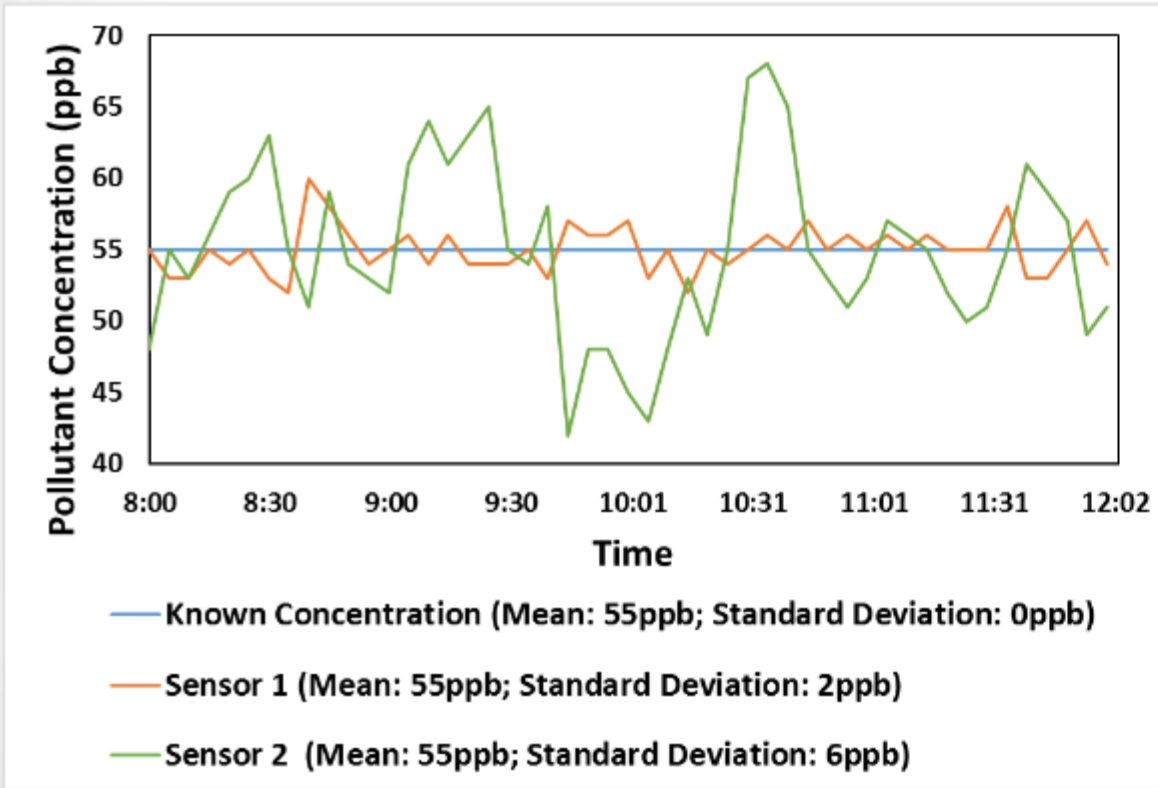
More about precision

Precision is a measure of how close repeated measurements are to each other. It could be the same device making repeated measurements under the same conditions, or several of the same type of device making measurements at the same place and time.



What is standard deviation?

Standard deviation is a statistical measure of precision to describe how spread out numbers are. It is calculated by taking the square root of the *variance*.

And what is variance?

Variance is the average of the squared differences from the mean. *Mean* is just another word for average.

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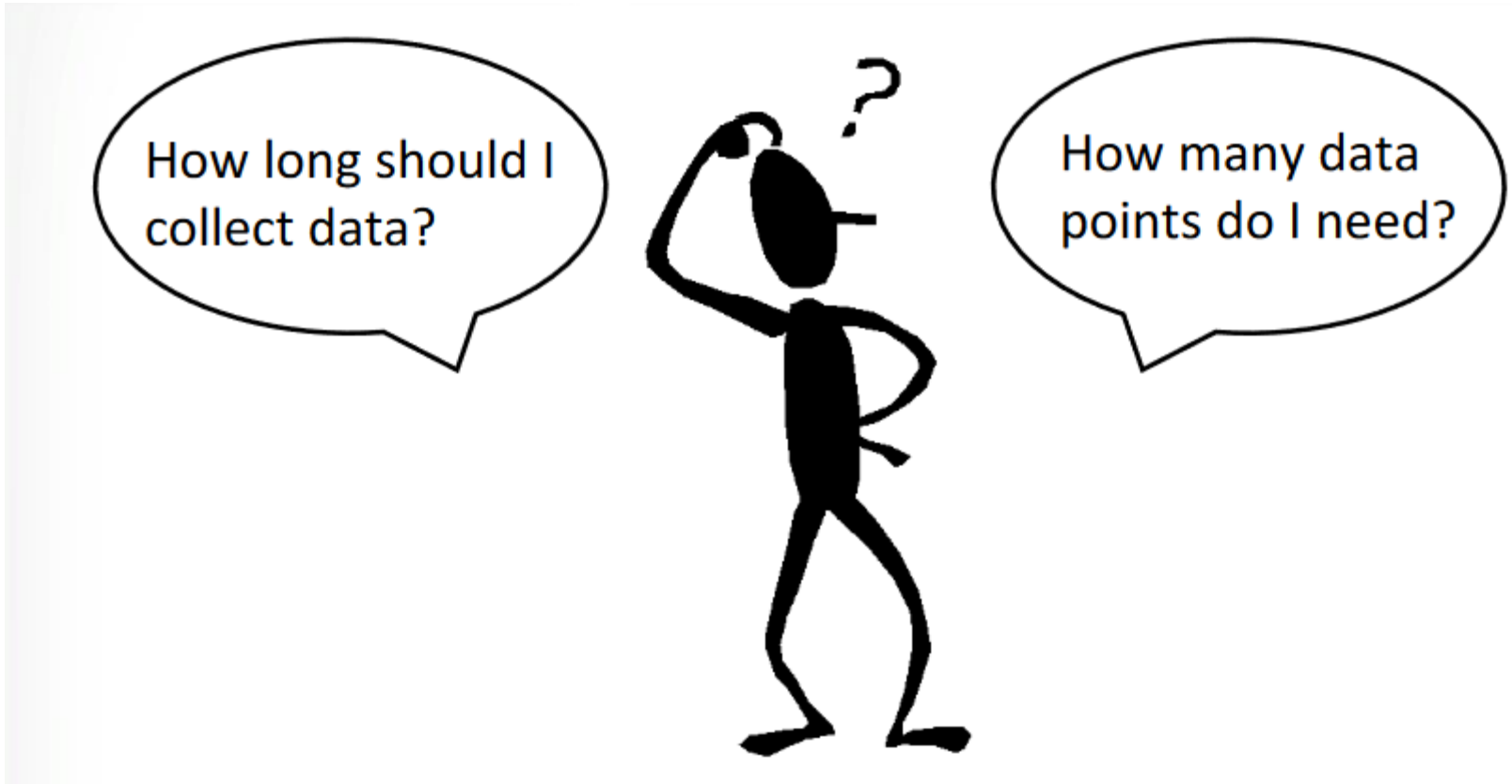
How long should I collect data?
How many data points do I need?

For how long we will measure in a certain location will depend on what is our purpose. However, we need to ensure that our measurement is representative.

TIPS:

- If your sensor is static, leave it in the location for at least 3 days, better if over a week
- If your sensor is mobile, do the same route several times on different days and time of the day

Luftkvalitet.info

Tabell 1. Varslingsklasser for PM_{10}, $PM_{2,5}$, NO_2, SO_2 og O_3

Varslings-klasser	Forurensnings-nivå	Helserisiko	PM10 *Døgn* (µg/m³)	PM2,5 *Døgn* (µg/m³)	PM10 *Time** (µg/m³)	PM2,5 *Time** (µg/m³)	NO_2 *Time* (µg/m³)	SO_2 *Time* (µg/m³)	O_3 *Time* (µg/m³)
	Lite	Liten	< 30	< 15	< 60	< 30	< 100	< 100	< 100
	Moderat	Moderat	30 - 50	15 - 25	60 - 120	30 - 50	100 - 200	100 - 350	100 - 180
	Høyt	Betydelig	50 - 150	25 - 75	120 - 400	50 - 150	200 - 400	350 - 500	180 - 240
	Svært høyt	Alvorlig	> 150	> 75	> 400	> 150	> 400	> 500	> 240

* Timenivåene for PM10 og PM2,5 er vurdert ut ifra statistisk sammenheng mellom døgnet høyeste timemiddel og tilsvarende døgnmiddel. Timenivåene ble endret desember 2018 etter en ny statistisk evaluering.

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Takk for oppmerksomheten!

Ved spørsmål ta kontakt med sg@nilu.no eller ncb@nilu.no

Annex 3 - Consent form

SAMTYKKEERKLÆRING

Kjære deltager,

Du har blitt spurt om å delta i forskningsprosjektet ACTION. Denne samtykkeerklæringen inneholder informasjon som kan hjelpe deg med å avgjøre om du ønsker å delta eller ikke. Deltagelse er helt frivillig, og hvis du ikke lenger ønsker å delta i prosjektet etter å ha lest gjennom dette skjemaet, står du fritt til å trekke deg. Selv om du signerer denne avtalen kan du trekke deg når som helst om du ønsker det. Spørsmål kan rettes til kontaktpersonen oppgitt nedenfor.

Formålet med prosjektet

Mange europeiske innbyggere bekymrer seg over luftforurensing, og føler at de ikke vet nok om luftkvaliteten der de bor. Det europeiske forskningsprosjektet **ACTION** har som mål å gi innbyggere mulighet til å gjennomføre egne luftkvalitetsmålinger og gjennom dette øke kunnskap og bevissthet om tematikken. I denne sammenheng skal vi gjennomføre aktiviteter i samarbeid med elever på videregående skoler i Oslo og Akershus. Aktivitetene vil være spesielt tilrettelagt for elever som tar Teknologi- og forskningslære (TOF).

Beskrivelsen av aktiviteten

Målet med aktiviteten er at TOF-elever skal få mulighet til å bygge sin egen luftmålesensor, gjennomføre målinger og evaluere måleresultatene. Resultatene skal presenteres på en elevkonferanse i slutten av semesteret. Vi vil ta en del bilder av utstyr og elevene gjennom aktivitetene og på konferansen. Bildene skal kun brukes til kommunikasjonsformål og uten å bruke navn på deltakerne. Ønsker du ikke å være med på bildene kan du reservere deg mot dette nedenfor. Etter elevkonferansen vil vi be deg om å fylle ut et evalueringsskjema.

Personvern og konfidensialitet

All personlig informasjon behandles strengt konfidensielt. Behandling av evalueringsskjema skal skje anonymisert og besvarelsene vil ikke kunne spores tilbake til den enkelte elev (navn skal ikke oppgis).

Samtykke

Jeg har lest og forstått informasjonen over. Jeg gir mitt samtykke til å delta i aktiviteten. Ved å signere bekrefter jeg at jeg er minst 18 år gammel og at jeg har fått en kopi av dette skjemaet. I det tilfelle at jeg ikke har fylt 18 år enda, har en av mine foresatte signert dette skjemaet for meg:

Navn: _____

Dato: _____

Underskrift: _____

Det er greit at det blir tatt bilder av meg under prosjektaktivitetene.

Ja ☐ Nei ☐

Kontaktinformasjon

Sonja Grossberndt NILU – Norsk institutt for luftforskning Instituttveien 18, 2007 Kjeller	Telefon: 63 89 82 45 E-post: sg@nilu.no

Annex 4 - Information material about health effects of air pollution

Norsk institutt for luftforskning
Norwegian Institute for Air Research

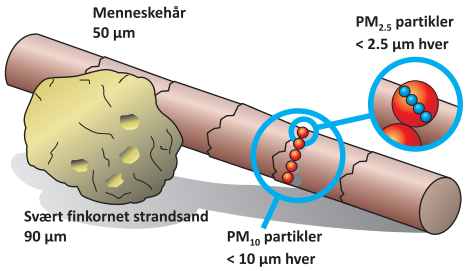
3/2014 N

Svevestøv – hva er det egentlig?

Svevestøv er støv som oppholder seg i luften over en viss periode. Det kalles også for PM (Particulate Matter).

PM_{10} og $PM_{2,5}$

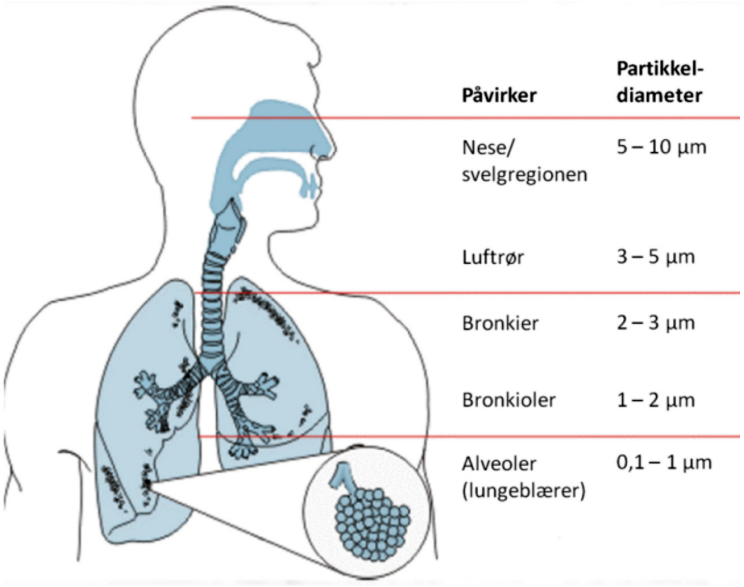
Svevestøvet deles vanligvis i to kategorier: PM_{10} og $PM_{2,5}$. Tallet angir størrelsen i mikrometer (1 µm = 1/1000 mm = 1/10 000 cm = 1/1 000 000 m). PM_{10} kommer først og fremst fra mineraler, som fra slitasje på vei etter piggdekkavriving og oppvirvling, men kan også være av naturlig opprinnelse (pollen). $PM_{2,5}$ er en type svevestøv som for det meste inneholder partikler fra forbrenningsprosesser som vedfyring og eksos. Dieselkjøretøyer bidrar særlig med utslipp som skaper svevestøv av denne typen.




Svevestøv som virvles opp fra veibanen.
Foto: Stein Manø

Kilder

Ca 44 % av PM_{10} utslippet i Norge skyldes biltrafikken (eksos). I tillegg kommer partiklene fra veislitasje fra veidekk. Noe av dette støvet virvles opp og kan bli et miljøproblem. Det meste av støvet består av grove partikler som faller ned nær kjørebanen (innenfor de nærmeste 10 til 20 meterne). Mindre enn 10 % av støvet blir svevestøv (PM_{10}) og bidrar til luftforurensning på en større skala. I tillegg til partikkelutslipp fra trafikken, kan utslippene fra fyring (særlig bruk av ved og annet fossilt brensel) være betydelig




Svevestøv fra utslipp fra industri og vedfyring.
Foto: Stein Manø

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www.nilu.no

på kalde vinterdager. I Norge står denne oppvarmingen for ca. 47 % av PM_{10}-utslippene.

Hvordan partiklene påvirker helsen

Partiklenes egenskaper som kjemisk sammensetning, størrelse, form og antall, påvirker hvor de avsettes, hvor lenge de forblir i kroppen og hvordan de påvirker helsen. Svevestøv er særlig knyttet til økt hyppighet og forverring av luftveisproblemer (hoste, bronkitt og bihulebetennelse) og hjerte- og karsykdommer. Svevestøv kan også forverre sykdom hos folk med kroniske luftveislidelser, eldre og små barn med luftveissykdommer. De kan også være bærere av stoffer som gir økt forekomst av allergier og kreft.

Svevestøv fra utslipp av bensinmotorer og slitasje av veibanen.

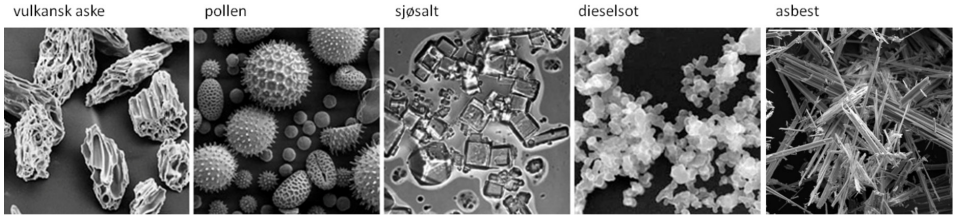
Grenseverdier

I tabellen nedenfor oppgis varslingsklasser for partikkelkonsentrasjoner i gjennomsnittlig timeverdi, med benevningen i mikrogram pr. kubikkmeter ($\mu g/m^3$). En kubikkmeter luft veier ca. 1 kg.

Konsentrasjon	Helsevirkninger knyttet til luftforurensning	PM_{10}	$PM_{2,5}$
Svært mye	Svært stor helserisiko	>200	>100
Mye	Helserisiko forekommer i visse områder	100-200	50-100
Noe	Moderat helserisiko	50-100	25-50
Lite	Liten helserisiko	<50	<25

Hvordan partikler ser ut

Utseendet av partikler varierer sterkt, som man kan se i bildene nedenfor. Avhengig av partiklenes sammensetning kan man skille partikler ved å betrakte de gjennom mikroskopet.



Kilde: *www.luftkvalitet.info*

Tiltak

Det finnes en rekke tiltak for å redusere utslipp av svevestøv:

Redusere lokal trafikk ved for eksempel veiprising, parkeringsrestriksjoner eller kollektivsatsing.

Renhold av gatene ved å fjerne støvdepotet i rennesteinen.

Nedsatt hastighet vil redusere danningen av piggdekkstøv, fordi det reduserer turbulensen bilene skaper og kraften som piggene slås ned i asfalten med. Permanent nedsatt hastighet er mer kostnadseffektivt enn nedsatt hastighet som akuttiltak.

Utslippsreduserende tiltak som tekniske tiltak for å redusere eksosutslipp fra kjøretøy for eksempel eller forbedring av kvaliteten på bensin og diesel.

Drivstoff kan bli erstattet med alternative drivstoff, for eksempel gass, hydrogen eller elektrisitet.

Piggdekkgebyr kan redusere bruk av piggdekk.

Vedfyring kan forbedres ved å installere nye rentbrennende ovner, renseenheter på piper eller montering av etterbrennere i eldre, forurensende ovner. Lovgiving kan bidra til reduksjon av utslipp av svevestøv fra nye vedovner.

Norsk institutt for luftforskning
Norwegian Institute for Air Research

Når er det mest forurensning i lufta vår?

Her i Norge nyter vi godt av stort sett frisk luft og sunt miljø. Vi er heldige!
Men det hender at vi opplever dager med mye luftforurensning – kan du gjette når det er?

Det er om vinteren. Da er det flest aktive kilder til forurensning, blant annet vedfyring og piggdekkbruk.

Ett av de viktigste stoffene som bidrar til lokal luftforurensning i norske byer er nitrogenoksider (NO og NO_2, omtalt som NO_x). Dette er reaktive gasser som dannes ved forbrenning, og eksos fra tunge og lette dieselkjøretøy er den dominerende kilden.

En annen viktig forurensningstype er svevestøv, som deles inn etter størrelse. $PM_{2,5}$ er partikler mindre enn 2,5 mikrometer, og lokale kilder er vedfyring om vinteren, veistøv og eksos. PM_{10} er partikler mindre enn 10 mikrometer, med veistøv fra piggdekkbruk som hovedkilde. Noe kommer også fra eksos og vedfyring.

Om vinteren kjører vi bil, vi bruker piggdekk og vi fyrer med ved. Dermed kan svevestøvnivåene bli høye. I tillegg slipper kalde bilmotorer i kuldegrader ut litt mer NO_2 enn ellers.

Kulda jobber mot oss
Årstid og meteorologi spiller også en stor rolle for luftkvaliteten. Vinteren er den verste tiden på året når det gjelder luftforurensning, fordi det oftere er værtyper som gjør at konsentrasjonene av forurensende stoffer blir høyere.

Noen ganger får vi såkalt «inversjon» over lengre tid, et værfenomen der temperaturen øker jo høyere du kommer i troposfæren (i stedet for det vanlige, at det blir kjøligere høyere opp), og den kalde lufta legger seg nærmest bakken. Kald luft er tyngre enn varm luft, så et luftlag med en inversjon er svært stabilt, og fungerer som et «lokk» over byen. Dermed blir forurensningen nede ved bakken fanget der, og dersom inversjonen varer i flere dager vil luftkvaliteten stadig bli dårligere.

Skifter fra time til time
Mengden forurensning i lufta henger sammen med antallet aktive utslippskilder. I rushtidsperioden, når det er mange biler og mye trafikk i en gitt periode, begynner nivåene av både svevestøv og NO_2 å stige rundt kl. 07 om morgenen. Så dabber det raskt av igjen fra kl. 09, før vi får en ny forurensningstopp under ettermiddagsrushet mellom kl. 15 og 17.

Tilsvarende ser vi at det er mest forurensning i form av det fine svevestøvet fra vedfyring om ettermiddagen og kvelden. Det er jo fordi vi som regel fyrer opp i peisen når vi kommer hjem fra jobb og skole.

Været kan også bidra til brå endringer i forurensningsmengdene i lufta. Hvis det f.eks. begynner å regne tar nedbøren med seg mesteparten av svevestøvpartiklene ned mot bakken og holder det der – helt til det tørker og kan virvles opp igjen av vindkast eller passerende trafikk.

Følg med, og bidra til så god luft som mulig!
Målestasjonene for luftkvalitet måler forurensning i lufta fortløpende, 24 timer i døgnet hele året. Hver time registreres data om forurensningstype og -nivå, og disse dataene vises i sanntid på portalen www.luftkvalitet.info. For å se hvordan luftkvaliteten er i dag, kan du altså gå inn der.

Hvis du ser at luftkvaliteten er dårlig en dag, bør du unngå de mest trafikkerte områdene om du kan. Velg en vei med minst mulig trafikk når du skal til jobb eller skole, og luft via vinduer som vender vekk fra veien.

Så hva kan du gjøre for å være med på å sikre god luft? Du kan la være å kjøre bil når det er mulig, og bytte til piggfrie dekk om du ikke allerede har gjort det. Uansett hva slags bil du har er det også viktig at du overholder fartsgrensene, også miljøfartsgrensene som bare gjelder om vinteren, da blir den totale produksjonen av svevestøv mindre.

NILU – Norsk institutt for luftforskning Instituttveien 18, postboks 100, 2027 Kjeller
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www.nilu.no

Annex 5 – Example presentation for high schools

Det er noe i luften

Sonja Grossberndt
Nuria Castell

NILU-Norsk institutt for luftforskning

18.1.2019

Innhold

- Om NILU
- Luftforurensning
- Helseeffekter
- Forurensningskilder
- Hva sier loven?
- Måling og overvåkning av luftkvaliteten
- Hva kan dere måle selv?

NILU-Norsk institutt for luftforskning

- Uavhengig stiftelse etablert i 1969
- Hovedkontor på Kjeller med ca. 150 ansatte
- Kontor på Framsenteret i Tromsø med 15 ansatte
- 3 hovedområder:
  - Forskning
  - Tjeneste- og produktutvikling
  - Forskningsformidling og rådgiving

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NILUs forskningsområder

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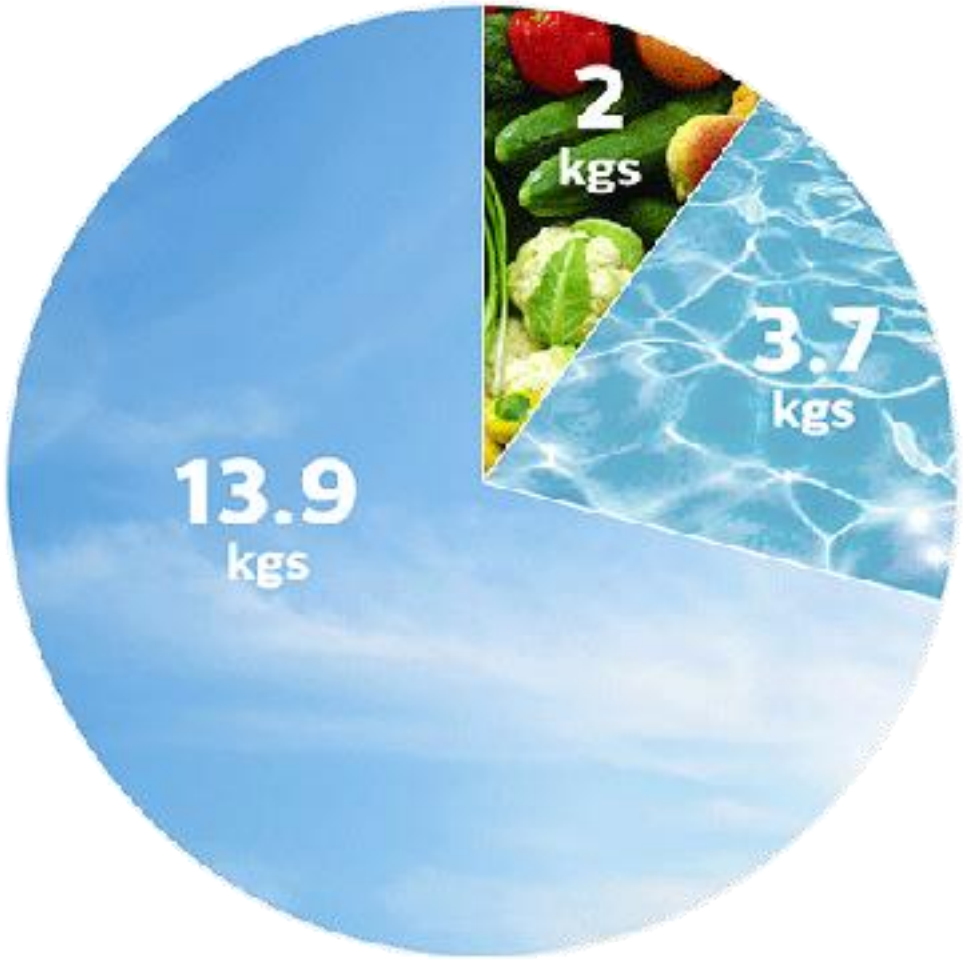
Luften vi puster

- Vi puster ca. 12-15 kg luft/døgn (eller ca. 10.000 liter)
- Vi er opptatt av maten vi spiser og vannet vi drikker –
  men hvor opptatt er vi av luften vi puster?



Hva er luft?

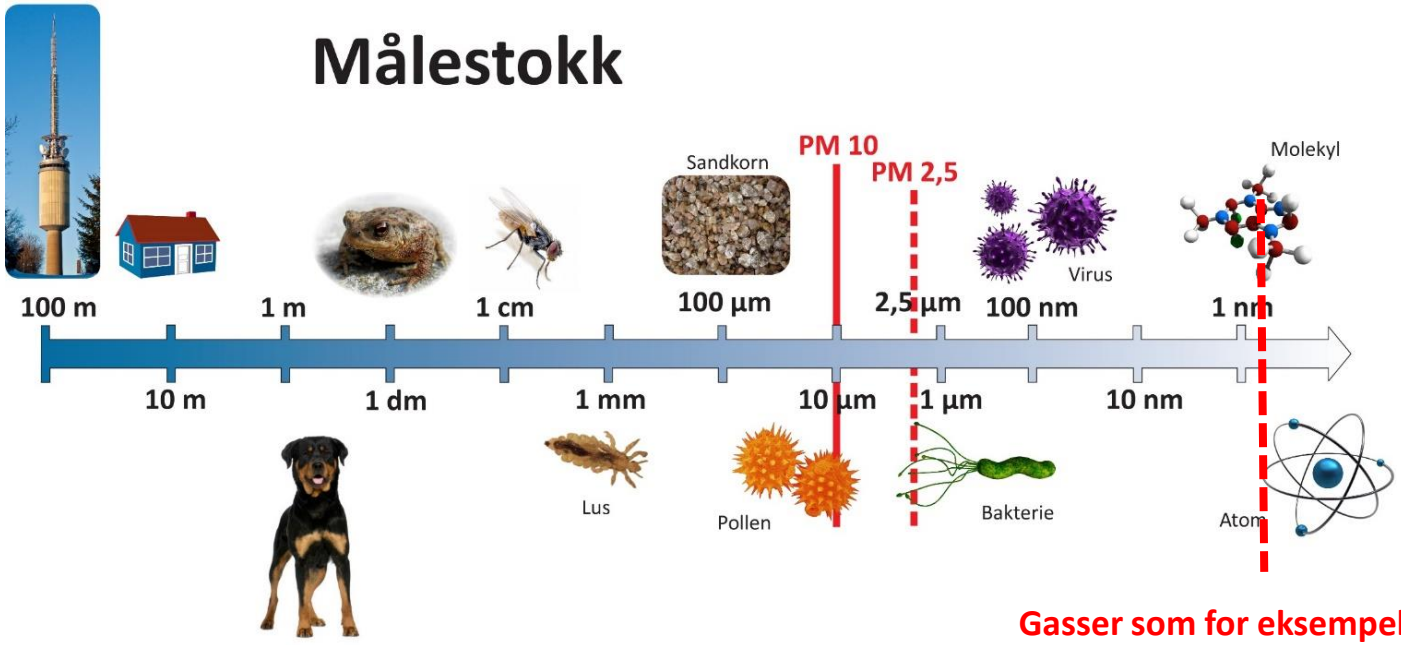
- Består av forskjellige gasser og partikler
- Vi puster luft
- Noen av gasser er skadelig for mennesker og naturen (luftforurensning)
- Andre gasser (for eksempel CO_2) er kanskje ikke skadelig, men fører til endring av klima (klimagasser)

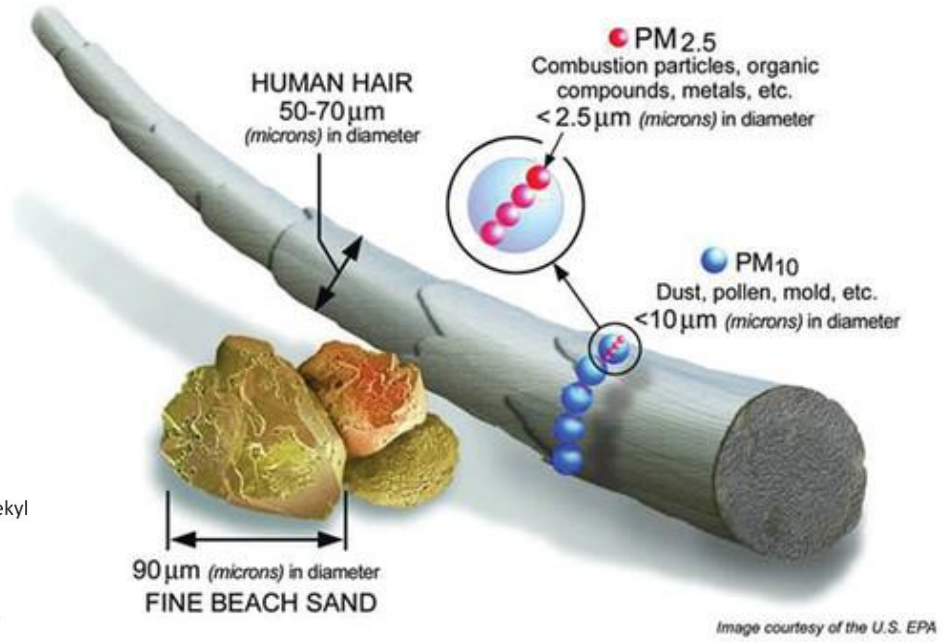
Luftforurensning

- Luftforurensning er en blanding av partikler og gasser
- Det finnes naturlige og menneskeskapte kilder
- Naturlige kilder: Vulkan-utbrudd, sand + støv, pollen
- Menneskeskapte kilder: forbrenning, trafikk, industri, byggearbeid

Luftforurensningskomponenter

- Svevestøv (PM_{10}, $PM_{2,5}$)
- Nitrogendioksid (NO_2)





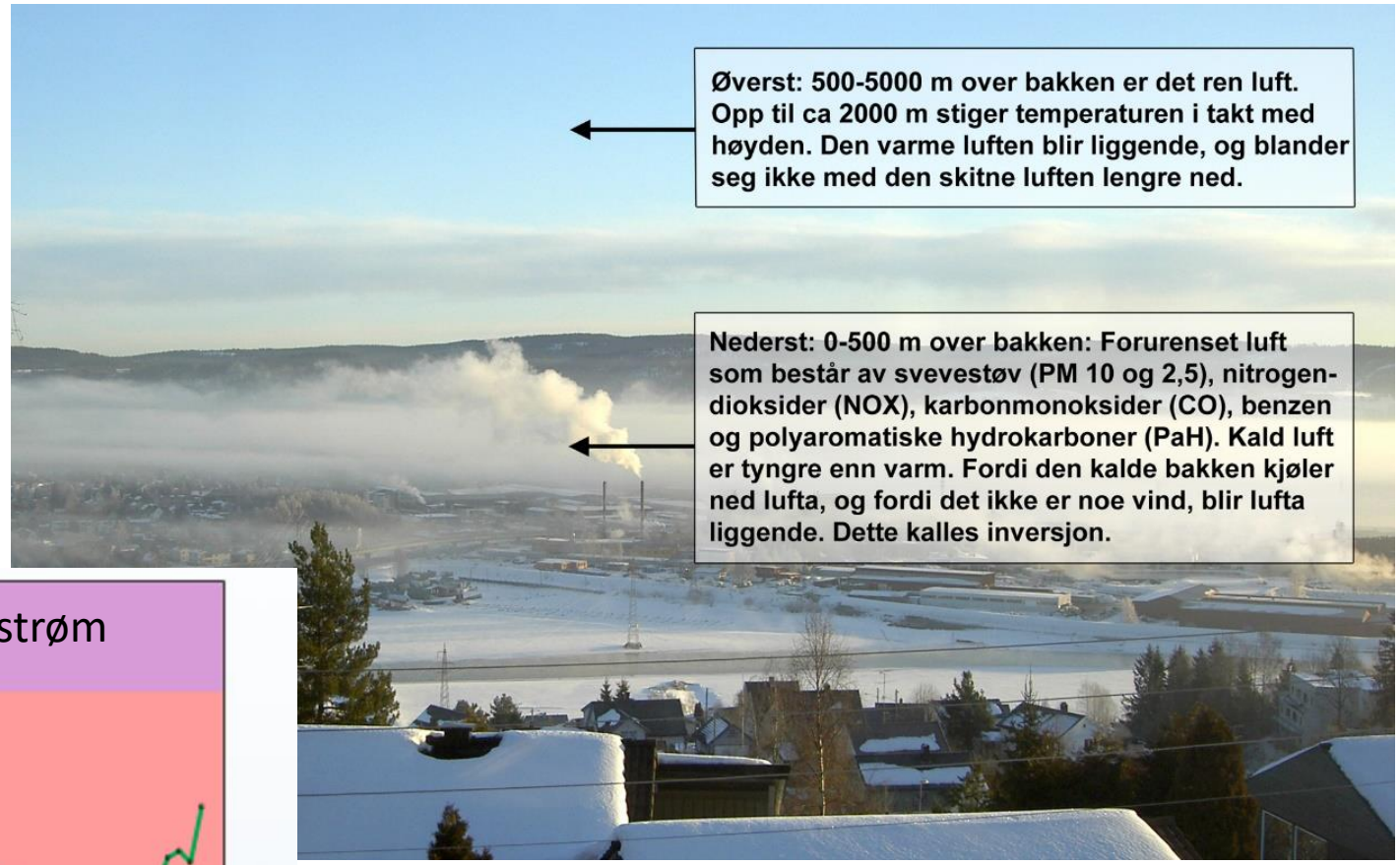
Gasser som for eksempel NO2

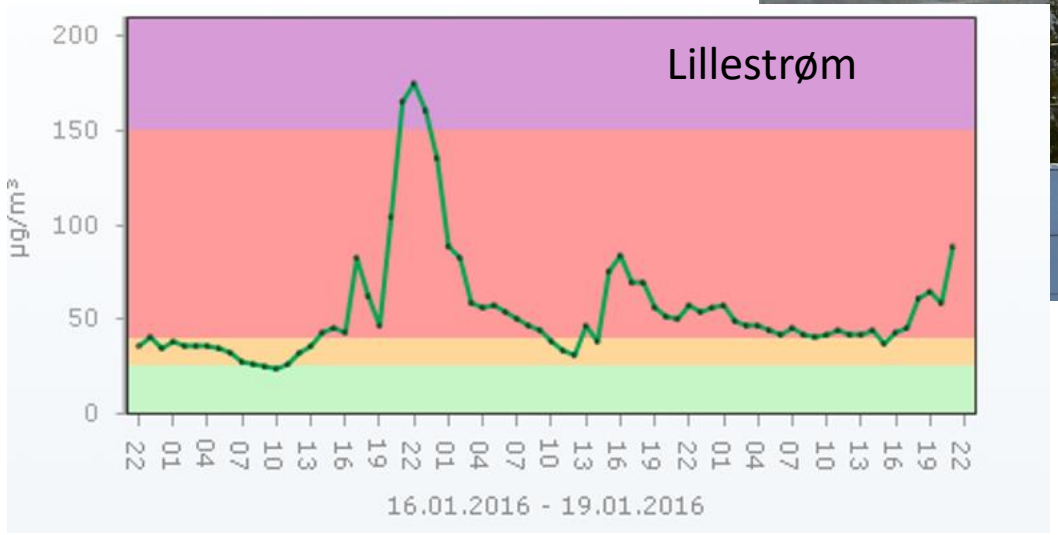
Hva er svevestøv?

- Små partikler som holder seg svevende i luften over lengre tid
- Partiklene kan være naturlige eller menneskeskapte
- Naturlige partikler: vulkanutslipp, skogbrann
- Menneskeskapte partikler: eksos, industriutslipp, vedfyring

Hvorfor er forurensning høyre om vinteren?

- Kaldt, stabilt vær
- mye utslipp fra vedfyring





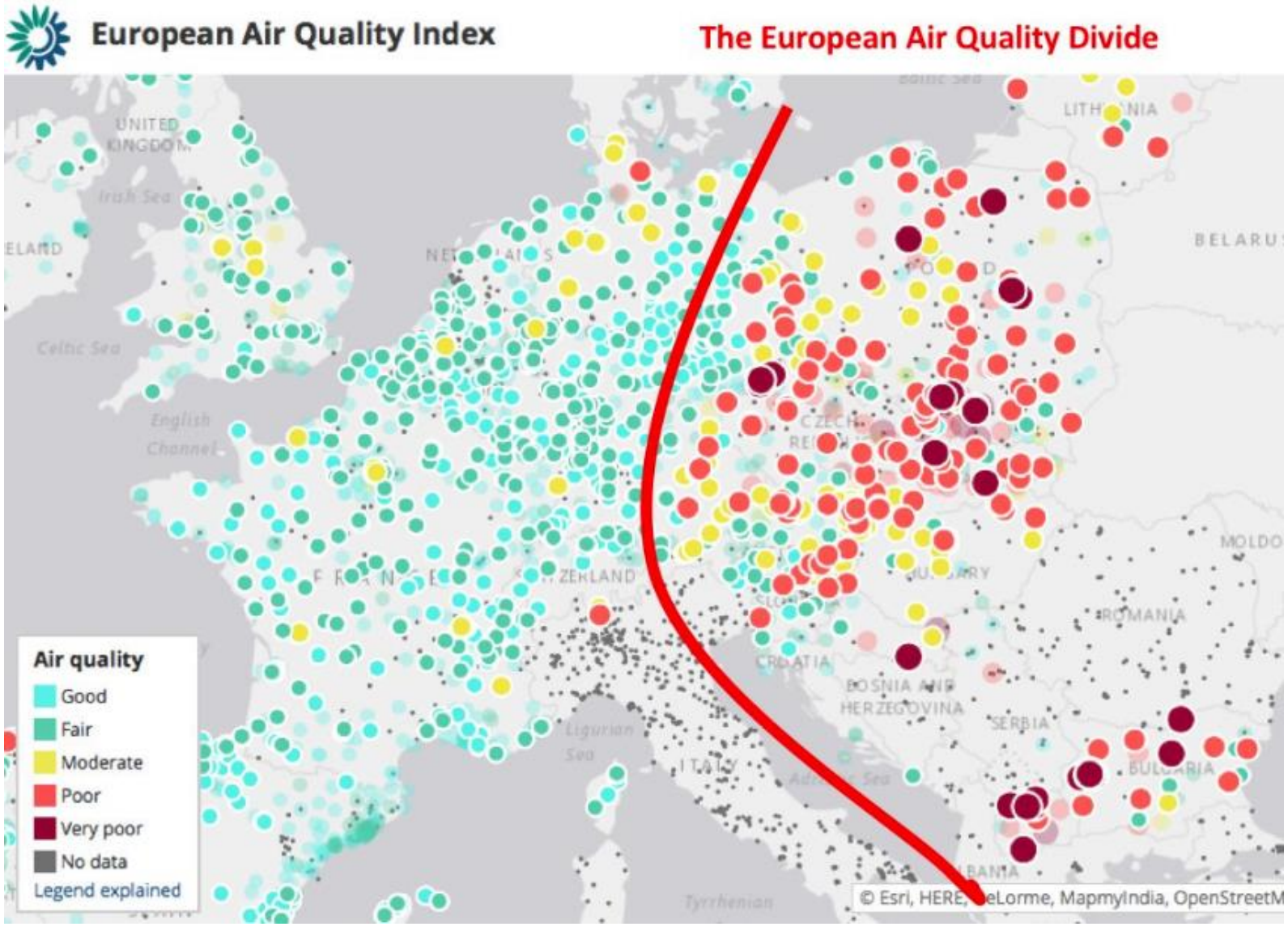
Luftforurensningsepisoder

Kuala Lumpur i en klar dag (over)
og i en veldig forurenset dag (nede)

Paris, mars 2014

Bergen, januar 2010

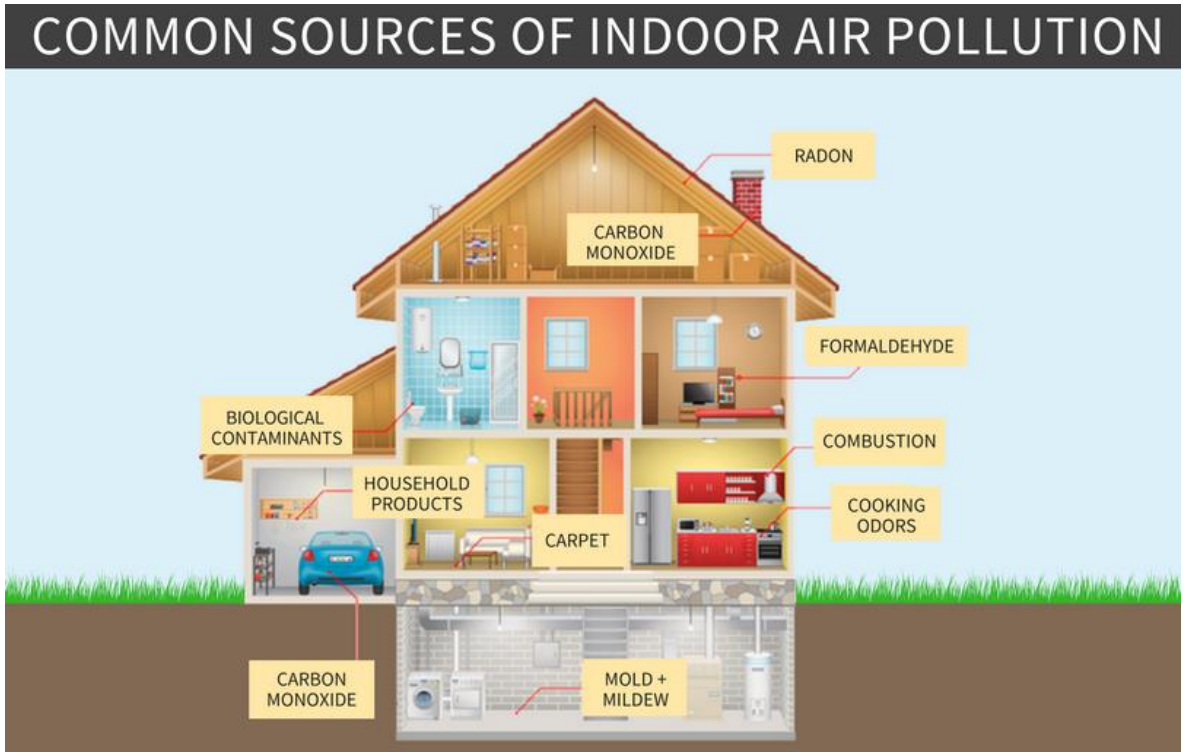
Episode med høy luftforurensning i Europa



Et problem også inne

Vi tilbringer 80-90% av vår tid innendørs!

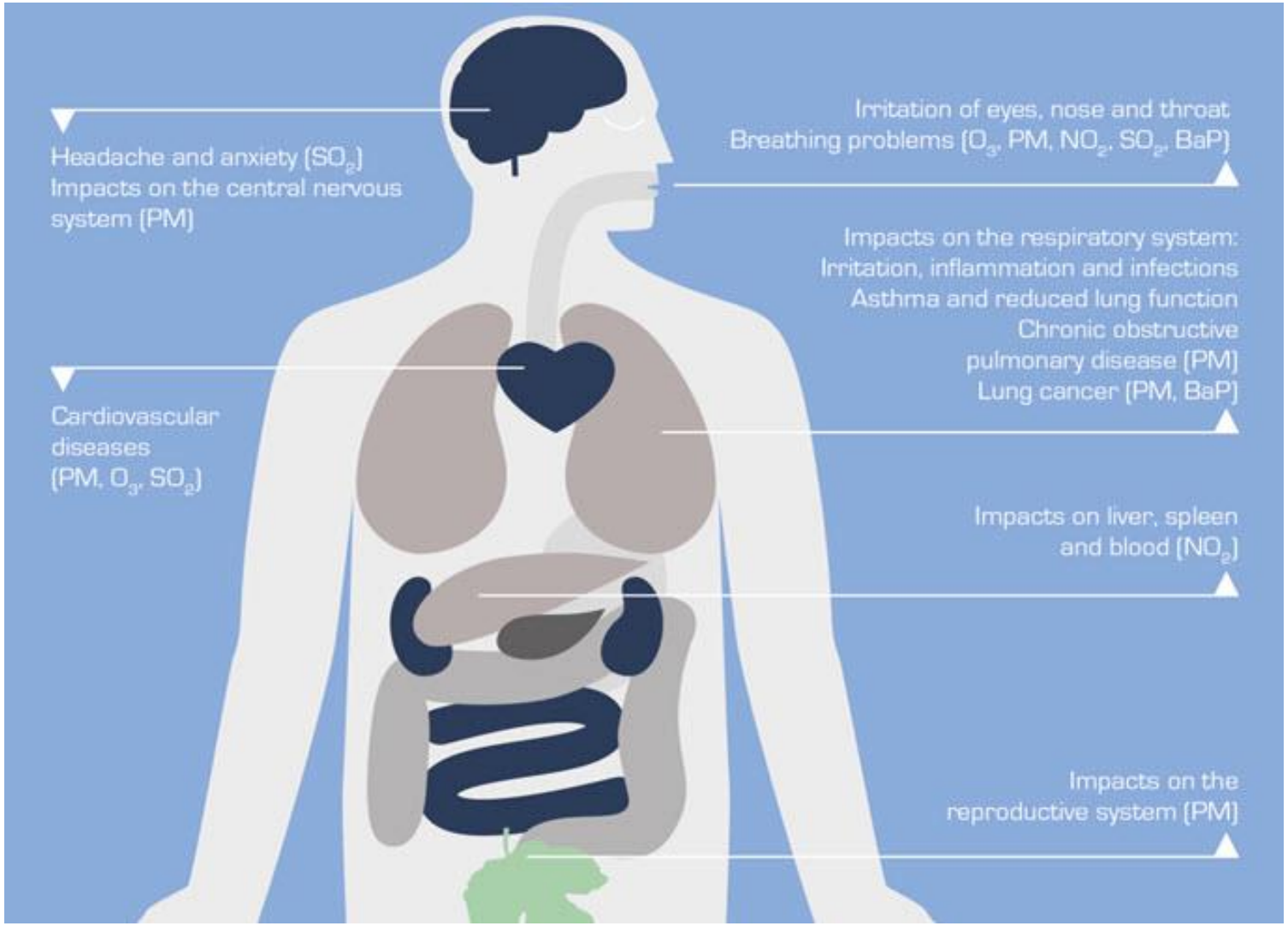
Kilde: Global Alliance for Clean Cookstoves



Kilde: BEYOND BY AERUS JOURNAL

Helseeffekter av luftforurensning

- Forurenset luft pustes inn og kan gjennom lungene spre seg gjennom hele kroppen



Kilde: European Environment Agency, 2013

Helseeffekter

- Hyppigste sykdom som følge av luftforurensning: hjerte- og karsykdommer
- Opp til 7 mill. mennesker dør for tidlig hvert år som følge av forurenset luft

Viktigste forurensningskilder i Norge

Veitrafikk

Industri

Vedfyring

Skipstrafikk

Partikler (svevestøv)	Nitrogendioksid
Trafikk, veislitasje, fyring, byggearbeid, industri	Utslipp fra dieselkjøretøy er hovedkilde
Flere kilder – flere muligheter å redusere utslipp	Mindre trafikk og/eller lavutslippskjøretøy

Aftenposten A-magasinet Osloby Sport Meninger Bli abonnent | Meny

Osloby Restaurantguiden Sulten Byliv

annonse

EFTA COURT

JUDGMENT OF THE COURT
2 October 2015

(Failure by an EFTA State to fulfil its obligations – Directive 2008/50/EC on ambient air quality and cleaner air for Europe – Limit values for certain pollutants in ambient air – Air quality plan)

ULOVLIG: Norge gjør ikke nok for å bekjempe luftforurensning, ifølge den ferske EFTA-dommen. FOTO: ARKIV

Norge felt for dårlig luftkvalitet

Luftkvaliteten i flere områder av Norge er så dårlig at den bryter med EØS-reglene, konkluderer EFTA-domstolen.

Les hele saken med abonnement på Bergens Tidende

Allerede abonnent? Logg inn

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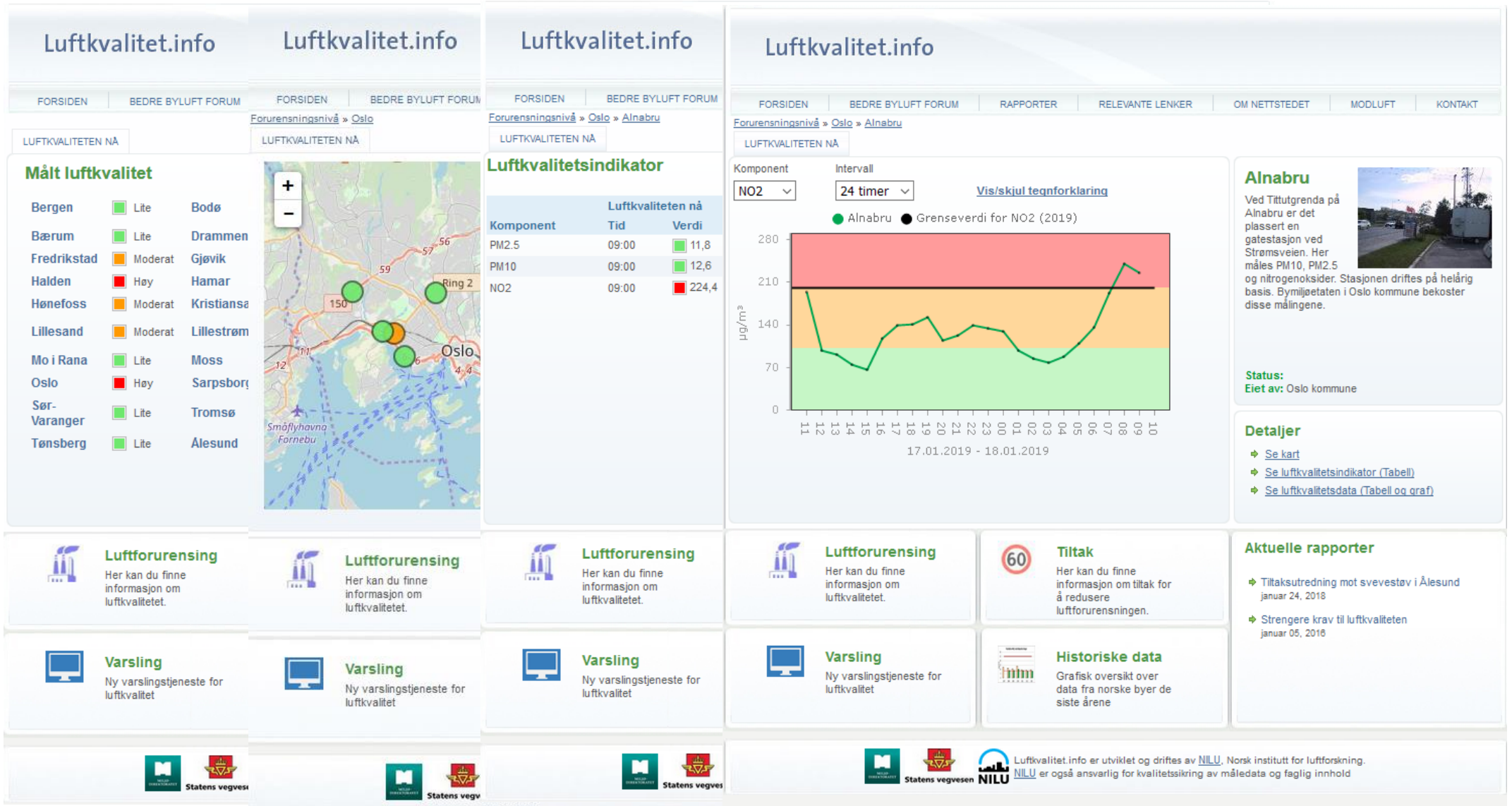
Varslingsklasser og helseanbefalinger

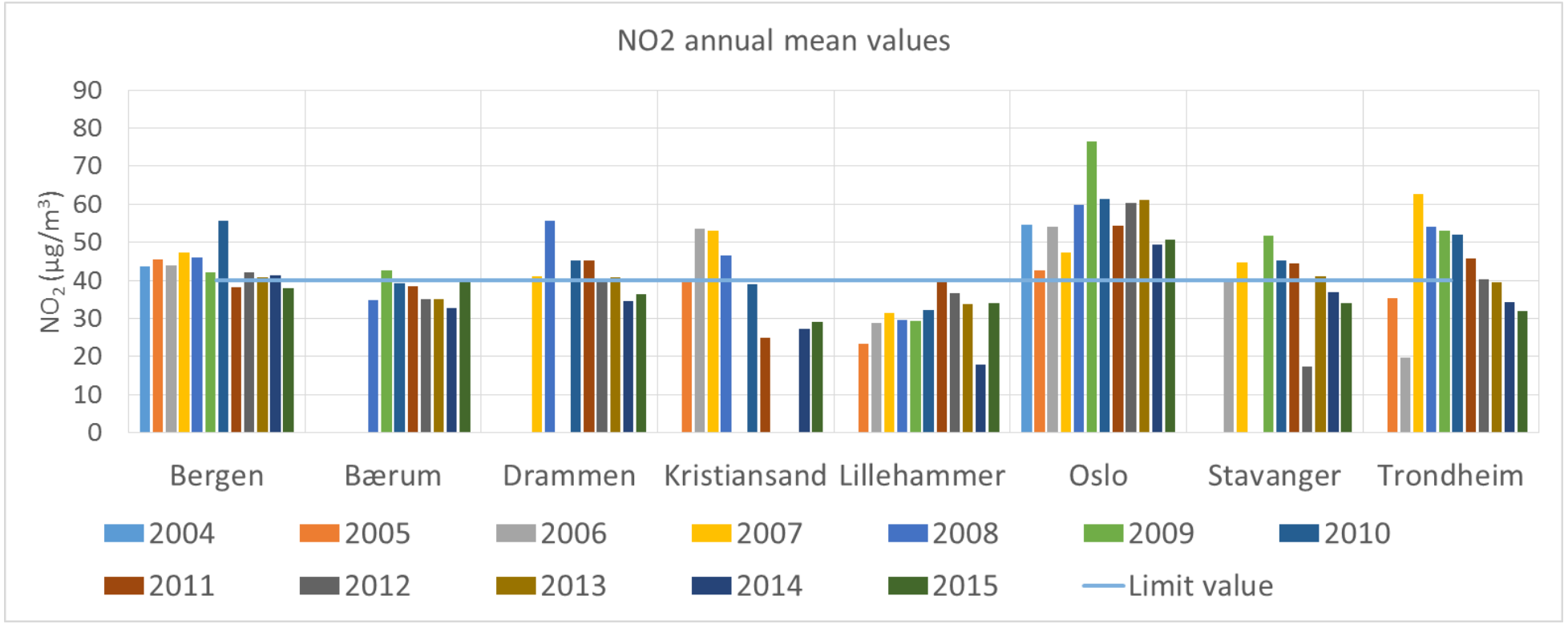
Tabell 2. Helsevirkninger og helseråd for PM_{10}, $PM_{2,5}$ og NO_2

Nivå	PM_{10} *Døgn* ($\mu g/m^3$)	$PM_{2,5}$ *Døgn* ($\mu g/m^3$)	PM_{10} *Time** ($\mu g/m^3$)	$PM_{2,5}$ *Time** ($\mu g/m^3$)	NO_2 *Time* ($\mu g/m^3$)	Varslings-klasser	Helsevirkninger	Helseråd
Lite	<30	<15	<50	<25	<100		**Liten eller ingen helserisiko**	Utendørs aktivitet anbefales
Moderat	30-50	15-25	50-80	25-40	100-200		**Moderat helserisiko** Helseeffekter kan forekomme hos enkelte astmatikere og personer med andre luftveissykdommer, samt alvorlige hjertekarsykdommer	Utendørsaktivitet kan anbefales for de aller fleste, men enkelte bør vurdere sin aktivitet i områder med mye trafikk eller høye andre utslipp
Høyt	50-150	25-75	80-400	40-150	200-400		**Betydelig helserisiko** Helseeffekter kan forekomme hos astmatikere og personer med andre luftveissykdommer, samt alvorlige hjertekarsykdommer	Barn med luftveislidelser (astma, bronkitt) og voksne med alvorlige hjertekar- eller luftveislidelser bør redusere utendørsaktivitet og ikke oppholde seg i de mest forurensede områdene
Svært høyt	>150	>75	>400	>150	>400		**Alvorlig helserisiko** Følsomme grupper i befolkningen kan få helseeffekter. Luftveisirritasjoner og ubehag kan forekomme hos friske personer	Personer med hjertekar- eller luftveislidelser bør redusere utendørsaktivitet og ikke oppholde seg i de mest forurensede områdene

www.luftkvalitet.info



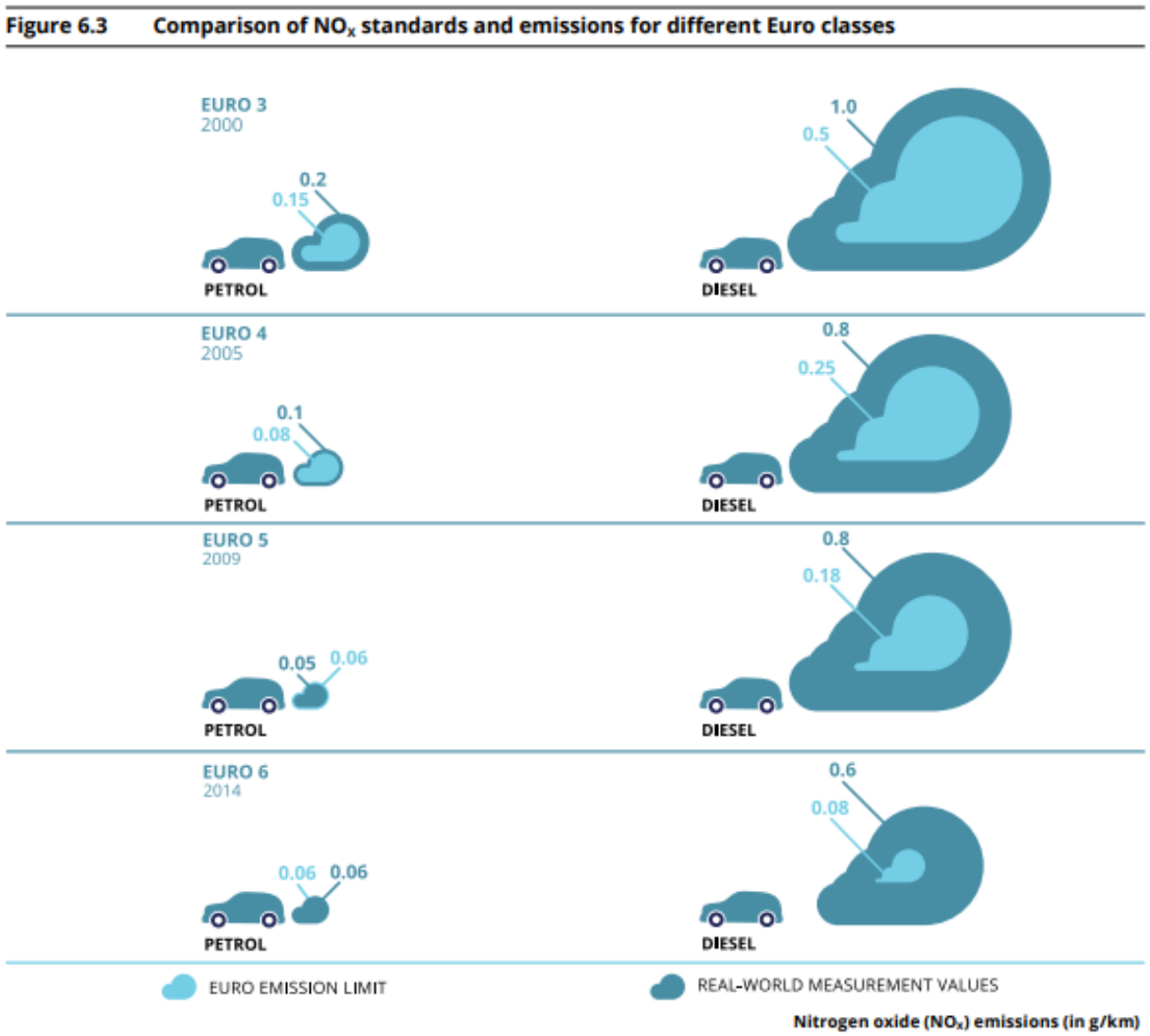
Luftforurensning i norske byer – NO_2



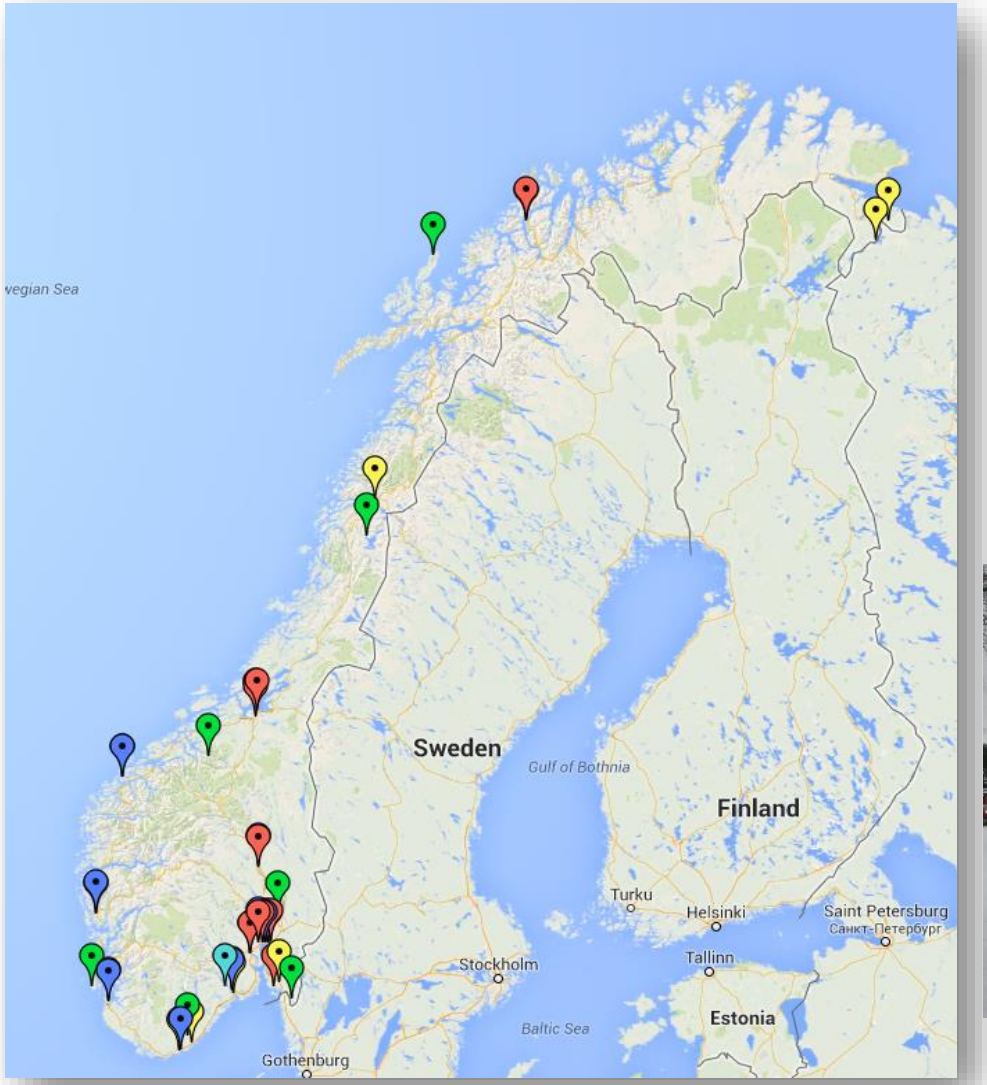
- NO_2 årsgjennomsnitt overstiger grenseverdiene i mange byer

Hovedkilde: utslipp fra dieselbiler og tunge kjøretøy

Hva er kilden til problemet med NO_2?



Hvordan måler vi luftkvaliteten?

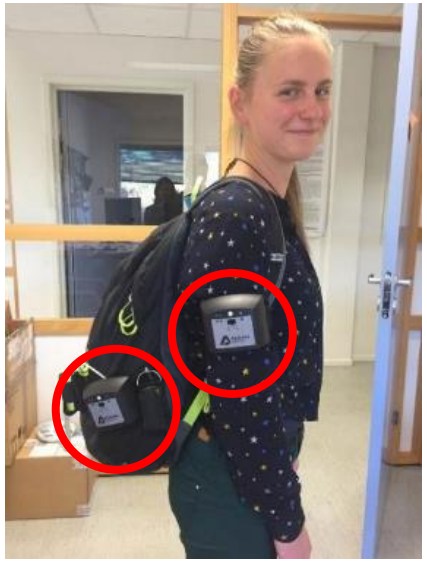


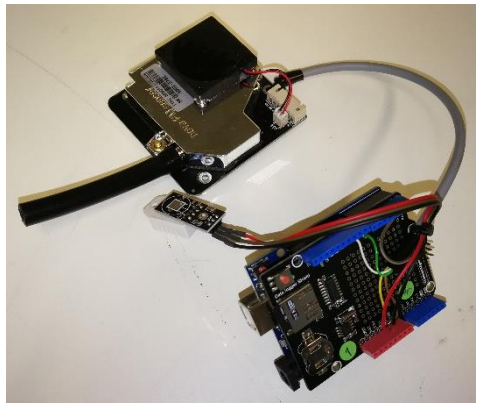
Tradisjonell luftovervåkning

- Veldig nøyaktig
- Konsistente dataserier
- Arkiv med flere tiårs data fra hele verden

- Store, komplekse stasjoner
- Dyrt vedlikehold
- Begrenset antall

Alternativet: mikrosensorer





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Hvordan fungerer mikrosensorer?

Elektrokjemiske

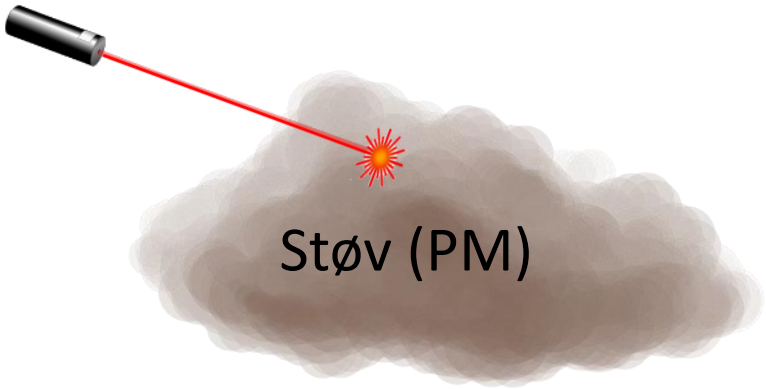
Også:

MOx (Metal Oxide)

-NDIR (CO_2)

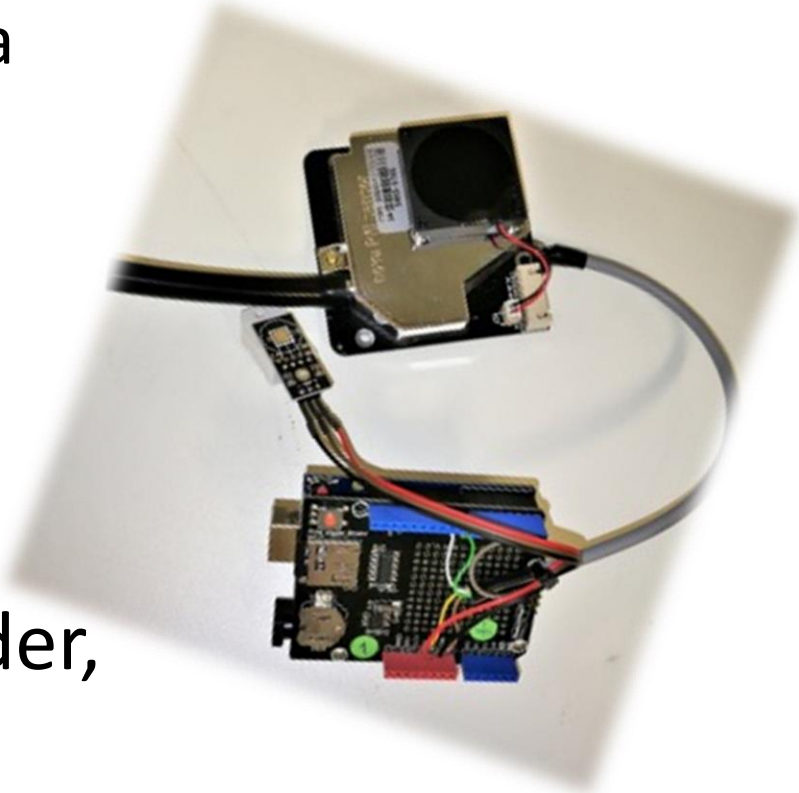
-PID (Flyktige organiske komp.)

Optiske metoder
(lysspredning,
Mie teori)



Godt å vite

- Mikrosensor-teknologien er fremdeles umoden
  - Høy usikkerhet og mange enheter gir feil data
  - Hver enhet bør kalibreres før bruk
- Resultater fra mikrosensorer kan ikke brukes på samme måte som målinger fra målestasjoner
- Men det kan brukes til å se hvordan luftforurensning varier med avstand til kilder, eller over en kort tidsperiode



Hva kan dere måle?

- Etter at dere har bygd sensoren kan dere undersøke utslippskilder til svevestøv
- Dere kan se på ulike nivåer fra ulike kilder og hvordan verdiene varierer over tid. Hvorfor det?
- Hvis dere måler på kun ett sted, la sensoren bli stående på samme sted i flere dager. Hvis dere måler på ulike steder, ta samme rute på forskjellige tidspunkt på dagen og på flere dager
- Husk at været påvirker og varier. Utslipp varierer gjennom dagen

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Nå kan dere sette i gang!

Ved spørsmål ta kontakt med sg@nilu.no eller ncb@nilu.no

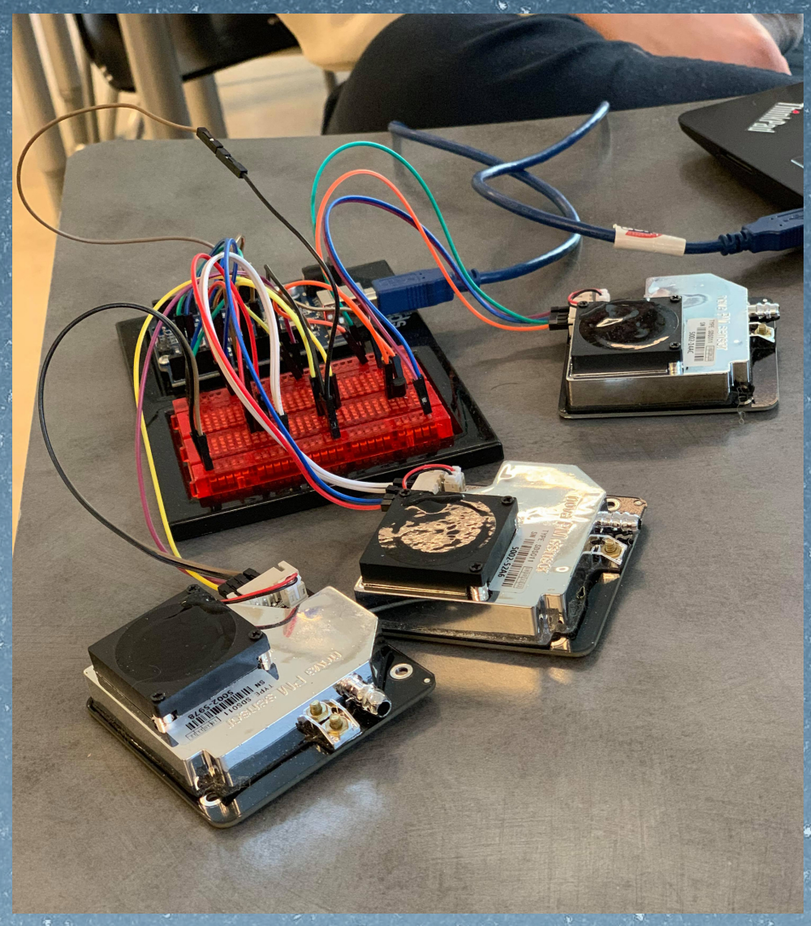
Annex 6 - Examples of scientific posters at the student conference

HVOR PRESISE MÅLINGER KAN VI FÅ?

Hypoteser:

1. Sensoren har god presisjon og nøyaktighet hvis vi ikke får systematiske avvik.

2. Kan vi komme nærmere riktige måleverdier når vi måler med flere sensorer?



Standardavvik:
Standardavviket defineres som kvadratroten av variansen.

Standardavvik for x:

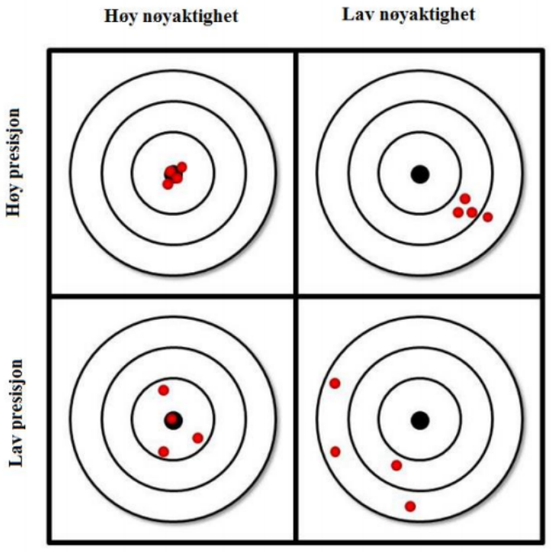
$$\sigma_x = \sqrt{V_x} \qquad \sigma_x = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2}$$

Variansen:
Er gjennomsnittlig kvadratavvik fra gjennomsnittet.

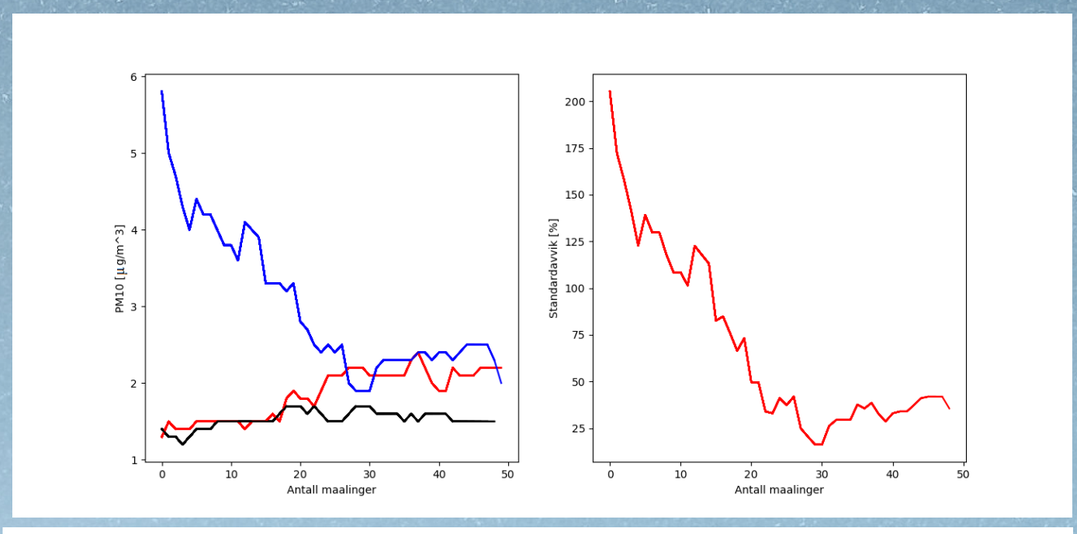
Varians for x:

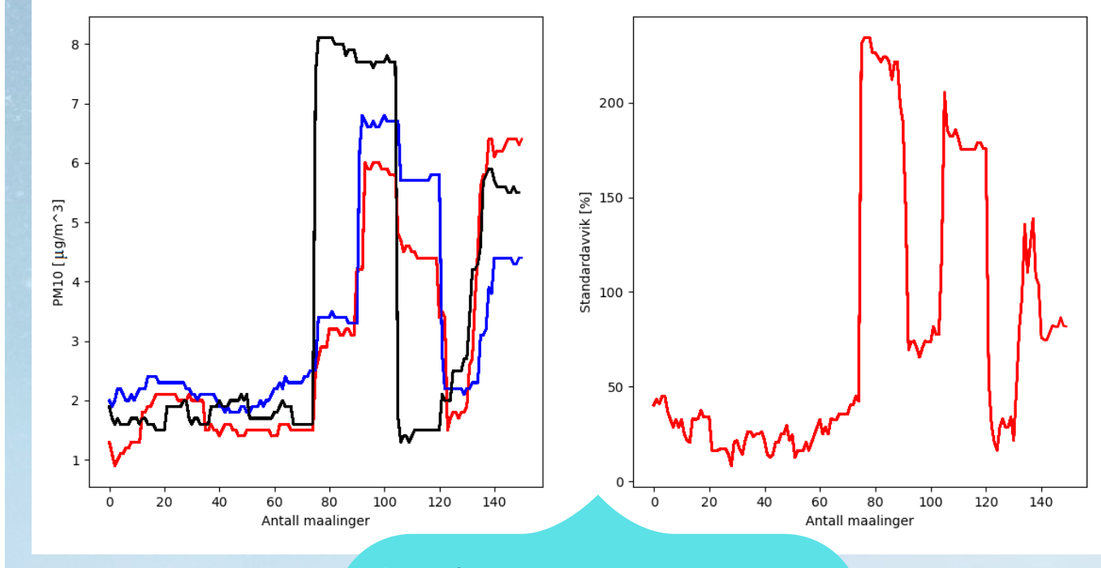
$$V_x = \sigma^2 = \frac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2$$

Presisjon og nøyaktighet:
Høy nøyaktighet betyr at snittet av flere målinger ligger nær referanseverdien (riktig verdi). Høy presisjon betyr at måleverdiene fra flere målinger har nær samme verdi. Høy presisjon sier ikke noe om hvor "riktige" måleverdiene er,men hvor nære referanseverdien vi er.



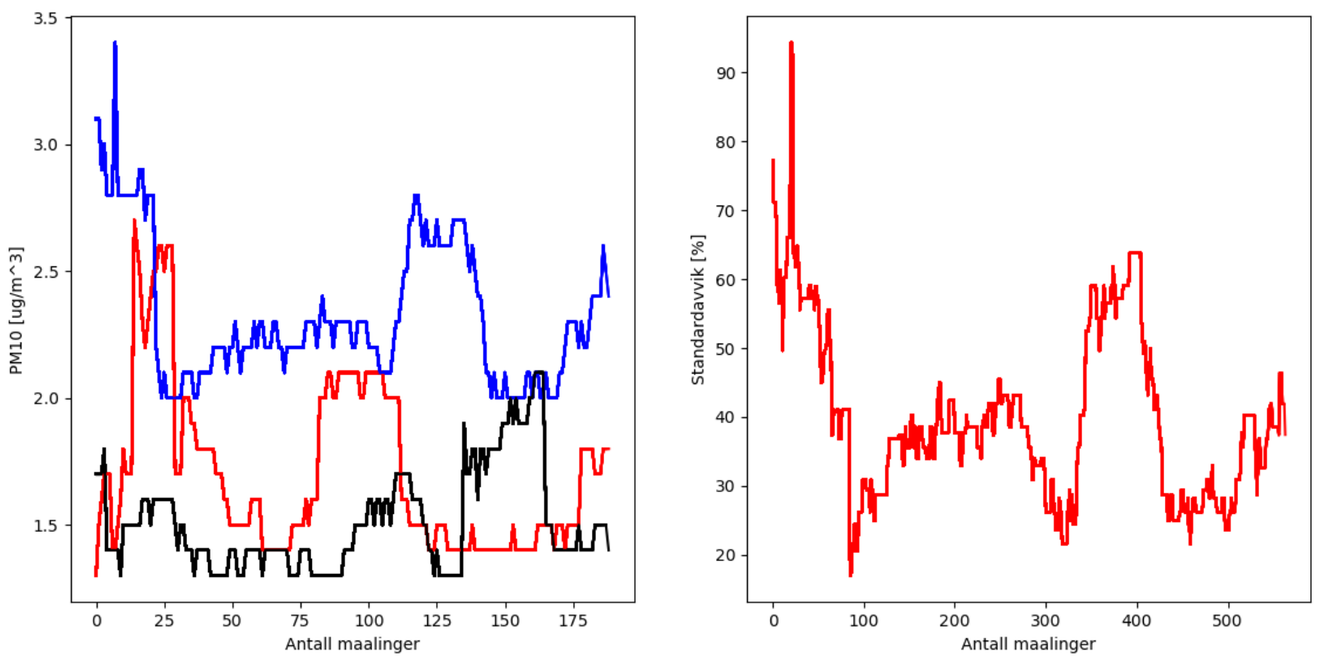
Figuren (venstre): Rad 1, første kolonne, ser vi at alle verdiene treffer blinken (i midten) som vil si at vi har høy nøyaktighet og presisjon.
I rad 1 ,andre kolonne, er verdiene nære hverandre som gir høy presisjon men lav nøyaktighet.
I rad 2, første kolonne , treffer vi midt på med en av som gir høy nøyaktighet med lav presisjon fordi alle verdiene har ulike verdier.
I rad 2, andre kolonne er verdiene ikke i nærheten av riktig verdi som gir lav nøyaktighet og alle verdiene er ikke nære hverandre som vil si det er lav presisjon.





Grafene (over): viser oss at man bør la vifta i sensoren gå litt før man starter målingene av PM 10.Da får vi bedre målinger.

Konklusjon:
Sensorene gir god presisjon i snitt, men er veldig sensitive for bråe forandringer og derfor kan vi se at standardavviket øker, når PM 10 øker.



RESULTAT AV MÅLINGENE I GRAF:

Her ser vi en fremstilling av målingene fra de 3 sensorene som måler PM 10 i lufta. Grafen til høyre viser oss at når PM 10 øker , øker også standardavviket.

Laget av: Mathias Bakkejord og Sidra Rana , Elvebakken Vgs

Er luftkvaliteten ved Ullern VGS skadelig for elevene? Og blir kvaliteten påvirket av ringveien like ved?

Mads Feiring, Thomas Fagerli og Sander Bakke
Ullern videregående skole

Bakgrunn

Luftforurensing i byer og tettsteder i dagens Norge bidrar til helseproblemer. Verdens helseorganisasjon (WHO) vurderer nedsatt luftkvalitet til å være en av de største risikofaktorene for tidlig død og helseskader.

Barn, unge, gravide og eldre er spesielt følsomme. Det er imidlertid også stadig sterkere holdepunkter for at luftforurensing kan påvirke nervesystem og sykdommer som diabetes.

Den største kilden til lokal luftforurensning i Norge er veitrafikk med utslipp av eksos og asfaltstøv særlig fra bruk av piggdekk, og dekkslitasje. Andre kilder er mer stedsavhengige, men viktige kilder er vedfyring, industri, havneanlegg, bygg- og anleggsvirksomhet og forbrenningsanlegg.

Utenfor Ullern, langs ringveien, er det satt en miljøfartsgrense for å minke utslipp av klimagasser og svevestøv. Eksempelvis CO_2, NO_x-gasser, svevestøv (PM_{10}, $PM_{2,5}$) etc.

Vi har målt temperatur, luftfuktighet og svevestøv på to forskjellige lokasjoner; ved veien som går 50 meter utenfor Ullern videregående skole, og på taket til Ullern VGS, som er ca. 100 meter fra ringveien.

(Miljødirektoratet, 2014), (Folkehelseinstituttet (FHI), 2015)

Kilder til svevestøv og tolkning av verdiene

Kilde / bidrag	PM_{10}	$PM_{2,5}$
Eksosutslipp	Noe	Mye
Slitasje fra vei, dekk og bremser	Svært mye	Noe

For å kunne sammenligne resultatene våre med anbefalte Krav, bruker vi indeksen til *UK Air Information Resource*. For $PM_{2,5}$ er indeksen:

Index	1	2	3	4	5	6	7	8	9	10
Band	Low	Low	Low	Moderate	Moderate	Moderate	High	High	High	Very High
µgm^{-3}	0-11	12-23	24-35	>36-41	>42-47	>48-53	54-58	59-64	65-70	71 or more

For PM_{10} er indeksen:

Index	1	2	3	4	5	6	7	8	9	10
Band	Low	Low	Low	Moderate	Moderate	Moderate	High	High	High	Very High
µg/m^3	0-16	17-33	34-50	51-58	59-66	67-75	76-83	84-91	92-100	101 or more

I vårt forsøk er vi bare interessert i de lave, moderate og høye verdiene. Ifølge indeksen vi følger vil de lave verdiene ikke utgjøre en helserisiko, og man kan være ute som vanlig. De moderate verdiene kan påvirke personer med lunge- eller hjerteproblemer. Ved høye verdier er det anbefalt at eldre, astmapasienter, unge, og personer med hjerte- og lungeproblemer tar ekstra forhåndsregler. Dette kan for eksempel være å bruke inhalatoren oftere.

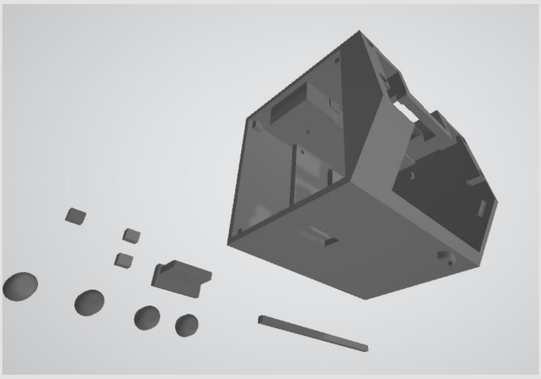
(UK Air Information Resource, hentet 03.04.2019)

Metode

- Et sensorsystem bestående av en humiture-sensor, en PM-sensor (10 og 2,5), en klokke, et SD-kort, en LCD-skjerm og en arduino uno
- Vi måler og lager informasjon på tre ulike steder; et høyt påvirket område, et lavt påvirket område og et område med ukjent påvirkning.
- Sammenlikne data for å se om områdene fyller de gitte kriteriene

Oppsett

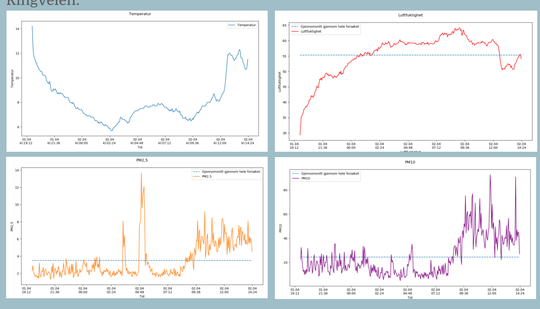
Boksen vår er modellert for at alle sensorene, skjermen og batteriet skal passe inn. Den ble 3D-printet i PLA-materiale. Boksen skal i utgangspunktet tåle små mengder vann.



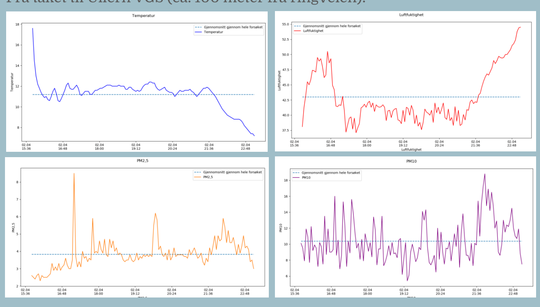
Resultater

Her er målingene fra rett ved ringveien, og fra taket til Ullern VGS:

Ringveien:



Fra taket til Ullern VGS (ca. 100 meter fra ringveien):



Grafene viser en stiplet linje med gjennomsnittsverdier. Denne linja gir en indikasjon på svevestøvverdiene bade på taket og langs ringveien. Vi kan først studeregjennomsnittsverdiene langs ringveien:

PM2,5: 3,8 µg/m3
PM10: 25 µg/m3
Luftfuktighet: 55%

Svevestøvverdier fra taket:
PM2,5: 3,9 µg/m3
PM10: 10,3 µg/m3
Luftfuktighet: 42,5%

Konklusjon

Resultatene våre sammenlignet med anbefalingene til UK Air Resource sier:

- Ingen direkte helserisiko ved ringveien
- Ingen direkte helserisiko på taket til Ullern VGS
- Alle verdiene har vært innenfor de lave verdiene til indeksen
- Luftkvaliteten er dermed ikke skadelig for noen elever på skolen
- Svevestøvgrafene langs ringveien får høyere verdier etter kl: 08:00. Siden dette er i rushtiden, tyder det på at bilene øker svevestøvverdiene i luften
- Siden det er høyere verdier langs ringveien enn på taket, blir luftkvaliteten påvirket av ringveien rett ved

Mulige feilkilder

- Kan aldi stole 100% på at sensorene måler helt riktig. Sensorene er derfor feilkilder
- Målingene foregikk over en kort tidsperiode
- Daglige variasjoner kan ha påvirket resultatet
- Målingene fra taket gikk I under 10 timer, siden batteriet gikk tomt

Kartet viser hvor målingene ble gjort

Annex 7 - Evaluation forms for both teachers and students

Hei!

Takk for at du tar deg tid til å fylle ut dette korte spørreskjemaet.

Skjemaet inneholder noen spørsmål rundt luftkvalitetsprosjektet du nylig har gjennomført i samarbeid med ACTION-prosjektet. Vil vil gjerne at du gir tilbakemelding på hvordan du likte aktivitetene, om du lærte noe og hva du synes kan forbedres. Det finnes ingen riktige eller gale svar – alt du svarer vil hjelpe oss med å forbedre våre fremtidige aktiviteter. Dette spørreskjemaet er en del av det europeiske forskningsprosjektet ACTION der vi utvikler løsninger for å involvere folk flest i forskningsaktiviteter. Ved hjelp av dette skjemaet, og andre forskningsaktiviteter, undersøker vi fordeler og utfordringer med prosjekter som det du nylig har vært med på. Derfor trenger vi din hjelp!

Takk for at du deltar!

Vennlig hilsen

Sonja Grossberndt, NILU
Dr. Antonella Passanti, T6

1) Alder

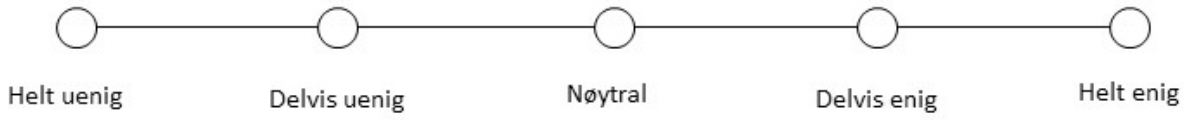
_____ år.

2) Kjønn

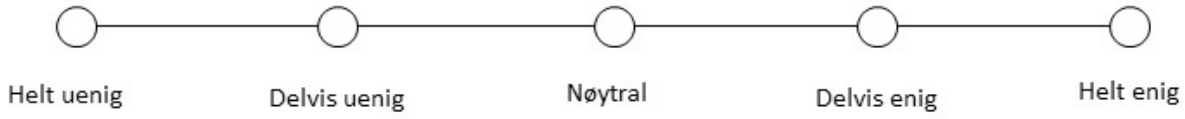
☐ mann ☐ kvinne ☐ ønsker ikke å svare

Vennligst les gjennom følgende utsagn. I hvilken grad er du enig/uenig? Kryss av på skalaen.

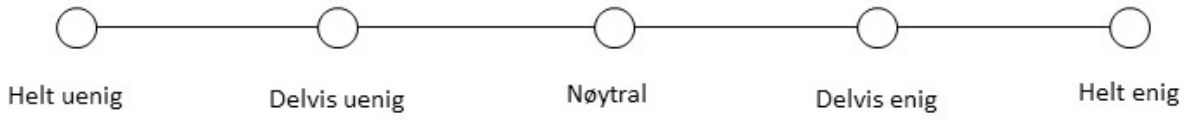
3) Denne aktiviteten har lært meg noe nytt om luftforurensning



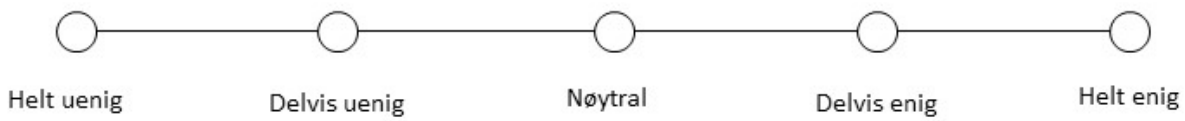
4) Denne aktiviteten har lært meg noe nytt om teknologi



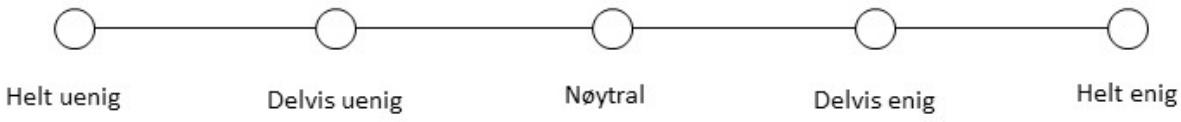
5) Denne aktiviteten har forbedret min forståelse for hvordan forskningsprosesser foregår



6) Denne aktiviteten har ført til at jeg vurderer å endre vaner for å redusere min eksponering for luftforurensning eller redusere mitt karbonutslipp.



7) **Denne aktiviteten har ført til at jeg føler at jeg kan oppnå mer og prestere bedre i realfag.**



8) **Hva likte du med denne aktiviteten?**

……

……

……

……

9) **Har du forslag til hva som kan forbedres og hvordan?**

……

……

……

……

10) **Vennligst skriv ned hvis du synes det er noe mer vi burde få med oss rundt aktiviteten du har deltatt i.**

……

……

……

……

Tusen takk for at du deltok!

Hvis du har spørsmål om dette skjemaet eller forskningsprosjektet kontakt:

Sonja Grossberndt, NILU – sg@nilu.no

Dr. Antonella Passanti, T6 – a.passanti@t-6.it

ACTION project: teachers' point of view on the citizen science activities carried out with high school students (NILU-ACTION project)

Within the ACTION project, a team of researchers and practitioners is developing technical and non-technical solutions to enable citizen science in becoming more open and inclusive. Within the project we have different citizen science initiatives (amongst them the NILU-ACTION project on air quality), and we are carrying out investigations to better understanding the benefits and challenges related to this practice. To understand these aspects, we need your help!

We kindly ask you to fill in this questionnaire and answer in line with your current mind-set. Please note that data collected during this study will be used solely for research purpose and will remain anonymous.

We acknowledge that you have read and signed the information sheet and the consent form for this research.

Thank you very much for completing this form!

1. **First of all, how did you find out about the citizen science approach and its use in teaching?**

2. **Please describe how the citizen science activities were organised.**
(*For example, how did you present the activity to the students? What did you ask them to do? How long the activity lasted?)*

3. **What were your expectations in adopting the citizen science approach with your students?**

4. **How many students participated in the activity? ……..**
    a. **How many boys?.....**
    b. **How many girls?.....**
    c. **How old are they approximately?** *(i.e. between 17 and 19 years old)*
    ……

5. **Did the activity meet your expectations?**

6. **What surprised you; did anything emerge that you were not expecting?**

7. **Did this activity, and the engagement with the ACTION project team, contribute to increase your awareness on air quality issues?**
   - ☐ Yes
   - ☐ No

   If you answered yes, how?

8. **Did this activity contribute in increasing the awareness of your students on air quality issues?**
   - ☐ Yes
   - ☐ No

If you answered yes, how?

If you answered no, why not?

9. **Did this activity, and the engagement with the ACTION project team, provide you with new skills and competences?**
   - ☐ Yes
   - ☐ No

   If you answered yes, how?

10. **Did this activity provide new skills and competences to your students?**
    - ☐ Yes
    - ☐ No

If you answered yes, how? Please specify if any difference emerged among students.
(*For example: on average the group showed improved ICT skills and a better understanding of the scientific research process. Especially students that were not particularly interested in science/technology related topics now show an increment of competences. Or, there is a clear difference among boys and girls in the way they achieved new skills.)*

If you answered no, why not?

11. **Do you think you will now have a more pro-environmental behaviour thanks to the knowledge gained with this activity?**
    - ☐ Yes
    - ☐ No

If you answered yes, how?

If you answered no, why not?

12. **Do you think your students will now have a more pro-environmental behaviour thanks to the knowledge gained with this activity?**
    - ☐ Yes
    - ☐ No

If you answered yes, how?

If you answered no, why not?

13. **Do you think the activity carried has influenced the way in which students view and value science?**
    - ☐ Yes
    - ☐ No

If you answered yes, how?

14. **Thinking of the activity carried out, please describe in short what did you like most and what did not work out so well**

15. **Thinking of the activity carried out, please describe in short what do you think your students liked most and what they found less interesting or difficult to understand**

16. **Do you think this activity will change the relationships among your students and the way they interact on a daily base?**
    - ☐ Yes
    - ☐ No

If you answered yes, how?

17. **Do you think this activity raised the motivation and self-esteem of your students?**

- ☐ Yes
- ☐ No

If you answered yes, how? Can you provide an example?

Thank you for your time!

For information and questions about this questionnaire you can contact:
a.passani@t-6.it
sg@nilu.no

Annex 8 – Example of an Arduino code for Nova SDS011

```
/* Headers for AdaFruit SD-shield data logger (up to 32GB SD-cards)
* Pinouts for the Adafruit shield ver.A:
* 4 pins for SPI (Serial Peripheral Interface bus):
* Arduino digital D13 - SPI clock
* Arduino digital D12 - SPI MISO
* Arduino digital D11 - SPI MOSI
* Arduino digital D10 - SD Card chip select (can cut a trace to re-assign)
* 2 pins for I²C (Inter-Integrated Circuit serial bus)
* Arduino analogue A4 connected to I²C SDA (Serial Data Line)
* Arduino analogue A5 connected to I²C SCL (Serial Clock Line)
*/
// For this sketch, two libraries are expected to be found in a subdirectory named src
// inside the sketch folde:r
#include "src/RTClib/RTClib.h" //Real Time Clock header
#include "src/cactus_io_DHT22/cactus_io_DHT22.h"
//#include <DHT.h>  // (Alternative library for DHT22)
// Other libraries must be installed in the Arduino IDE via the Manage Libraries menu item.
#include <SPI.h> //SPI communication with SD-card controller
#include <SD.h> //SD-card headers
#include <Wire.h> //I²C communication with RTC (Real Time Clock)


//RTC_DS1307 rtc; // define the Real Time Clock object //For old Adafruit SD-card logger
RTC_PCF8523 rtc; // define the Real Time Clock object //For newer Adafruit SD-card logger


// IN SETUP SD.begin(10); //Digital pin 10 is for Adafruit SD-shield NB!!!!
/*Note: on using two serial ports simultaneously, for sensors DFrobot and Novafitness
* Receives from the two software serial ports.
* In order to listen on a software port, you call port.listen().
* When using two software serial ports, you have to switch ports by listen()ing
* on each one in turn. Pick a logical time to switch ports, like the end of an
* expected transmission, or when the buffer is empty. This example switches
* ports when there is nothing more to read from a port.
* Pin connections for communicating with 2 devices:
* First serial device's TX attached to digital pin 6(RX), RX to pin 7(TX)
* Second serial device's TX attached to digital pin 8(RX), RX to pin 9(TX)
*/
#include <SoftwareSerial.h> //Header for serial communication with sensor(s)

/*Novafitness SDS011 sensor
```

```
* ref. http://inovafitness.com/ and https://pan.baidu.com/s/1nvPqOXF
* Communication via software serial port #2
* Pin order:
* SDS011 VCC => Aurduino 5V
* SDS011 GND => Aurduino GND
* SDS011 TX => Arduino digital pin D8 (RX)
* SDS011 RX => Arduino digital pin D9 (TX)
*/
SoftwareSerial portTwo(8, 9);
//SoftwareSerial portTwo(10, 11);
int Nova_PM25;
int Nova_PM10;
unsigned long Sum_PM25;
unsigned long Sum_PM10;
int nSamples;


#define DHT22_PIN 2 // what pin on the arduino is the DHT22 data line connected to
// For details on how to hookup the DHT22 sensor to the Arduino then checkout this page
//        http://cactus.io/hookups/sensors/temperature-humidity/dht22/hookup-arduino-to-dht22-temp-humidity-sensor
int a,b,c,d,e,f=0;
unsigned long time=0;
unsigned long sec = 1000;
unsigned long tmp=0;
unsigned long currentTime;

// Initialize DHT sensor for normal 16mhz Arduino.
DHT22 dht(DHT22_PIN);
//DHT22 dht(DHT22_DATA_PIN, 30);

/* Generic logging variables */
boolean boolStart=true;
const unsigned long loggerInt=10UL; // logger interval, seconds. Should not be less than 30 seconds. "UL" means Unsigned Long integer
unsigned long nextLog;
unsigned long micro0;
unsigned long micro1;
unsigned long micro2; //present time + 1 second (10^6 microseconds)

/* Miscellaneous constants */
const char charDash='-';
const char charColon=':';
```

```
/*=====================================================================
=========================================*/
void setup() {
  // Open serial communications and wait for port to open:
  Serial.begin(9600);
  while (!Serial) {;} // wait for serial port to connect. Needed for native USB port only
  SD.begin(10); //Digital pin 10 is for Adafruit SD-shield NB!!!!
  rtc.begin();
  // if (! rtc.isrunning()) rtc.adjust(DateTime(F(__DATE__), F(__TIME__)));
  // Sets clock at compile time via USB if clock is not running
  // To set exact time: (1) set time next exact minute in code below,
  //                    (2) compile and upload to Arduino,
  //                    (3) the Arduino immediately starts running,
  //                    (4) press Arduino reset button at precise time (when correct minute begins),
  //                    (6) comment out code below,
  //                    (7) compile and run [this ensures that time not reset every restart]

// The rtc.adjust command should be commented out when the RTC has been set, and the RTC
battery is OK
// rtc.adjust(DateTime(2019, 12, 6, 13, 57, 0));
  //March 21, 2017 at 3:30pm you would write DateTime(2017, 3, 21, 15, 31, 0)

  Serial.begin(9600);
//Serial.println("DHT22 Humidity - Temperature Sensor");
//  Serial.println("RH\t\tTemp (C)\tTemp");
  dht.begin();

  //iNovafitness sensor:
  portTwo.begin(9600);
  Sum_PM25=0UL;
  Sum_PM10=0UL;
  nSamples=0;

  //Logging:
  DateTime date1 = rtc.now();

  nextLog= long(date1.unixtime());
  micro1=micros();
  micro2=micro1+1000000;

  Serial.println("Setup done...");
}
```

```
/*================================================================================
=========================================*/
void loop() {
  unsigned long thisLog;
  String strLine;
  String strDate;
  int ii;
  char index;
  char receiveflag;
  int receiveSum;
  unsigned char _buffer[32]; //32-byte buffer for reading serial bus
  //*****************************************************************************************
  dht.readHumidity();
  dht.readTemperature();

  // Check if any reads failed and exit early (to try again).
  if (isnan(dht.humidity) || isnan(dht.temperature_C))
  {
    Serial.println("DHT sensor read failure!");
    return;
  }
//  Serial.print(dht.humidity); Serial.print(" %\t");
//  Serial.print(dht.temperature_C);
//  Serial.print(" *C\t");
// Serial.print("Time: ");

currentTime=millis();

  // Wait a few seconds between measurements. The DHT22 should not be read at a higher
frequency of
  // about once every 2 seconds. So we add a 3 second delay to cover this.
  delay(10000);


//*****************************************************************************************
// Temperature and humidity measurement


  micro0=micro1;
  micro1=micros();
  if (micro1<micro0) {// In case the counter overflows (gets automatically zeroed) approx every 70
minutes.
    micro2=micro1+1000000; //reset second target
  } else if (micro2<=micro1){ // if 1 second passed
```

```
  // Read iNovafitness sensor:
  // Step1: read 10 bytes from serial bus
  index=0;
  while (portTwo.available() && index != 10) {
    _buffer[index] = portTwo.read();
    index++;
  }
  while (portTwo.read() != -1) {}
  // Step2: Check the package integrity
  if (_buffer[0] == 0xAA && _buffer[1] == 0xC0 && _buffer[9] == 0xAB) {
    receiveSum = 0;
    for (int i = 2; i < 8; i++) {receiveSum += _buffer[i];}

    if ((receiveSum & 0xFF) == _buffer[8]) { //package is valid
      Nova_PM25 = ((_buffer[3] << 8) + _buffer[2]);
      Nova_PM10 = ((_buffer[5] << 8) + _buffer[4]);
      Sum_PM25 += (long)Nova_PM25;
      Sum_PM10 += (long)Nova_PM10;
      nSamples += 1;
      //Serial.print(Nova_PM25);
      //Serial.print("\t"); // tab space
      //Serial.print(Nova_PM10);
      //Serial.print("\t"); // tab space
      //Serial.print(Sum_PM25);
      //Serial.print("\t"); // tab space
      //Serial.print(Sum_PM10);
      //Serial.print("\t"); // tab space
      //Serial.println(nSamples);
    }
  }
  micro2=micro2+1000000; // next log in 1 second

  DateTime date1 = rtc.now(); //read time from Real Time Clock (RTC)
  thisLog=long(date1.unixtime()); //convert time to integer seconds

//  Serial.println(thisLog);
  if (nextLog <= thisLog){

    strDate=String((int)date1.year());
    strDate += charDash;
    strDate += twoDigit((int)date1.month());
    strDate += charDash;
    strDate += twoDigit((int)date1.day());
    strDate += ' ';
```

```
    strDate += twoDigit((int)date1.hour());
    strDate += charColon;
    strDate += twoDigit((int)date1.minute());
    strDate += charColon;
    strDate += twoDigit((int)date1.second());



    File dataFile = SD.open("datalog.txt", FILE_WRITE); //Open file
    if (dataFile) { // file is available, write to it:
      if (boolStart){ //Write column header
        // "\n"=new line, "\t"=tab
        dataFile.println("\nDate\ttime\t\tPM2.5\tPM10\thum\ttemp");
        Serial.println("Date\ttime\t\tPM2.5\tPM10\thum\ttemp");

        boolStart=false;
      }
      // make a string for assembling the data to log:
      if (nSamples==0) nSamples=-1; //prevent divide by zero if there is no data. Outputs negative
value instead
      strLine = strDate;
      strLine += "\t";
      strLine += (float)Sum_PM25/(float)(10*nSamples);
      strLine += "\t";
      strLine += (float)Sum_PM10/(float)(10*nSamples);
      strLine += "\t";
      strLine += (dht.humidity);
      strLine += "\t";
      strLine += (dht.temperature_C);
      strLine += "\t";
//      strLine += nSamples;

      dataFile.println(strLine);



      dataFile.close();
      Serial.println(strLine); // print to the serial port too:
    //   Serial.print("\t");
    } else { // file isn't open, pop up an error:
      Serial.println("error opening datalog.txt");
    }

    nextLog=nextLog+loggerInt; //logger interval
    micro1 = micros(); //reset timer for Shinyei
```

```
    Sum_PM25=0UL;
    Sum_PM10=0UL;
    nSamples=0;
   }//endif date=nextLog
  }//endif micro2<micro1 (1 second logger-interval)
}

/*=========================================================================
=========================================*/
String twoDigit(int ii){
  // Converts an integer to a right-justified two-character string left-padded with zeros, e.g. 1 => "01"
  // This function is used to output date/time, e.g. months, minutes, hours, minutes, seconds
  String string2=String(ii);
  if (ii<10){
    return String("0" + string2); //pad with leading zero
  } else {
    return string2;
  }
}
```