The school project was inspired by some important themes we discussed in class during the '***National Food Waste Prevention Day***', an important event established to raise world public awareness, especially young people, about food waste; the event will celebrate its 10th anniversary this year, committed to pursuing the Sustainable Development Goals of the 2030 Agenda regarding food system, that reads as follow:

"*Mentre un impatto ambientale significativo nel settore alimentare si verifica a partire dalle fasi di produzione (agricoltura e settore agro-alimentare), le famiglie influenzano tale impatto attraverso scelte e abitudini alimentari. Ciò, a sua volta, ha un impatto sull'ambiente attraverso l'energia consumata per la produzione di cibo e la generazione di rifiuti*."

The food we throw away generates between 8 and 10 % of global greenhouse gas emission, waste that costs too much to the environment and that must be absolutely limited. The issue of food waste is identified as one of the most serious problems of the current production system. Since the world's food security is not ensured everywhere, reducing food losses and waste has the potential to improve food availability and reduce greenhouse gas (waste is responsible for emitting 10% of "unnecessary" greenhouse gas), as well as to ease the pressure on natural resources, in particular on water consumption and land use, in order to increase the sustainability of our production. This is mainly due to poor food preservation causing its rapid deterioration (World **Day** Against **Food Waste**).

We must definitely reduce damages on the food supply chain starting from our daily habits, whose impact is about 50%. As a consequence, food safety has inevitably become a global issue for the system of production, storage, distribution and consumption.

All food, over variable period of time depending on their nature or storage conditions, undergo alteration of varying degrees due to different agents, such as:

- *biological agents (microorganisms, insects, animals);*
- *chemical agents (enzymes)*
- *physical agents (heat, light).*

The most evident signal of the alteration of food is its smell; in fact; unpleasant odours play a key role in detecting spoiled food. To efficiently develop a smart food monitoring system, we could design an 'electronic nose' able to identify harmful molecules of gas causing deterioration.

The "***Smart Food Conservation System***" (***SFCS***) is an integrated system, based on IoT and AI technologies, checking the conservation status of unpackaged food by monitoring the behaviour of some gases, such as:

- *ethanol concentration*

- *ammonia concentration*
- *trimethylamine concentration*
- *Sulfide concentration*

In case of packaged food, we need to just scan the expiry date shown on the barcode.

The system consists of a ***Data Logger*** (***DL***) to be applied externally to the refrigerator and, through a PAN network based on ***Blue Tooth*** technology, is connected to smart plastic food containers (***SPFC***) we designed and equipped with gas sensors for measuring aromatic compounds. The ***DL*** shows on its display data of the conservation status of unpackaged food contained in the ***SPFC***, as well as the expiry date of packaged food.

Each ***SPFC*** includes a microcontroller card dedicated to set of sensors used for measuring the emission of aromatic gases signals of spoiled food, such as:

- *Ethanol*
- *Ammonia*
- *Organic amines*
- *Sulfide*

The ***DL*** uses a ***Barcode Scanner*** for collecting the information recorded in the barcode of packaged food, before putting it in the fridge. In addition, it allows to interface with ***Smartphones*** to run an ***App*** we designed in order to get real-time information on the contents and status of the fridge. It is a system consisting of 4 functional elements:

- Advanced sensors to detect gases indicating the state of preservation of previously treated food
- Connectivity system based on ***Blue Tooth*** and ***WiFi*** technology;
- Local server connected to ***D.L***., to manage ***Data Base*** containing parameters detected by each ***SPFC*** sensor
- ***Cloud*** resources for ***data analysis***

The sensor block is placed on the cover of each ***SPFC*** to ensure monitoring of volatile gases developed in containers. The sensors used are:

- *Ethanol sensors, for checking the freshness of fruit and vegetables*
- *Ammonia sensors, for checking the freshness of meat*
- *Trimethylamine sensors, for checking the freshness of seafood*
- *Sulfide sensors, for checking the freshness of eggs and milk*
- *Trimethylamine sensor*

The following information is sent to ***DL***

- unpackaged food
  - ***ID_ SPFC:*** *identification of* ***SPFC***

    Ethanol: measured value of ethanol concentration

    Ammonia: measured value of ammonia concentration

    Trimethylamine: measured value of trimethylamine concentration

    Sulfide: measured value of sulfide concentration
- For packaged food.

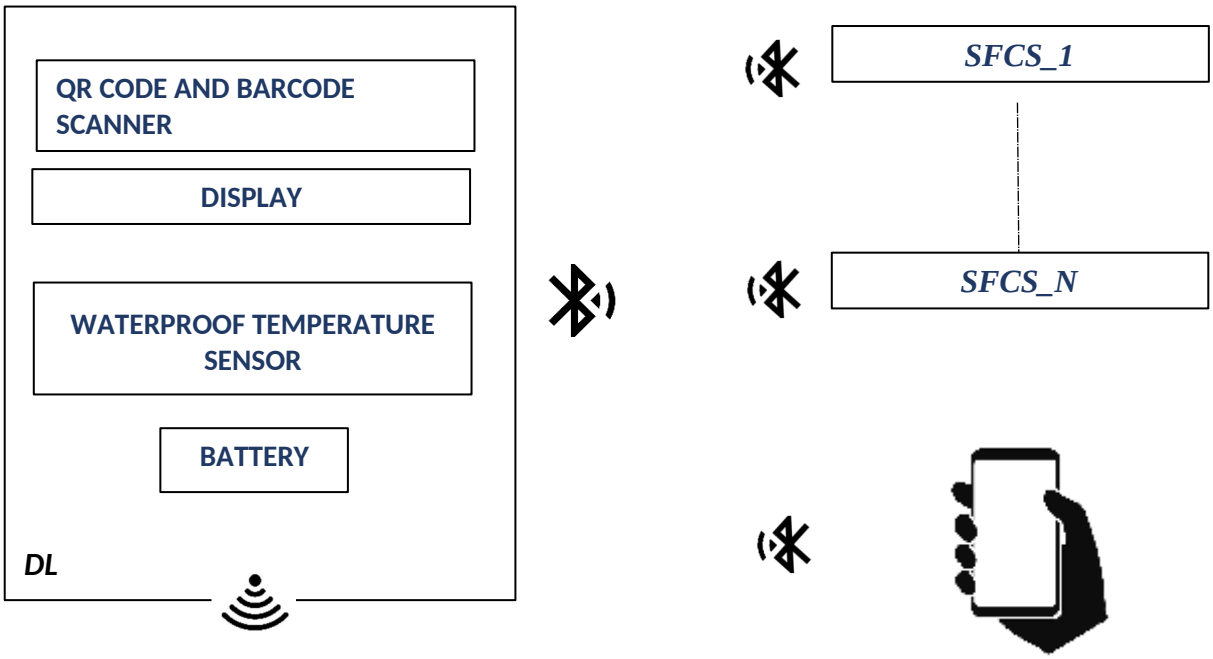
  Production company

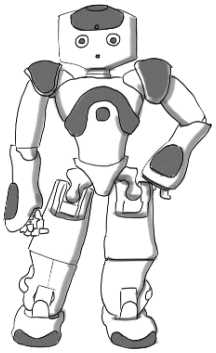
  Product

  Lot number, variable weight, expiry date, place of production, place of processing

- We have implemented the integration with the humanoid robot NAO which performs the task of a home assistant; specifically, it interacts with the ***SPFC*** system, monitoring the condition of food stored in the fridge and indicating which one to consume before spoilage, also suggesting recipes to cook it. The system based on IoT and AI new technologies allows continuous and automatic monitoring of food, useful to reduce waste; this technology could be a good support for people with visual or olfactory impairment, allowing them to check food preservation, but in the future it could be used by food business operators (production, distribution, catering), in order to cut down waste, choose the best time for consumption and improve safety
- In the case of visually impaired people, the robot NAO works as synthesizer for the reproduction of sent text messages shown on the display; in addition, Nao is modular and scalable, therefore we are already to think of future expansions allowing to monitor household electrical and thermal consumption and report any critical situations.
- According to a careful analysis of food trends provided by Whole Food Market, the two key concepts driving businesses and consumers in the future will be: search for greater sustainability and fight against waste; this suggests there is increasing awareness towards these issues and the ***SPFC*** system can be easily applied in new technologies related to food preservation

BLOCK DIAGRAMS OF THE SFCS SYSTEM





SENSORS

- *Ethanol*
- *Ammonia*
- *Trimethylamine*
- *Sulfide*

BATTERY

SFCS

PARTICULAR SUBSYSTEM SFCS