WP T1 - Deliverable 3.1
Working prototypes using sensor technology

Improving Resources Efficiency of Agribusiness supply chains by Minimizing waste using Internet of Things sensors (REAMIT)

Interreg North-West Europe
REAMIT
European Regional Development Fund

www.reamit.eu

RESOURCE & MATERIALS EFFICIENCY

REAMIT will adapt and apply existing innovative technology to reduce food waste in agribusiness supply chains of North-West Europe

Yumchop Foods and the REAMIT Project
Pilot-test start date: September-2021

YUMCHOP®
Naturally tasty meals in minutes!

We are REAMIT

REAMIT is a transnational European territorial cooperation project funded by Interreg North-West Europe (NWE) Programme aiming to reduce food waste. The project focuses on fruits, vegetables, meat and fish supply chains as these are wasted in large quantities. It is being carried out in Ireland, Germany, France, UK and the Netherlands due to the amount of interconnected food supply chains and huge food waste in these countries. The REAMIT project is using existing Internet of Things and Big Data technologies to best fit the needs of the food supply chain management system in the NWE region. Through testing and adaptation, these technologies are being enabled to continuously monitor and record food quality and signal potential food quality issues. Through analytics, owners of 'food at risk of becoming waste' are provided with decision support options to minimise food waste including redistribution to nearby customers. As part of the technology demonstrations, the REAMIT project team is working with Yumchop, helping to reduce food waste.

Who are Yumchop?

Yumchop specialises in producing African flavoured frozen ready meals. They provide flavoursome and authentic food from around the world with an African twist that is frozen to retain its goodness and freshness and minimise waste. Yumchop is using locally sourced raw materials to prepare their ready-meal products. Most of the ingredients are supplied by local vendors, located locally from the production plant of Yumchop in Towcester, Northamptonshire, UK. Their tasty meals are distributed at institutions such as universities or hospitals through self-service automated vending machines. These unattended retailing kiosks have been fitted with an integrated microwave oven which enables them to warm the food upon purchase. However, Yumchop also delivers food to customers' homes through direct purchase at their website, enabling one-off purchases and monthly subscriptions that customers can customise to receive food at their preferred intervals. Moreover, they also supply directly to retailers and large organisations. Click here to view their website.
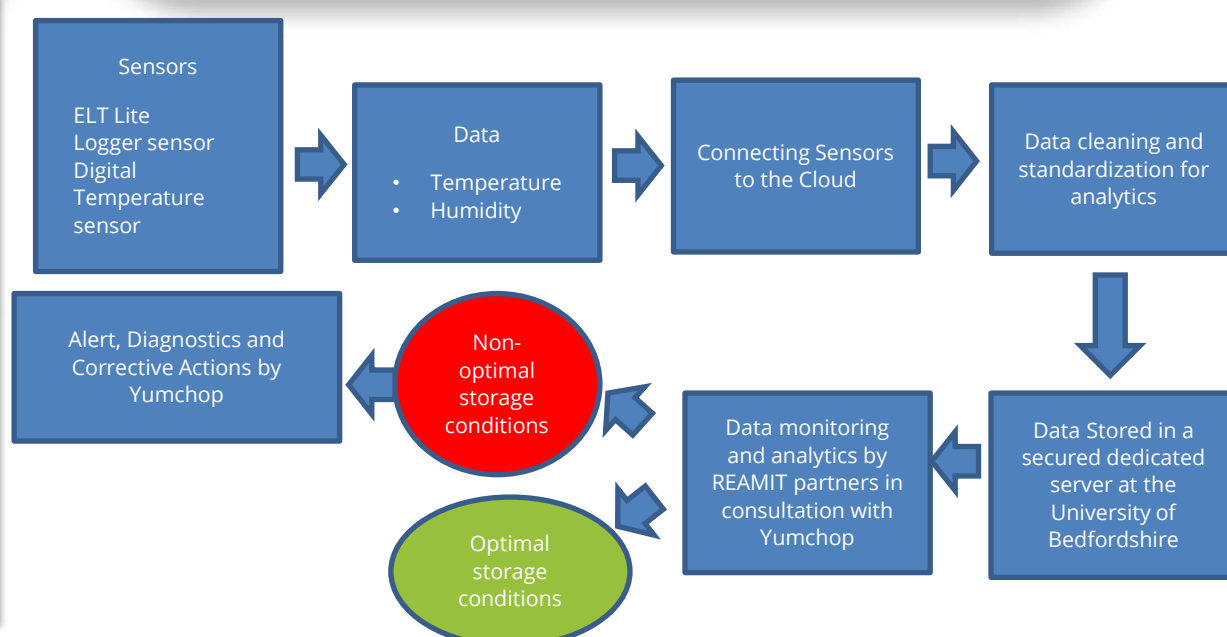
REAMIT-Yumchop collaboration with the University of Bedfordshire

REAMIT Lead partner, the University of Bedfordshire, UK is leading on a technology demonstration pilot test with Yumchop Foods. The REAMIT technology is integrated into the Yumchop operations starting from storing the raw materials and prepared foods in the internal storage until the 'ready-to-eat' meal packages are stored in the vending machines/outlets. In each stage of the operations namely sourcing, preparing, storing, logistics and delivering to customers, the REAMIT sensors monitor the temperature and transmit data to Yumchop team with an alerting system that helps the team know when there is a problem during storage, to avoid the food going to waste. Using REAMIT technology, the company prevents nearly 10% of food from being waste.

This REAMIT Pilot test with Yumchop aims to:

- **Ensure that frozen food and raw materials for preparing the food are stored in the right temperature in the frozen food manufacturer's factory.**

- **Ensure that frozen food is transported at the right temperature from frozen food manufacturer's food factory to where vending machines are located or to private homes (frozen food manufacturer's home delivery service).**

- **Provide food fingerprint (i.e. data on the condition in which food produced by the frozen food manufacturer has been stored and transported).**

- **Adhere to legal requirements (e.g., HACCP) on food quality.**

Current Potential Areas for food Waste	**Scenario 1: Warehouse, Freezers and refrigerators** Sudden and undetected rise in the warehouse temperature overnight. temperature fluctuations, equipment malfunctioning. **Scenario 2: Vending machines** Temperature fluctuations, equipment malfunctioning, user interference.	
REAMIT's Solution	**IoT sensors installed and connected to the cloud providing information in real-time means:** • Improved system efficiency by continuously monitoring the temperature of freezers. and refrigerators through an automated process. • Reduced food waste, saving the company from any loss due to temperature fluctuations. • Increase in food quality, revenue and transparency.	

Sensors

ELT Lite
Logger sensor
Digital Temperature sensor

Data
- Temperature
- Humidity

Connecting Sensors to the Cloud

Data cleaning and standardization for analytics

Data Stored in a secured dedicated server at the University of Bedfordshire

Data monitoring and analytics by REAMIT partners in consultation with Yumchop

Non-optimal storage conditions

Optimal storage conditions

Alert, Diagnostics and Corrective Actions by Yumchop

University of Bedfordshire Business School · images & réseaux · UCD Dublin · UNIVERSITÉ DE NANTES · LEVSTONE · NBS Nottingham Business School Nottingham Trent University · WHYSOR

MTU · SenX · Ulster University · WD MEATS · Valorial MAKING FOOD SMARTER · ActionSense · University of Essex Essex Business School

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The Human Milk Foundation and the REAMIT Project

Pilot-test start date: September-2021

REAMIT will adapt and apply existing innovative technology to reduce food waste in the supply chains of North West Europe

hmf HUMAN MILK FOUNDATION

www.humanmilkfoundation.org

RESOURCE & MATERIALS EFFICIENCY

We are REAMIT

REAMIT is a transnational territorial cooperation project funded by Interreg North-West Europe (NWE) Programme. The main aim of the project is to help reduce food waste. The project focuses on fruits, vegetables, meat and fish supply chains as these are wasted in large quantities. It is carried out in Ireland, Germany, France, UK and the Netherlands due to the amount of interconnected food supply chains and huge food waste in these countries. The REAMIT project is using existing Internet of Things and Big Data technologies to best fit the needs of the food supply chain management system in the NWE region. Through testing and adaptation, these technologies are being enabled to continuously monitor and record food quality and signal potential food quality issues. Through analytics, owners of 'food to be at risk of becoming waste' are provided with decision support options to minimise food waste including redistribution to nearby customers. As part of the technology demonstrations, the REAMIT project team is working with The Human Milk Foundation (HMF), helping to optimise the quality of donor human milk and maintain cold chain logistics.

Who are the Human Milk Foundation (HMF)?

The HMF is a UK charity (est. 2018) working to create an equitable national service that can support all families facing feeding challenges. The HMF operates the Hearts Milk Bank, which provides 1000s litres of screened donor human milk (DHM) to vulnerable babies in over 50 neonatal intensive care units, as well as where a bridge to a full milk supply is needed or the mother is receiving cancer treatment. REAMIT will improve logistics and produce first-in-world data on donor milk transportation.

REAMIT-HMF collaboration with the University of Bedfordshire (UoB)

REAMIT Lead partner, the University of Bedfordshire, UK is leading on a technology demonstration pilot test with the HMF

The aim of the REAMIT pilot test with the HMF is to develop a system that monitors the temperature at which human milk is transported from a milk donor to human milk bank and then to the hospital or home where a baby that needs the milk is located. The system will generate alerts if these conditions change to save precious human milk from being wasted and to ensure temperature stability.
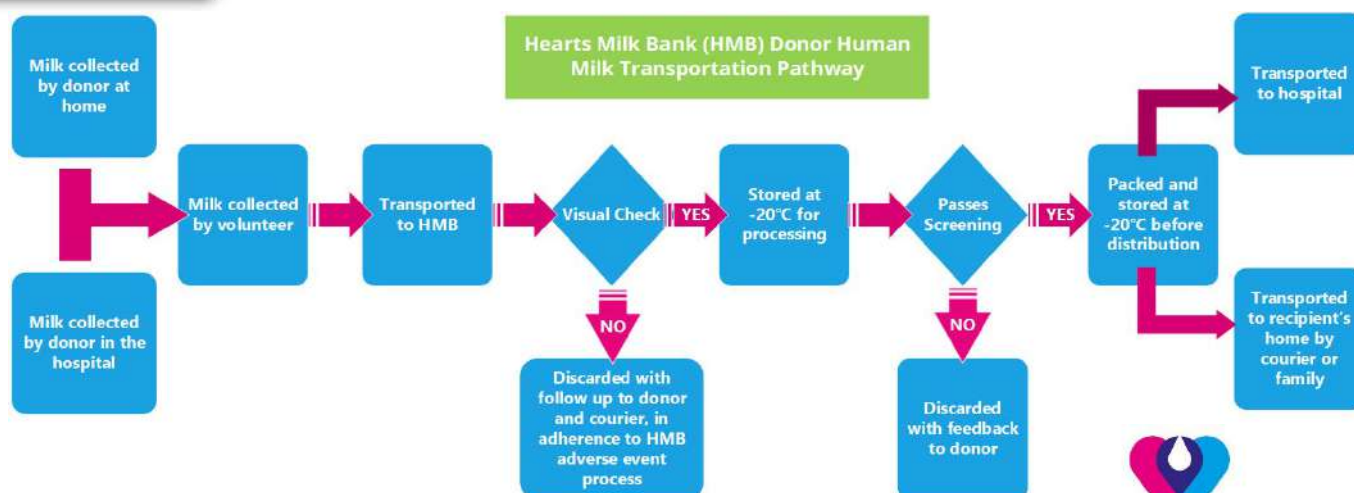
Challenges of DHM storage and transportation

• The main factor related to human milk wastage are **microbiological contamination,** which means around 10% of donated milk must be discarded currently. Fluctuating or high temperature and humidity levels can impact quality**.**

• The HMF is keen to accurately **monitor the temperature** during the transportation as they want to ensure that the milk has remained in optimal conditions from the point of expression until fed to a vulnerable infant.

• Unexpected problem with the freezers delay or skip alerts when the temperature raises. This could result in discarding more than 1000 L of human milk.

REAMIT's Solution

a) Monitoring services and
b) Optimizing the quality control services of human milk banks during transportation, processing and storage.

This REAMIT Pilot test with HMF aims to -

- Monitor temperatures in individual transport boxes when milk is transported between a donor to the Hearts Milk Bank and from the milk bank to hospitals, hubs or recipient homes.
- To send alerts if these conditions change.
- Maintain transportation temperatures at less than -18°C, according to the national NICE guideline for Human Milk Bank Operations
- Reducing the milk transportation costs by optimizing logistics operations.
- Achieve capacity to support 500 journeys per month

The REAMIT and HMF teams come together at the Hearts Milk Bank, Hertfordshire, UK

Hearts Milk Bank (HMB) Donor Human Milk Transportation Pathway

Milk collected by donor at home → Milk collected by volunteer → Transported to HMB → Visual Check → YES → Stored at -20°C for processing → Passes Screening → YES → Packed and stored at -20°C before distribution → Transported to hospital / Transported to recipient's home by courier or family

Milk collected by donor in the hospital

Visual Check → NO → Discarded with follow up to donor and courier, in adherence to HMB adverse event process

Passes Screening → NO → Discarded with feedback to donor

hmb HEARTS MILK BANK

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MTU Munster Technological University · SenX · Ulster University · WD MEATS · Valorial MAKING FOOD SMARTER · ActionSense · University of Essex Essex Business School

Evaluation of the impact of bad storage (temperature) on the chicken meat quality by Raman Spectroscopy

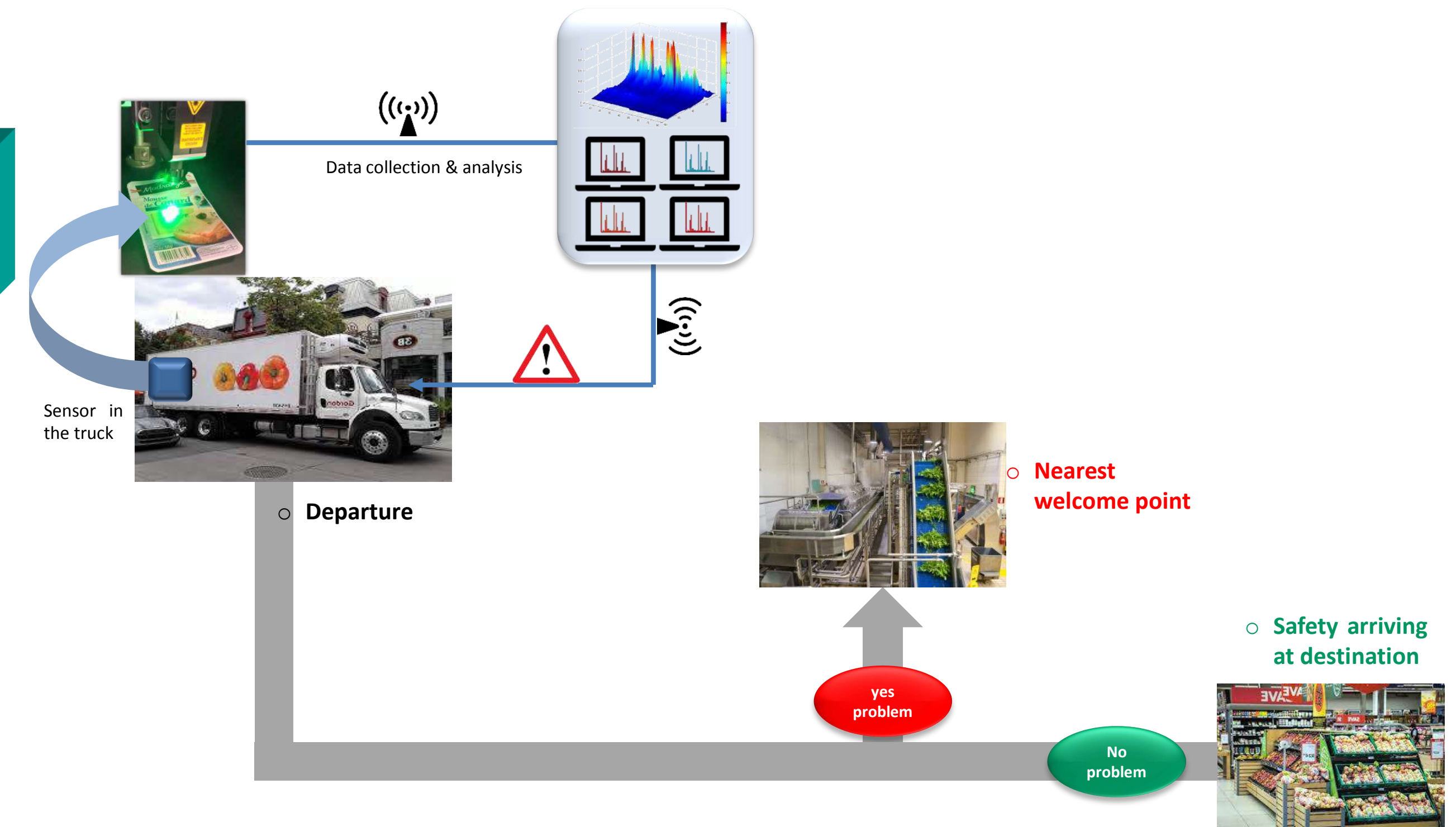**A. ASSAF[1], E. GRANGÉ[1], S. JOUANNEAU[1], J. LAHMAR[1], G. MAUGIS[2] and G. THOUAND[1]**

1) University of Nantes, UMR CNRS GEPEA 6144, TEAM-LRSY, 18 Boulevard Gaston Defferre, 85035 La Roche sur Yon, France.

2) Images & Réseaux, 4 rue Ampère, 22300 Lannion, France.

Contact: ali.assaf1@univ-nantes.fr

REAMIT project

The REAMIT project proposes to adapt and apply existing innovative technology to food supply chains in NWE to reduce food waste and hence improve resource efficiency. REAMIT will adapt existing technologies to continuously monitor and record food quality and signal potential food quality issues. In this context, optical sensors as Raman spectroscopy will be used for the monitoring of food quality during their refrigerated transport. Through these analytics, owners of "food to be at risk of becoming waste' will be provided with decision support options to minimise food waste including redistribution to nearby customers.

Data collection & analysis

Sensor in the truck

Departure

Nearest welcome point

Safety arriving at destination

yes problem

No problem

Technical development of Raman spectroscopy pilot

Proof of principle

The first analyses were done in lab-conditions on chicken samples bought from the market. Two conditions were tested: 1) bad storage at 20°C and 2) Good storage at 4°C.

Protocol of chicken analysis by a lab Raman spectrometer

Chicken Fresh samples

Chicken 24 h of bad storage

Chicken 48 h of bad storage

Chicken 60 h of bad storage

Chicken 72 h of bad storage

Raman shifts (cm⁻¹)   Raman shifts (cm⁻¹)

Fig.1: Spectra and 2D plots showing the differences in Raman shifts (in cm⁻¹) and the intensities between the studied samples. Raman parameters were λ= 785 nm, power= 25 mw (on sample) and acquisition time= 30 seconds

The statistical analysis shows the ability of Raman spectroscopy to classify Raman spectra of samples according to their storage temperature.
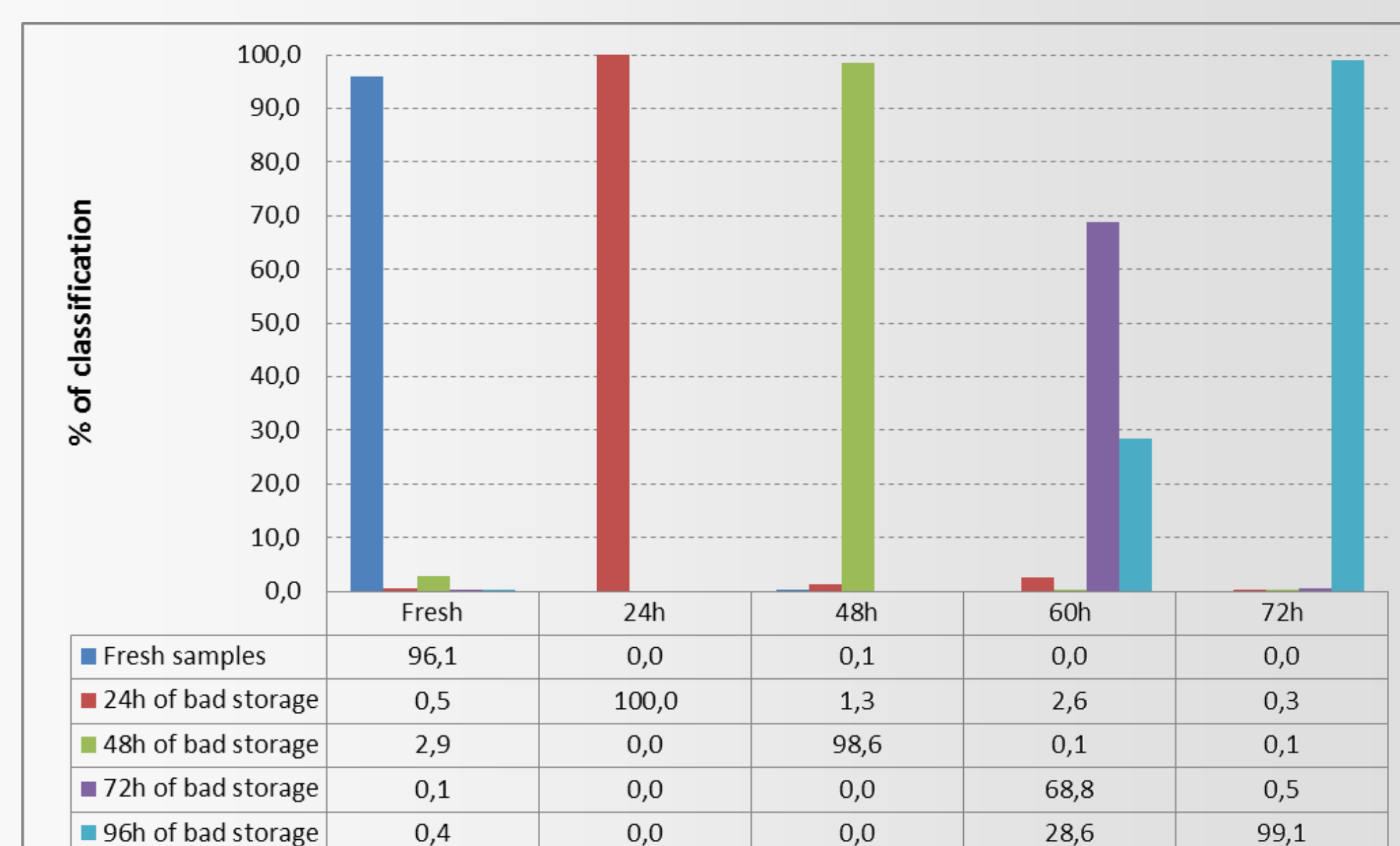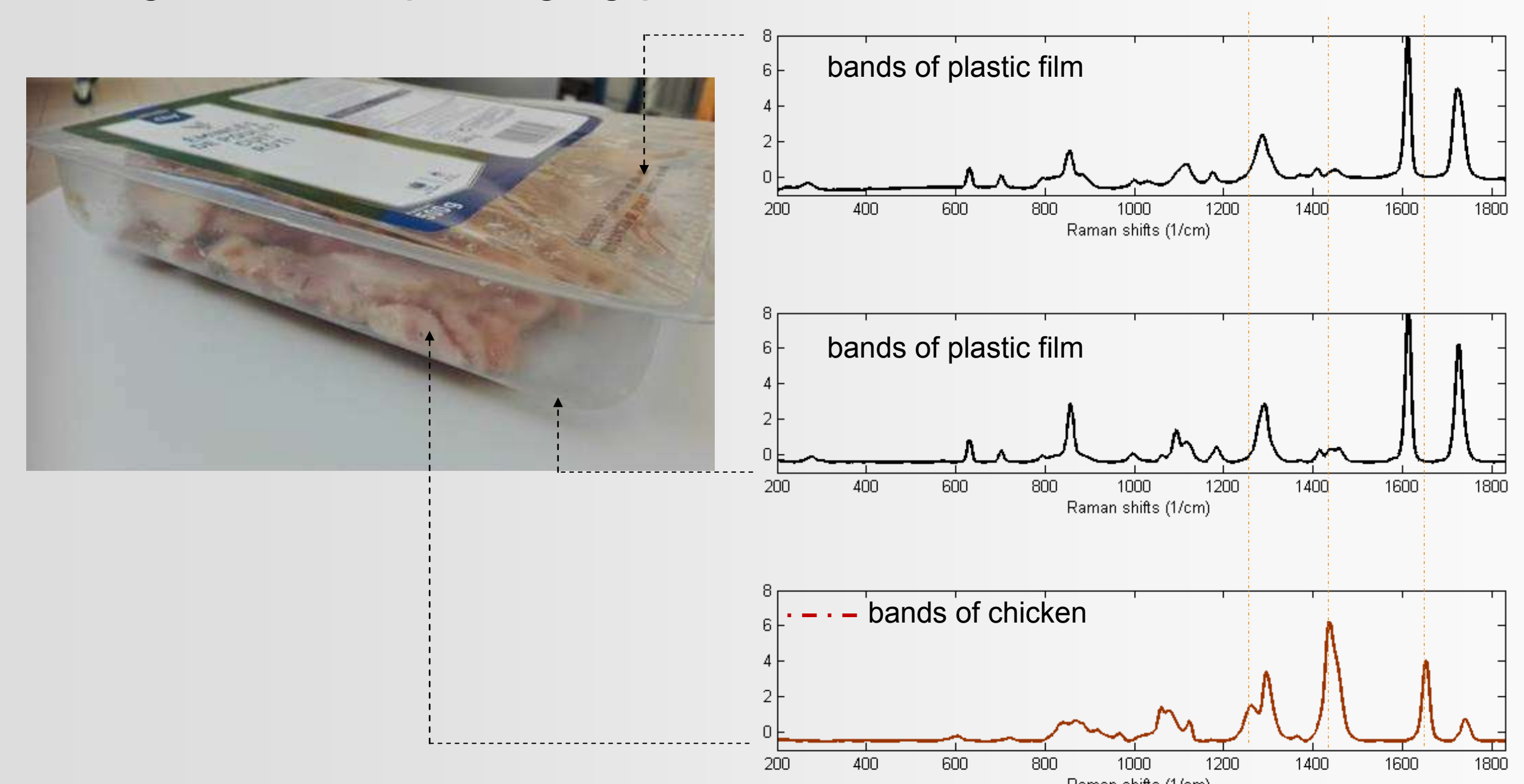
% of classification	Fresh	24h	48h	60h	72h
Fresh samples	96,1	0,0	0,1	0,0	0,0
24h of bad storage	0,5	100,0	1,3	2,6	0,3
48h of bad storage	2,9	0,0	98,6	0,1	0,1
72h of bad storage	0,1	0,0	0,0	68,8	0,5
96h of bad storage	0,4	0,0	0,0	28,6	99,1

Fig.2: Classification of the Raman spectra done on chicken samples according to their storage conditions by the factorial discriminant analysis

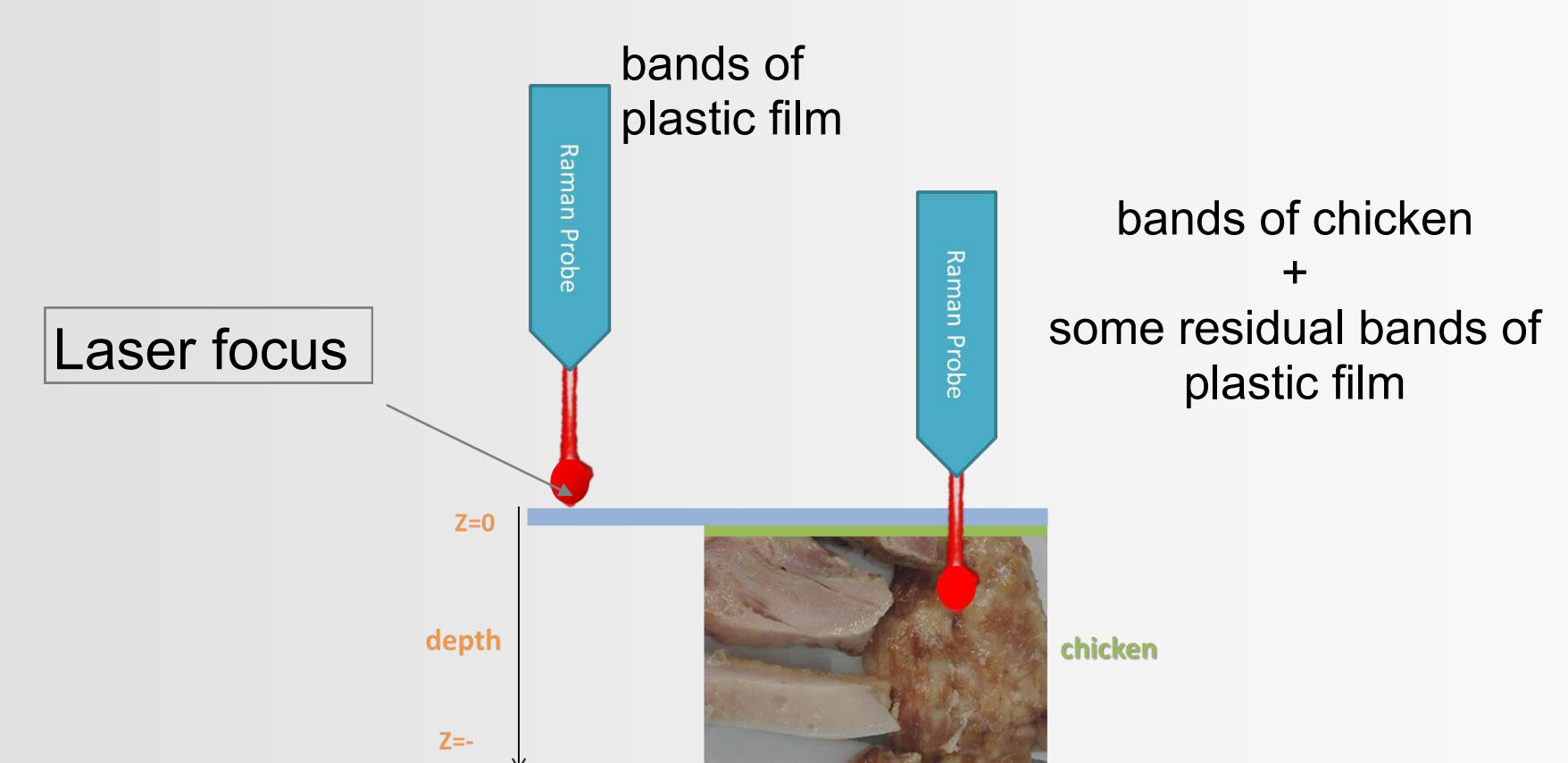### Adapting Raman sensor for the refrigerated transport

A portable device is currently used for the analysis of food without removing of the packaging film.

Raman spectra

Portable Raman spectrometer with optical probe for the analysis of food during transport

The preliminary experience shows the possibility to analyze the food samples directly inside the container. Nevertheless, the exploration of results reveals the overlapping between chicken bands with some Raman signals of the packaging plastic film.

bands of plastic film

Raman shifts (1/cm)

bands of plastic film

Raman shifts (1/cm)

bands of chicken

Raman shifts (1/cm)

The packaging impacts the Raman signal of chicken. Currently, we work on the optimization of analysis protocol to eliminate this impact .The focalisation of laser spot behind the film allows to have a signal specific to chicken, an mathematical algorithm is still necessary to eliminate bands of the plastic packaging (under construction).

bands of plastic film

bands of chicken + some residual bands of plastic film

Laser focus

z=0

depth

z= 1000µm

chicken

Conclusion

Raman spectroscopy revealed the impact of storage temperature on chicken samples and allowed to classify properly the samples according to their storage conditions. The use of portable device add more challenges for the analysis of packaged food. The combination between optical and mathematical solutions is necessary to eliminate signal of the packaging. The ultimate step is to integrate the Raman sensor directly into a refrigerated truck and to test it under real conditions.

Interreg North-West Europe REAMIT

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WD Meats – Pilot Tests

Pilot-test start date: March 2020

We are REAMIT

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The REAMIT project is using existing Internet of Things and Big Data technologies to best fit the needs of the food supply chain management system in the NWE region. Through testing and adaptation, these technologies are being enabled to continuously monitor and record food quality and signal potential food quality issues. Through analytics, owners of 'food to be at risk of becoming waste' are provided with decision support options to minimise food waste including redistribution to nearby customers. As part of the technology demonstrations (aka pilot tests), the REAMIT project team is working with WD Meats on two different activities, helping to reduce waste of beef meat.

Who is WD Meats in food sector?

WD Meats, based in Coleraine, Northern Ireland is a Beef Manufacturer since 1979. It provides a high-quality beef with full traceability of meat and livestock. WD Meats supplies beef to a wide range of retailers and other food services across the UK and Europe, as well as to markets in Asia and Africa. WD Meats also makes regular supply to various food services outlets such as catering butchers, independent retailers and as well as wholesalers.

REAMIT-WD Meats-Ulster University collaboration

Ulster University, one of the partners in the REAMIT consortium, is working closely with WD Meats on two pilot tests. One approaches the global food waste phenomenon known as "blown pack spoilage" (BPS) and the other investigates the impact temperature gradients can have on beef within dry-aging chambers.

How to prevent the spread of bacteria in the meat products?

BPS prevention trial : The occurrence of BPS is caused by several strains of the Clostridium bacteria, most notably Clostridium Estertheticum. Presence of this anaerobic bacteria within typical vacuum sealed packaging can result in notably reduced shelf life and an inevitable increase in wasted beef. Rapid detection of this bacteria could not only prevent the spread, but also, as it is a non-toxic bacteria, it could stop infected meat from being wasted by not giving the bacteria chance to reproduce. REAMIT sensor technology will be used to rapidly identify samples containing the virus and allow for the product removal and immediate sanitisation of exposed areas.

Dry-Aging trial : Due to the configuration of dry-aging chambers, the proximity of beef products to heat sources, such as doors and distance from refrigerators can affect the moisture content of the beef. These changes in beef moisture content can affect both business value and the overall quality of the beef. REAMIT will add a number of Ursalink UC-11 IoT-connected LoRaWAN temperature and humidity sensors to these chambers and analyse the outputted data against the meat produced.

Why REAMIT for WD Meats?

Current challenges of WD Meats	REAMIT technology for WD Meats	Objectives of REAMIT-WD Meats pilot test
Clostridium contamination through slaughtering process can result in huge loss of spoiled product.	✓ 3D Fluorescence sensors ✓ Internal on-site laboratory ✓ Tempo system for identifying bacteria counts on raw beef products ✓ Internal Swabbing system for detection of clostridium esters with external testing lab	**Clostridium trial** ✓To identify if the bacterium is present ✓To give a quick turnaround to help identify the problem ✓To isolate the contaminated product before carrying out full clean downs on affected areas
When process drift from set points, this can have a detrimental effect on yield, spoilage & and eating quality of finished products.	Company has been dry-aging meat produce for years. **REAMIT offers:** On-site Dry aging chambers and state of the art dry-ageing chillers.	**Dry-ageing trial** ✓To increase the monitoring capability of the relative humidity and temperature ✓To result in reduced yield-loss without affecting eating quality

REAMIT-WD Meats Collaboration output

Collaborative efforts between WD Meats and Ulster University on the REAMIT project, promise to save a substantial amount of food. For instance, experience shows that an unprepared facility, experiencing an issue with the BPS causing Clostridium Estertheticum can result in approximately 7,800 kg of wasted beef per year. Early warning with REAMIT sensors is helping to avoid 25-50% of this waste so far, equivalent to 2,000-4,000 kg of meat saved or approximately £25,000 per year. In addition to this saving, the REAMIT project is saving much more meat waste- by providing optimal conditions through REAMIT technology, WD Meats will enhance the quality of the meat produced, which will make huge savings on resources and save meat products becoming waste.

The REAMIT consortium is looking for agri-food companies in North West Europe to demonstrate food waste reduction through its approach and technology. Do you think your company could benefit from REAMIT approach and technology? If you want to be more efficient with your resources, REAMIT can equip you with necessary tools to save you time and resources, and in the long-term to reduce food wastage locally and globally!

Biogros and the REAMIT Project

Pilot-test start date: November-2021

BIO GROS
Produits biologiques et demeter

https://www.biogros.lu

We are REAMIT

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We are Biogros

Biogros is a wholesaler for high quality organic and biodynamic foods (3.500 items in fruit, vegetables, dry goods and dairy produce) in Luxembourg. For more than 25 years, Biogros has been supplying high quality organic food six days a week to their Luxembourg customers. Biogros stocks products from well-known organic brands like Naturata, Rapunzel and Lebensbaum, as well as organic products from lesser known or smaller producers. Thanks to our close collaboration with organic farmers from the cooperative Bio-Bauern-Genossenschaft Lëtzebuerg (BIOG), who also offer a whole range of regional organic products.

Challenges at Biogros

While receiving deliveries from BIOG organic growers in Luxembourg, Biogros noticed that the quality of fragile produce, such as mushrooms, unions, potatoes and celery roots, would occasionally not be up to standard. Biogros wanted to gain insight in the climatic conditions (temperature and humidity) in the full supply chain, from grower to supermarket. Biogros sought a system which would perform the following:

1. The trucks should be connected to the cloud to allow for real-time data reporting / monitoring while the trucks perform deliveries
2. The warehouses of both grower and Biogros should be connected to the cloud, measuring temperature and humidity to allow for real-time data reporting/ monitoring
3. An alerting system should send SMS messages to drivers and warehouse logistics staff notifying if any anomalies occur
4. Alerts should not be sent when the trucks are stationary e.g., parked overnight, performing a delivery, etc.
5. The power consumption of the proposed system should be such that maintaining the equipment does not become an arduous task

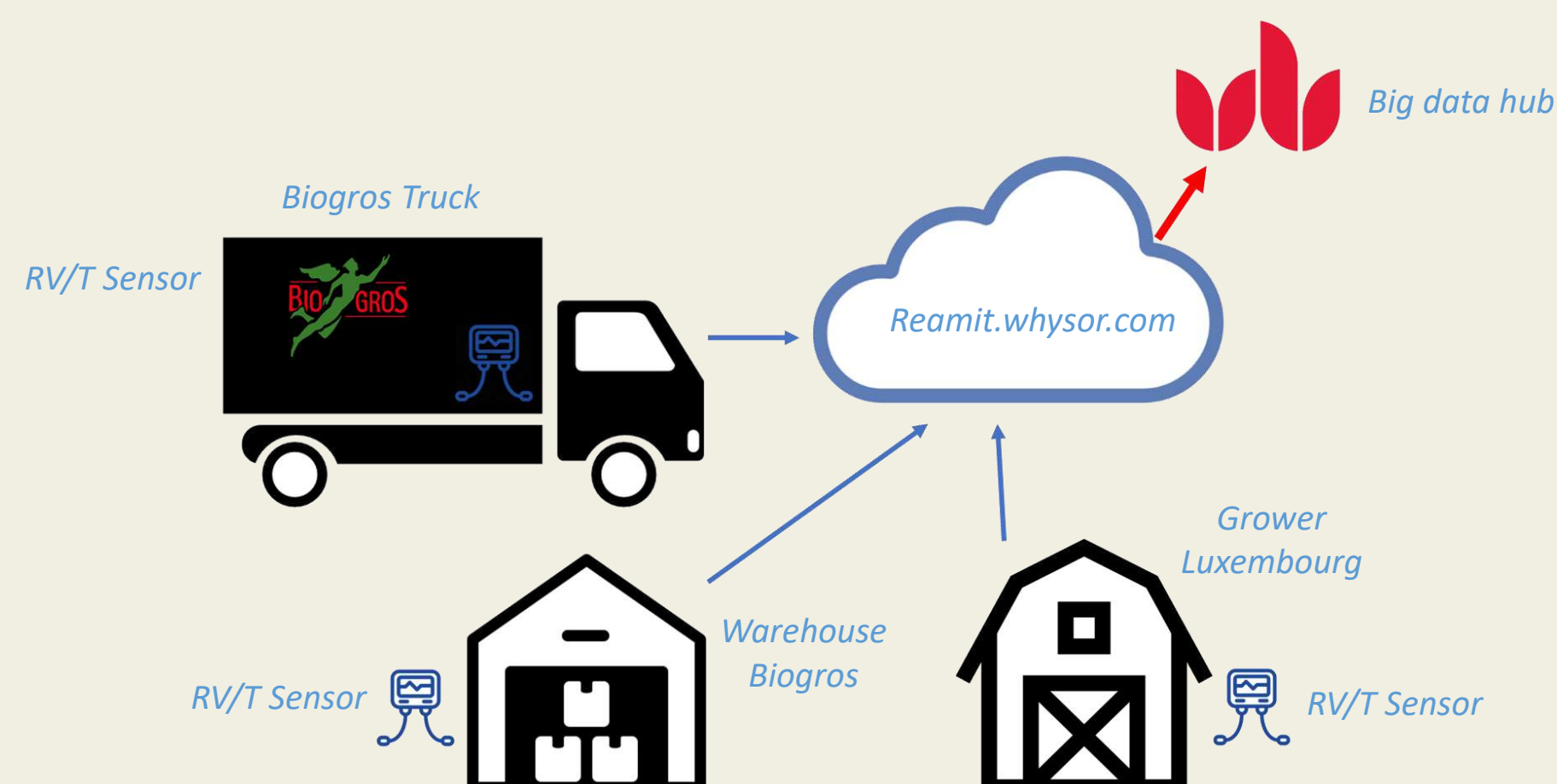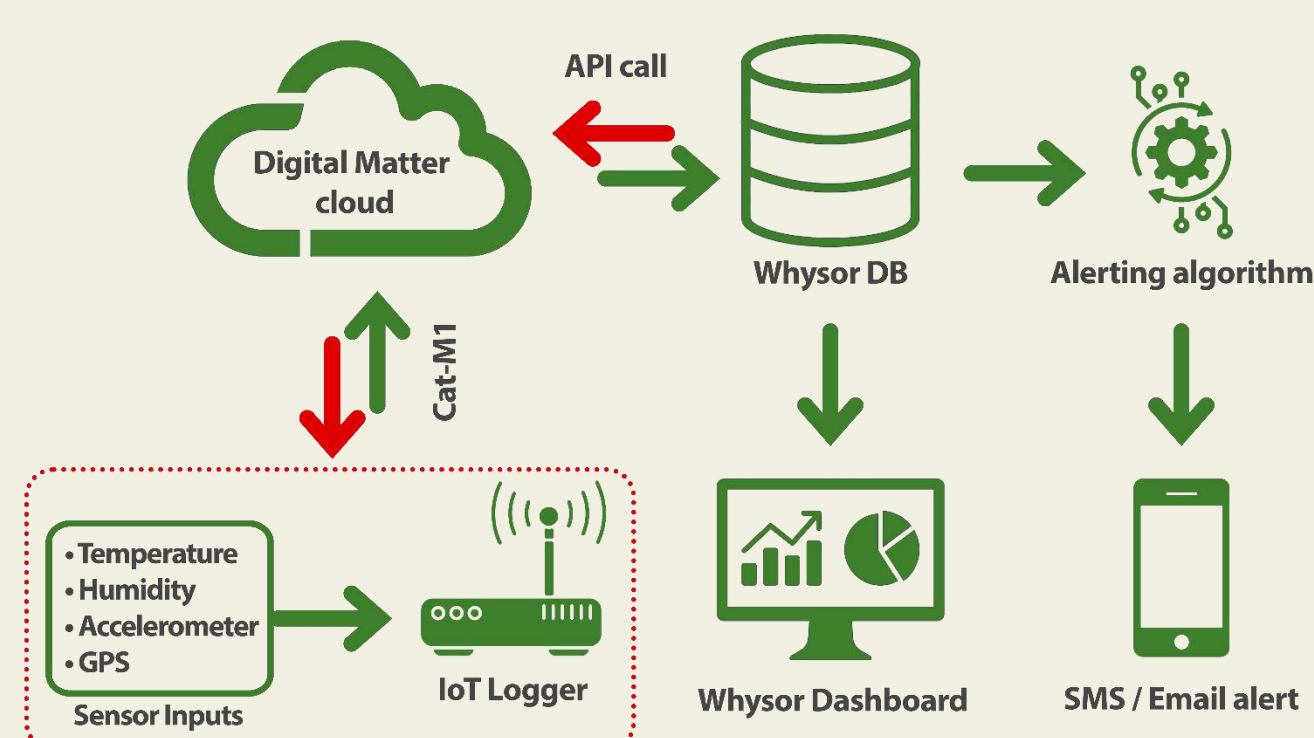Grower Luxembourg → Warehouse Biogros → Reseller

REAMIT's solution

The REAMIT team at Whysor (the Netherlands) examined Biogros' system requirements and proposed a real-time monitoring and alerting system for anomaly detection during the full supply chain. The Eagle datalogger (Digital Matter, South Africa) was selected as the platform for the development of the REAMIT solution. The logger is an IP67 rated rugged cellular IoT device, supporting a range of inputs for various IoT applications. The Eagle runs on either batteries or can be wired to permanent power. It has analog, digital and serial inputs. It contains a GPS module and an accelerometer for geofencing and movement detection and is equipped with a sim card allowing the device to perform as an IoT gateway, running on the GPRS LTE / 4G network.

For the Biogros pilot, the logger was fitted with a T9602 Temperature/Relative Humidity sensor (Amphenol, USA), to allow monitoring in ambient and chilled zones of trucks and warehouses.

Whysor developed the REAMIT dashboard for real time monitoring and alerting, which was utilized by each pilot study in the project. The dashboard runs on both desktop computer and smartphone. The alerts can trigger an e-mail or SMS notification.

Biogros Truck
RV/T Sensor
Reamit.whysor.com
Big data hub
Warehouse Biogros
RV/T Sensor
Grower Luxembourg
RV/T Sensor

System Architecture

Digital Matter cloud
API call
Whysor DB
Alerting algorithm
Cat-M1
Sensor Inputs: Temperature, Humidity, Accelerometer, GPS
IoT Logger
Whysor Dashboard
SMS / Email alert

Alerting logic. The threshold values for the alerting system are defined by the technical team at Biogros, for all locations inside the warehouse or inside the truck. Text messages are sent if the limit value is exceeded, e.g., above 8°C in the vegetable department or above 10°C inside the truck.

To avoid false alerts, the system records 2 consecutive values above the threshold before sending the alert. The values are recorded every 5 minutes by the logger.

Trip detection. A trip detection algorithm was developed based on accelerometer measurements and GPS data reported by the Eagle logger. A trip would be reported if motion was detected by the accelerometer and if the GPS coordinate had changed from the previous reading. This algorithm allowed the system to sleep when trips are not being performed to conserve battery life, as well as avoiding sending false alerts while trucks are parked overnight.

Results and Conclusion

The IoT anomaly detection system was deployed in Biogros between March-July 2022 in nine trucks, at three growers and at seven departments inside the Biogros warehouse. Logistics staff at the warehouse were given access to the REAMIT dashboard for real-time monitoring of the vehicles and warehouses and were added to the alerting service. This allowed them to receive text messages to their smartphone if an anomaly was detected. Early results show that the system is robust and avoids sending false alerts due to the trip detection algorithm, a purpose-built customised system.

Practical application. We have developed an IoT solution which monitors in real time the temperature and humidity of the full supply chain.

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RESOURCE &
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Picnic and the REAMIT Project

Pilot-test start date: November 2020

PICNIC

https://picnic.app/nl/

We are REAMIT

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We are Picnic

Picnic was founded in the Netherlands in 2015 and started with 4 delivery vans. In 2022 more than 1,000 electrical vans drive around in about 120 Dutch cities. With hundreds of thousands of customers and a monthly expansion to new cities, Picnic was named the fastest growing company in the Netherlands in 2019. Picnic thinks grocery shopping can be done differently: faster, easier and cheaper.
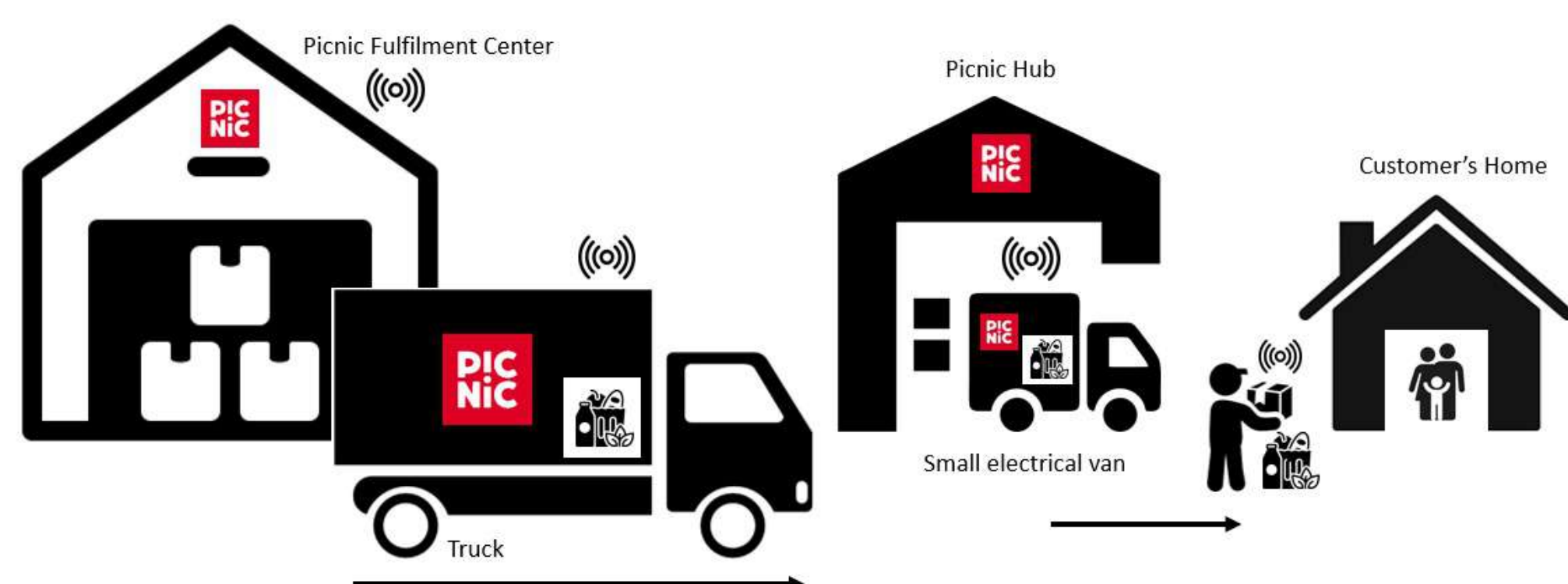
The idea is simple. Picnic arranges the groceries, so that you have more time for more fun things. At Picnic you can order all your groceries online within a few minutes. And all this for the lowest price and free home delivery. All groceries are delivered directly to the customers home, without expensive shops in expensive locations.

Challenges at Picnic

Based on the Picnic data driven weather regime, Picnic decides daily how many icepacks are added to every box that contains refrigerated items and how much dry ice is added to every box that contains frozen items. Picnic wants REAMIT to prepare a personalized cooling profile per box, using data from a.o. the Picnic weather regime, the duration of travel, such as shipment from Picnic regional fulfilment center to Picnic local hub and the duration of the last mile delivery of every box. Picnic is looking for a system which will perform the following:
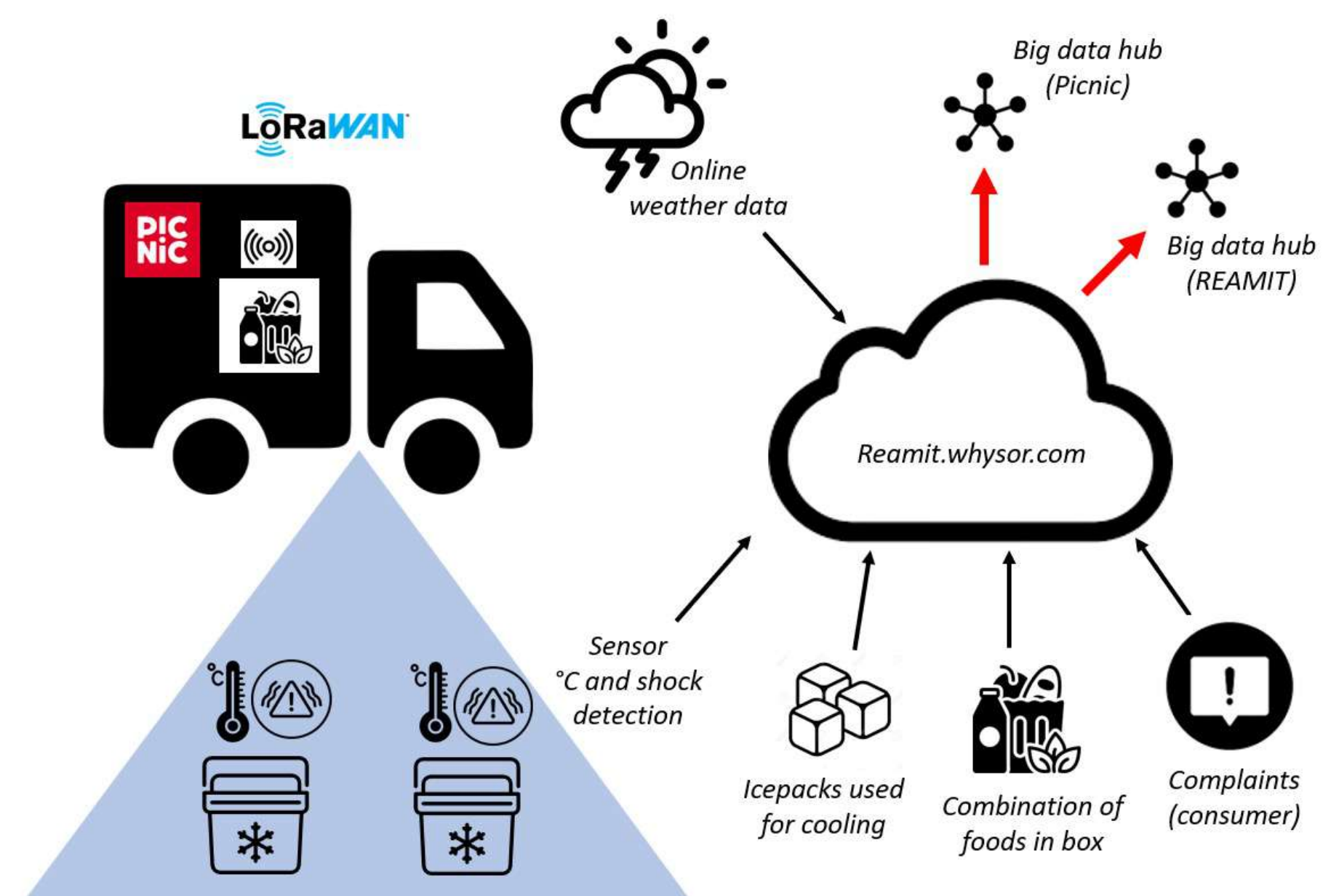
1. The boxes should be connected to the cloud to allow for (near) real-time data reporting / monitoring while the boxes are being transported.
2. The sensor housing should be able to withstand forces of heavy groceries and differences in temperature and humidity.
3. Development of a personalized cooling profile per box, based upon outside weather conditions combined with the difference in temperature inside the cooling box during transport.
4. The power consumption of the proposed system should be such that maintaining the equipment does not become an arduous task.
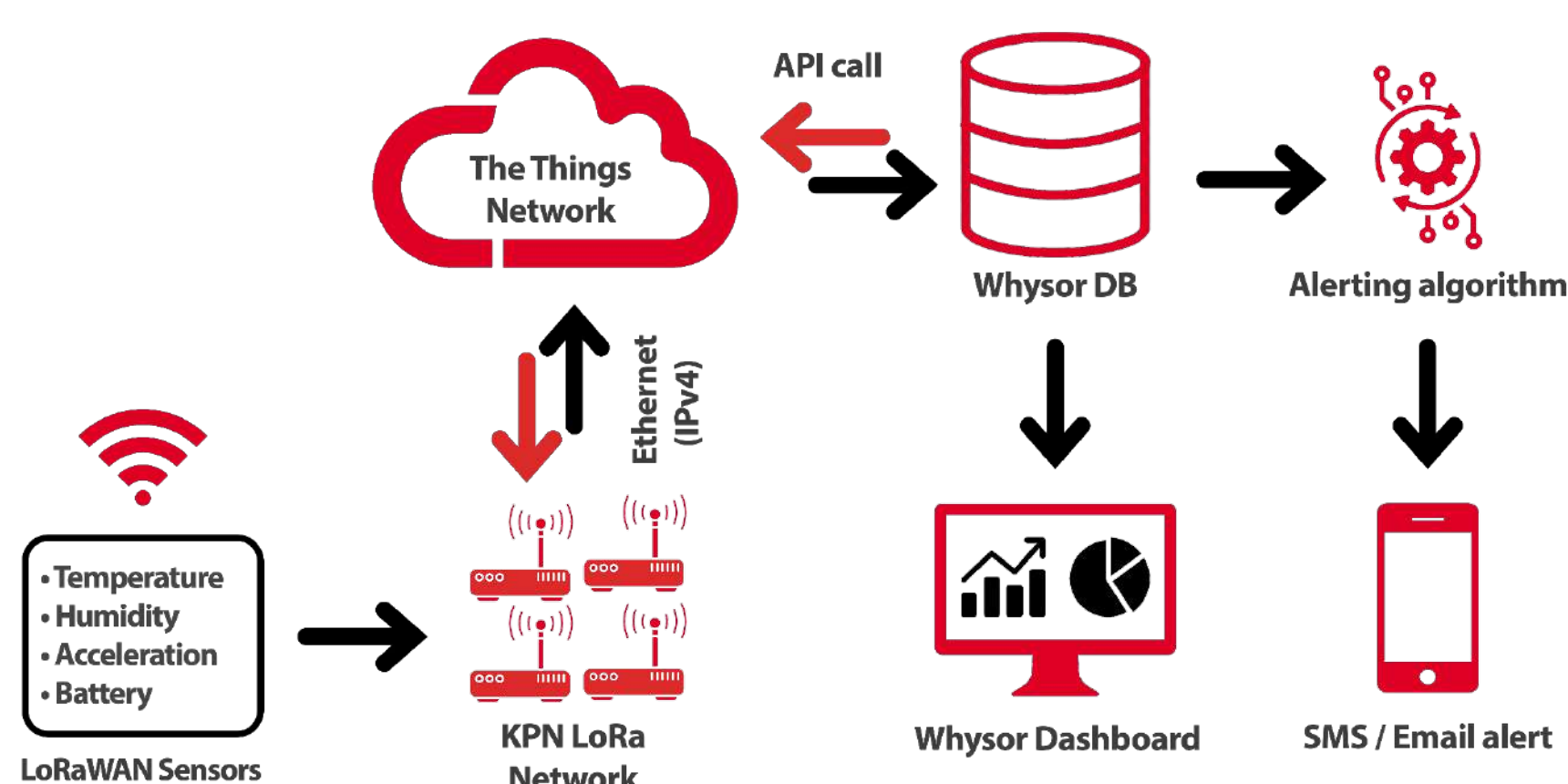

REAMIT's solution

The REAMIT team at Whysor (the Netherlands) examined Picnic's system requirements and proposed a real-time monitoring and alerting system for anomaly detection during the complete transportation process of cooling boxes. The EMS sensor (Elsys, Sweden) was selected as the sensor of choice to measure temperature and humidity. The EMS is slightly larger than an AA-battery and runs on 1 x 3.6 V AA Lithium battery, with an expected battery life of up to 10 years (depending on configuration and environment). The EMS is connected to the cloud by the LoRaWAN network, provided by KPN in the Netherlands.

Whysor developed the REAMIT dashboard for real time monitoring and alerting, which was utilized by each pilot study in the project. The dashboard runs on both desktop computer and smartphone. The alerts can trigger an e-mail or SMS notification.

System Architecture

Sustainable sensor housing. After the first testing period with the EMS sensor, the REAMIT team noticed that the original housing of the sensor was not sustainable enough to withstand the heavy forces of groceries inside the box. The team developed several prototypes of 3D-printed flexible rings to better protect the sensor.

Power consumption. The EMS sensors are configured to send data every 10 minutes. A lower transmission speed has been chosen because there is no consistent signal quality in the trucks. With the current configuration of the sensors, battery life is expected to be 1-2 years.

First conclusions

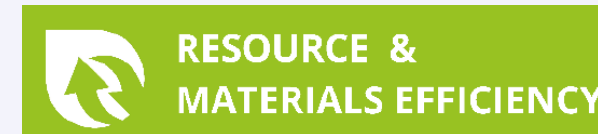**Conclusions after first and second testing round**

1. The technical specifications of the sensors meet the expectations of Picnic. The sensor responds well to changes in temperature and has a stable signal during all phases of the transport.
2. Protecting the sensor when the boxes are filled with groceries, has appeared to be challenging, due to the frequency of handling and the impact of heavy groceries.
3. The tracing of sensors that are not working needs more research because of the complexity of the Picnic box routing method.

Reducing Food Waste during the Dry Ageing of Beef using IoT Technology

REAMIT Pilot study with Burns Farm Meats

Cama-Moncunill, X.[1], Da Costa, T.[1], Murphy, F.[1], Ward, S.[1], Gillespie, J.[2], Ramanathan, R[3].   http://reamit.eu

Interreg North-West Europe
REAMIT
European Regional Development Fund

RESOURCE & MATERIALS EFFICIENCY

We are REAMIT

REAMIT is a transnational European territorial cooperation project funded by Interreg North-West Europe (NWE) Programme aiming to reduce food waste. The project focuses on fruits, vegetables, meat, and fish supply chains as these are wasted in large quantities. It is being carried out in Ireland, Germany, France, UK and the Netherlands due to the amount of interconnected food supply chains and huge food waste in these countries. The REAMIT project is using existing Internet of Things and Big Data technologies to best fit the needs of the food supply chain management system in the NWE region. Through testing and adaptation, these technologies are being enabled to continuously monitor and record food quality and signal potential food quality issues. Through analytics, owners of 'food at risk of becoming waste' are provided with decision support options to minimise food waste including redistribution to nearby customers. As part of the technology demonstrations, the REAMIT project team is working with Burns Farm Meats, helping to reduce food waste.

Who are Burns Farm Meats?

Burns Farm Meats Ltd. is a long-established family-owned company located in north Sligo, Ireland. Their main activities include farming, operation of an abattoir, processing of organic meats, and delivery of retail orders to the public. As part of these activities, being firmly committed to animal welfare and providing meat of the highest quality, Burns Farm Meats runs a dry ageing process to deliver tender cut meat of their own locally raised, fed and cared for animals.

Burns Farm Meats are especially interested in the monitoring of the dry-ageing process. In fact, despite increasing the flavour and tenderness of the meat, it is still a costly process for abattoirs because of shrinkage of the meat, trim loss, and risk of contamination

Challenges at Burns Farm Meats

Due to the configuration of dry-ageing chambers, the proximity of beef products to heat sources such as doors and distance from refrigerators can affect the moisture content of the beef. These changes in beef moisture content can affect both business value and the overall quality of the beef. Burns Farm sought a system which would perform the following:

➢ Real-time monitoring of environmental parameters, i.e., temperature and humidity, in the dry-ageing chambers

➢ The proposed system should be such that maintaining the equipment does not become an arduous task and does not interrupt their day-to-day operations

➢ An alerting system should send emails and/or SMS messages to staff notifying if any anomalies occur

➢ Understand the influence of more even distribution of temperature in the refrigerator on the quality of beef
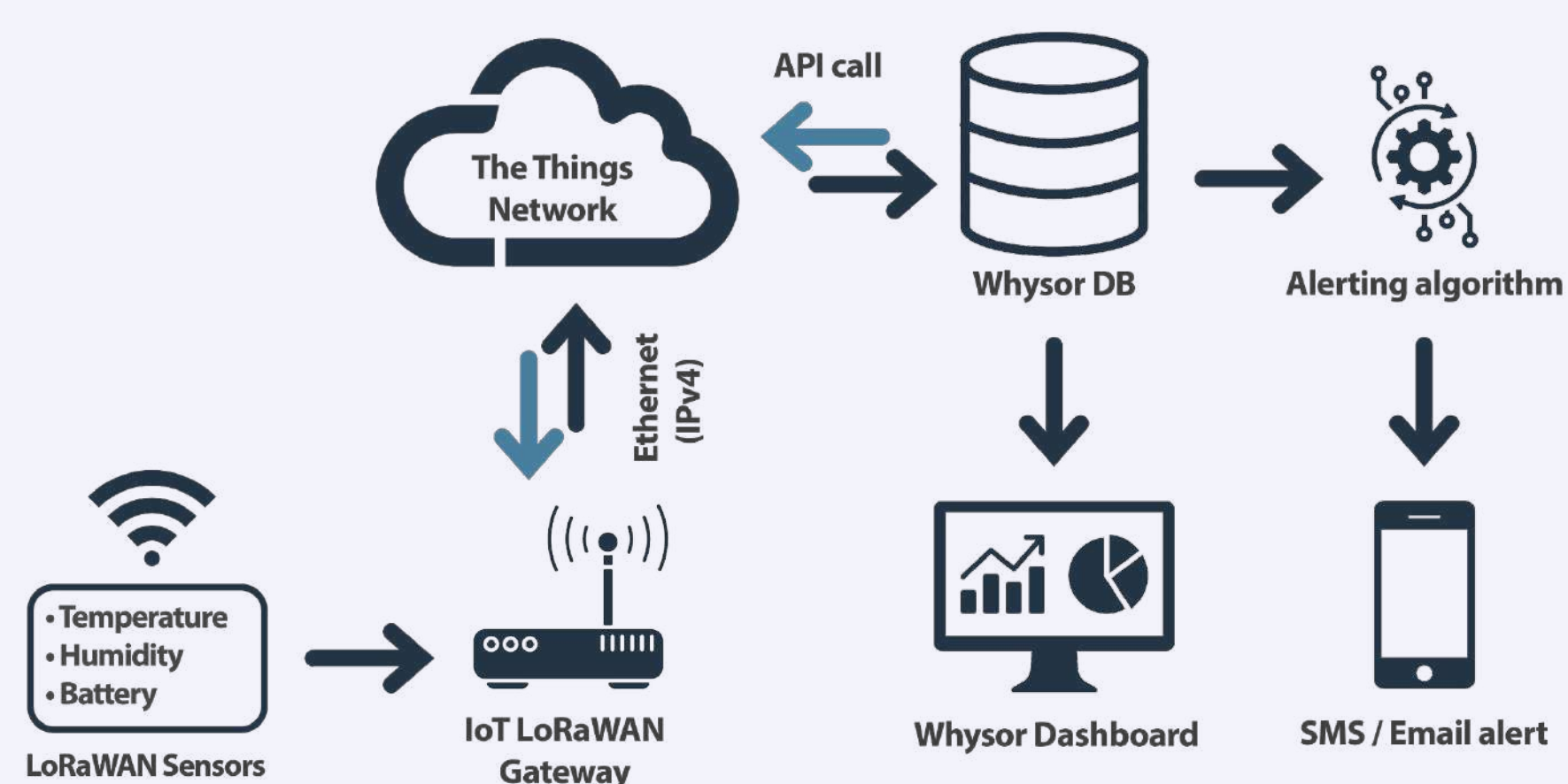

REAMIT's solution

The REAMIT team at University College Dublin evaluated the system requirements by Burns Farm Meats and proposed a real-time monitoring and alerting system for anomaly detection during dry ageing of beef. The ELT-2 Internal antenna (Elsys, Sweden) was selected as the platform for the development of the REAMIT solution. The ELT-2 is enclosed in an IP67 rated box which makes it suitable for extreme conditions. While it is possible to connect external sensors to the ELT-2, it already contains four built-in internal sensors, including temperature and humidity, which will be employed for monitoring of the environmental parameters in the dry-ageing chambers. An ELT-2 is powered by one 3,6V AA lithium battery and has an expected battery life of <10 years (subject to environment and configuration).

For the Burns Farm Meats pilot, we fit several ELT-2 Internal antenna sensors in two refrigerated chambers spatially distributed in such a way, that allows for collecting data from different areas: closer to doors, closer to the refrigeration unit, and in between the former two. The ELT-2 sensors transmit data through LoRa communication signal to a gateway device, a Tektelic Kona Micro IoT Gateway (Tektelic, Canada), which in turns sends the data to The Things Network cloud via an internet connection.

REAMIT partners Whysor (Netherlands) developed the REAMIT dashboard for real-time monitoring and alerting, which was utilized by each pilot study in the project. The dashboard runs on both desktop computer and mobile phone. SMS alerting was provided by Amazon Simple Notification Service (SNS).

System Architecture

Alerting logic. The threshold values for the alerting system were defined by Burns Farm Meats and UCD. Text messages are sent if the temperature in the chambers reach temperatures higher than 7ºC.

Results and Conclusion

The IoT temperature and humidity monitoring system was deployed with Burns Farm Meats in September 2022 in two dry-ageing chambers at their abattoir. The system provides real-time environmental condition logging of the fridges. The owners of Burns Farm Meats were given access to the Whysor dashboard for real-time monitoring of the fridges and were added to the alerting service. This allowed them to receive text messages to their mobile phones if an anomaly was detected. After more data is recorded, the REAMIT team will keep on performing analysis and provide recommendations as to how Burns Farm could minimise beef loss during their dry age.

Conclusion. We have developed an IoT solution which monitors in real time the temperature and humidity of dry ageing chambers at an abattoir. The end-to-end solution provides decision support options if anomalies are detected, helping staff correct any issues and thus reducing the spoilage and waste of food. Future work will focus on improving the proposed IoT system and identifying the underlying causes of loss of quality of beef in dry ageing chambers to minimise waste and increase efficiency even further.

Additional Information

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For further information about the REAMIT project, please visit http://reamit.eu

Real Time Anomaly Detection in Cold Chain Transportation using IoT Technology

REAMIT Pilot study with Musgrave Marketplace

Gillespie, J.[1], Cadden, T.[1], Condell, J.[1], Ramsey, E.[1], Gallagher, R.[2], Ramanathan, R[3]. http://reamit.eu

Interreg North-West Europe REAMIT
European Regional Development Fund

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Who are Musgrave?

Musgrave Group Ltd. is an Irish food wholesaler, founded in Cork by the Musgrave brothers, Thomas and Stuart in 1876. It is currently Ireland's largest grocery distributor, with operations in Ireland and Spain, and have estimated annual sales of over €4 billion. The company is still largely-owned by the Musgrave family. Musgrave Northern Ireland

is headquartered in Belfast, Northern Ireland. Musgrave clients include local restaurants, fast-food outlets, and convenience shops in Northern Ireland, and also operate multiple large cash and carry facilities for the general public. Musgrave maintain their own fleet of delivery vehicles to facilitate deliveries to their business customers.

The Problem at Musgrave

While performing deliveries to their business customers, Musgrave noticed that the refrigeration units in the delivery vans operating in the greater Belfast area would occasionally break down, without any indication to either the driver or the logistics staff at the warehouse. The temperature of the chilled and frozen food products inside the van would increase, surpassing the food storage temperature safety threshold, resulting in a van load of spoiled stock. Musgrave sought a system which would perform the following:

1. The vans should be connected to the cloud to allow for real-time data reporting / monitoring while the vans perform deliveries
2. The vans have both a chill and a freeze zone, both of which should be monitored throughout a journey
3. An alerting system should send SMS messages to drivers and warehouse logistics staff notifying if any anomalies occur
4. Alerts should not be sent when the van is stationary e.g., parked overnight, performing a delivery, etc.
5. The power consumption of the proposed system should be such that maintaining the equipment does not become an arduous task.
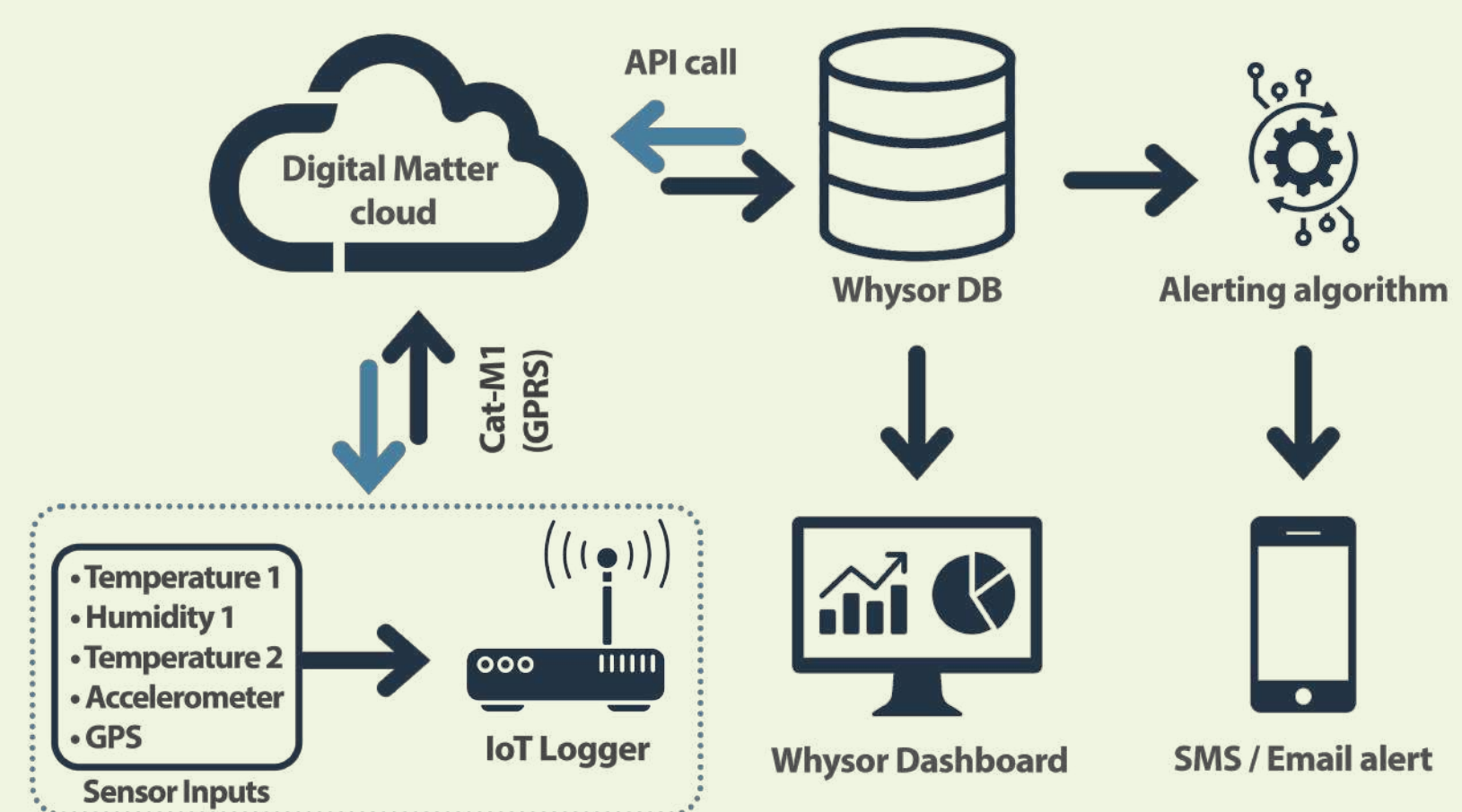
REAMIT's solution

The REAMIT team at Ulster University examined the system requirements by Musgrave and proposed a real-time monitoring and alerting system for anomaly detection during cold-chain transportation. The Eagle datalogger (Digital Matter, South Africa) was selected as the platform for the development of the REAMIT solution. The logger is an IP67 rated rugged cellular IoT device, supporting a range of inputs for various IoT applications. The Eagle runs on either 4x C Alkaline or LTC batteries, or can be wired to permanent power, and contains I2C, SDI-12 and RS-485 interfaces as well as 2x analogue inputs, 3x digital inputs, 2x switched ground inputs, and 2x 4-20mA inputs. It contains a GPS module and an accelerometer for geofencing and movement detection, and is equipped with a sim card allowing the device to perform as an IoT gateway, running on the CAT-M1 GPRS network. The Eagle offers third party cloud integration via HTTPS webhook.

For the Musgrave pilot, we fit the logger with a T9602 T/RH I^{2}C sensor (Amphenol, USA), and a DS18B20 temperature probe (Maxim Integrated, USA) to allow monitoring in both chill and freeze zones of the van.

REAMIT partners Whysor (Netherlands) developed the REAMIT dashboard for real time monitoring and alerting, which was utilized by each pilot study in the project. The dashboard runs on both desktop computer and mobile phone. SMS alerting was provided by Amazon Simple Notification Service (SNS).

System Architecture

Alerting logic. The threshold values for the alerting system were defined by the logistics and warehouse manager at Musgrave. Text messages are sent when the van is performing a delivery and either the chill zone rises above 5°C, or the freeze zone rises above -8°C. To avoid false alerts, the system records 6 values above the threshold before sending the alert. The values are recorded every 5 minutes by the logger.

Trip detection. A trip detection algorithm was developed based on accelerometer measurements and GPS data reported by the Eagle logger.

A trip would be reported if motion was detected by the accelerometer and if the GPS coordinate had changed from the previous reading. This algorithm allowed the system to sleep when trips were not being performed to conserve battery life, as well as avoiding sending false alerts while vans were parked overnight.

Results and Conclusion

The IoT anomaly detection system was deployed with Musgrave Marketplace in April 2022 in three delivery vans operating in the greater Belfast area. The system monitors both the frozen and fresh produce refrigeration areas of each van in 5-minute intervals while deliveries are being performed. Logistics staff at the warehouse were given access to the Whysor dashboard for real-time monitoring of the vehicles, and were added to the alerting service. This allowed them to receive text messages to their mobile phone if an anomaly was detected. Early results show that the system is robust and avoids sending false alerts due to the trip detection algorithm which was developed. At the time of writing (July 2022), the batteries have not needed replaced in the loggers yet, proving that the bespoke system developed with trip detection technology is energy efficient and of minimal maintenance. After successful initial testing, two more of the IoT temperature

monitoring systems have been prepared and are due to be installed in Summer 2022.

Conclusion. We have developed an IoT solution which monitors in real time the temperature of cold chain delivery vehicles transporting perishable items. The end-to-end solution provides decision support options if anomalies are detected, helping staff redirect the delivery to a closer drop-off point and thus reducing the spoilage and waste of food.

Additional Information

[1]Ulster University, Northern Ireland, United Kingdom [2]Musgrave Northern Ireland, Northern Ireland, United Kingdom. W: http://musgravegroup.com [3]University of Essex, Colchester, United Kingdom

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