AURA

A Retrofit, Modular, Smart Fridge Focusing on Reducing Personal Food Waste

10 Page Summary

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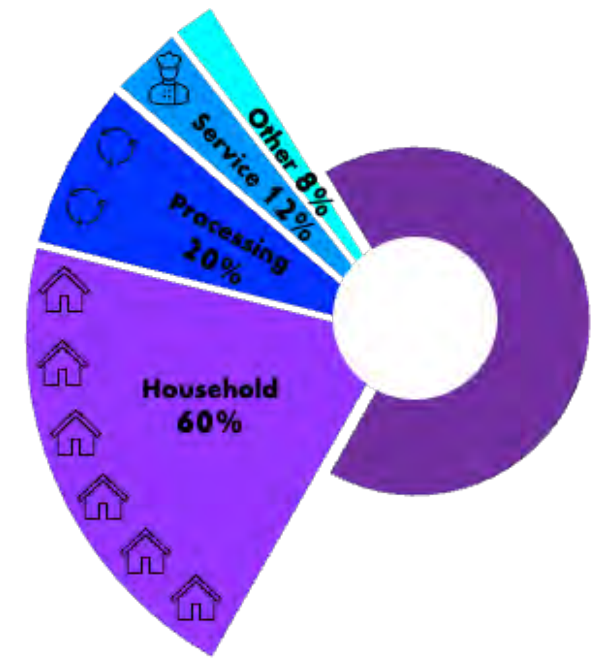
26% of total global greenhouse emissions is generated by food production[1] with food waste alone making up 8-10%[2]

1/3 of all food produced is wasted[3]
worth roughly £1 trillion a year[4]
60% of this happens in the home[5]



the average UK household wastes £600 a year on wasted food[6]

50% is made up of fruit and veg[7]

in landfill just 1kg of food waste produces the same amount of emissions as 25,000 plastic bottles[8]

The volume of edible food waste in the UK alone is equivalent to 10billion meals[9]

[1] J.Poore, & T.Nemecek, (2018). Reducing food's environmental impacts through producers and consumers. Science, 360(6392), 987-992.
[2] [1] EC, JRC/PBL, (2012). Emission Database for Global Atmospheric Research, version 4.2
[3] FAO, (2011). Global Food Losses and Food Waste. Extent, Causes and Prevention.
[4] United Nations Department of Economic and Social Affairs, (2021). The Sustainable Development Goals Report.
[5] WRAP, (2020). Food surplus and waste in the UK.
[6] Dr. Ashok Chapagain, Keith James, (2020). The water and carbon footprint of household food and drink waste in the UK
[7] Valeria De Laurentiis, Sara Corrado, Serenella Sala, (2018). Quantifying household waste of fresh fruit and vegetables in the EU, Volume 77, Pages 238-251.
[8] Zero Waste Scotland (2021). Food waste vs. plastic waste [online]
[9] Rebecca Smithers, (2020). UK households waste 4.5m tonnes of food each year [online]

The reasons for food waste can be split into two main categories: physical and psychological.

Temperature

Incorrect storage temperature causes food to spoil prematurely.

Too high temperatures causes accelerated spoilage

Freezing fresh produce causes cell walls ruptures making them slimy when defrosted.

Hygiene

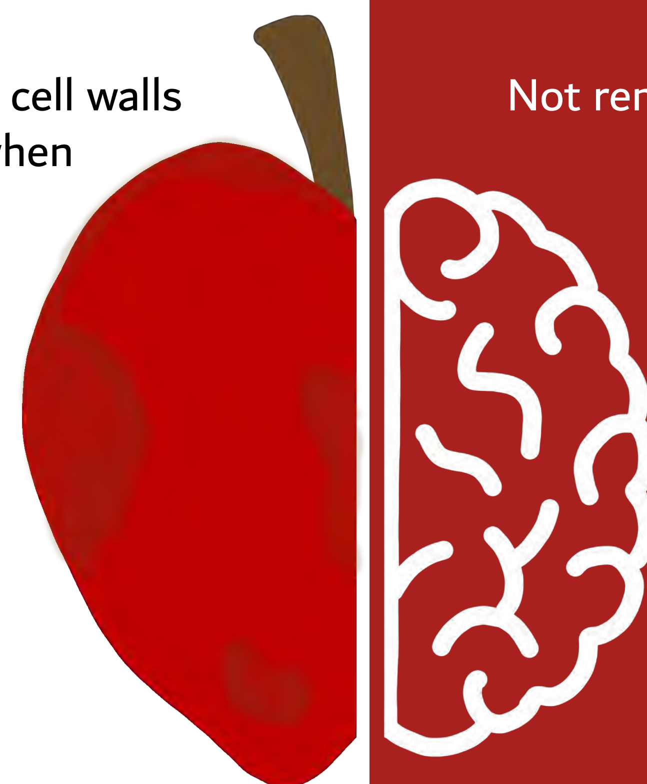
Unclean environments allow bacteria and fungus to contact food which then multiply causing food to go off.

If ingested some of these can also cause discomfort, disease or illness.

Ethylene

This gas is known as the “fruit ripening hormone”. This triggers fruit and vegetables to ripen.

Some fresh produce is only susceptible to ethylene and some like bananas also produce it.



Memory

Forgetting what food is at home while at the shops means unnecessary food is bought.

Forgetting about food in the fridge until it goes off.

Not remembering correct portion sizes for rice, pasta, potatoes etc.

Lack of Time

Buy more food than needed to reduce trips to the shops.

No time to check up food about to go off and learn how to make a meal with it.

Rushed end of mealtimes means food is thrown into landfill.

Awareness

Not knowing/paying attention to the temperature of the fridge.

Fear of days old food and poor conception of “leftovers”.

Not realising how polluting food waste is.

Smart Fridges

These are often prohibitively expensive, come with a fixed set of features that the customer may not want and requires buying a whole new fridge (creating more waste).

Fridges last 12-20 years meaning built-in technology becomes outdated well before it needs replacing

Reasons for not owning a smart fridge:

23% My Fridge Doesn't Need Replacing
21% I Don't Own My Fridge
15% I Don't See the Point
11% Too Expensive

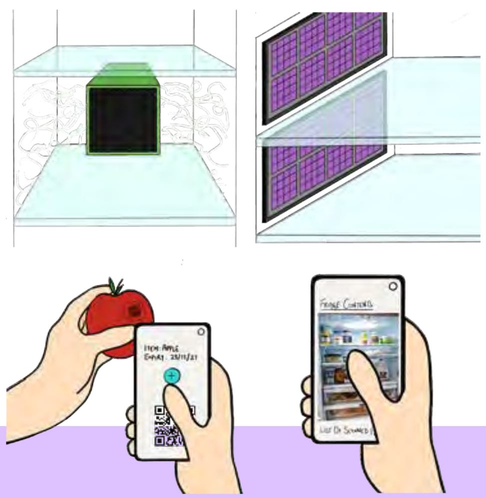
Aura's niche is being an all-in-one, retrofit, smart fridge that allows users to choose the features that they want, upgrade it throughout its life, add new features when they are developed and fit it into the fridge they already own.

Concept Development

Initial Concept Generation

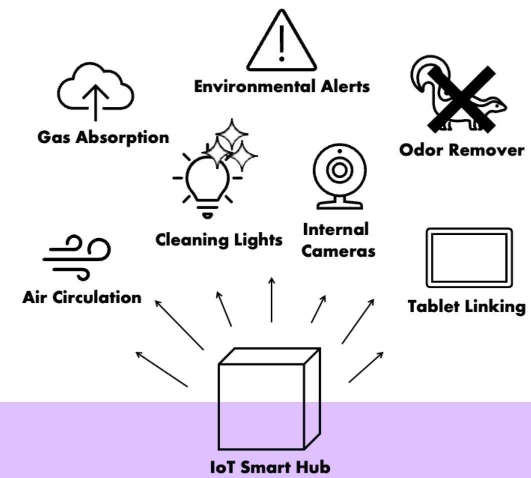
Initial concepts were created in a post-it style. This exercise revealed that there were two main categories ideas fell into: Action and Awareness. Lots of the concepts were focused around the fridge.

Refining & Evaluation Matrix



Concepts were refined and evaluated against each other. It became clear that these concepts did not need to exist independently and a combined solution would be much more effective.

Focus Expansion

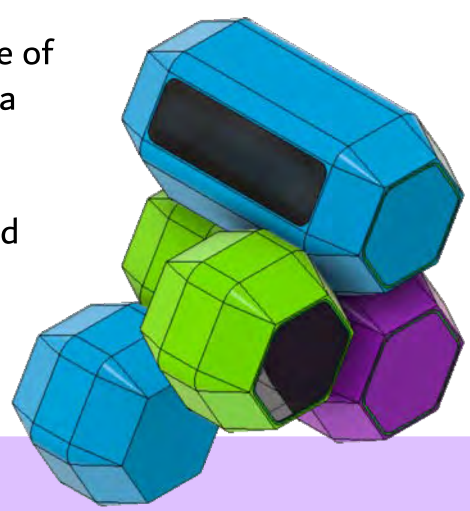


From gaining user's requirements and understanding the reasons they don't own smart fridges the focus of the project expanded and Aura found its niche: a modular, retrofit, smart fridge.

Initial Physical Prototyping

The initial prototype was created to understand the size of the product inside a fridge.
It was smaller than expected and lacked refinement.

Aesthetic Modelling

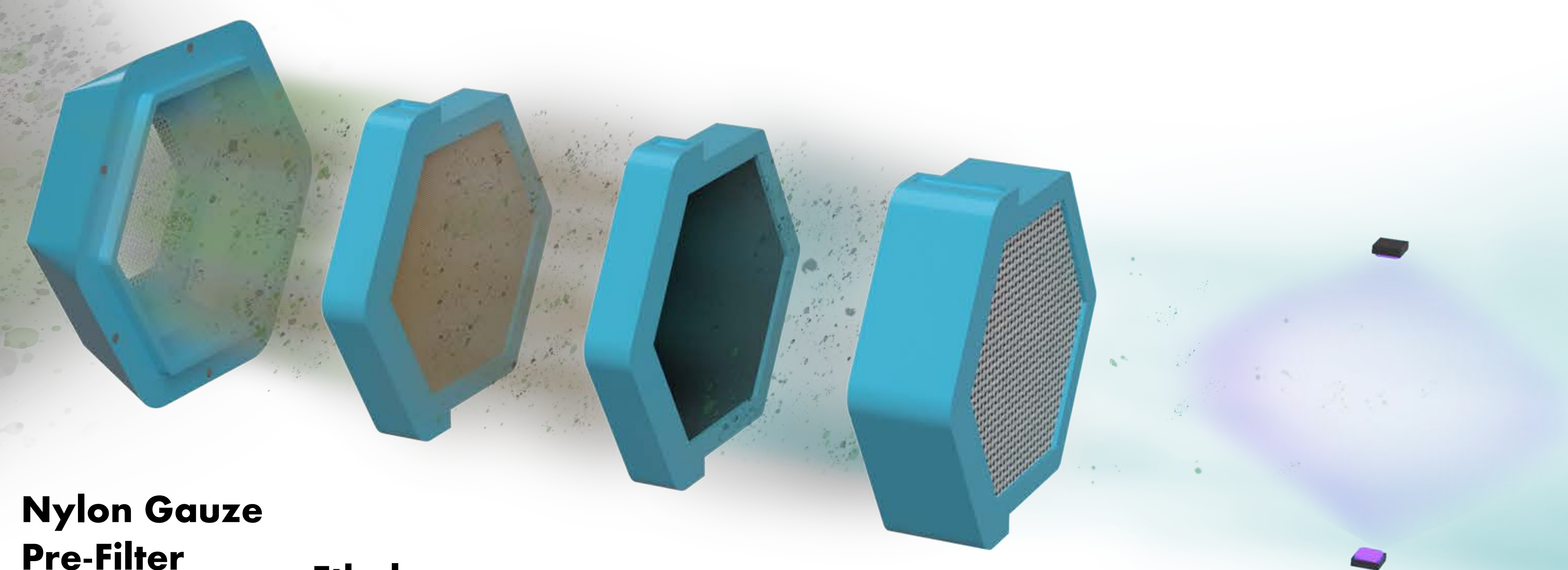


Aura took its design inspiration from Smeg, pushing bold and bright colours that aren't usually attributed to fridges. The hexagonal form was driven by their excellent tiling ability for additional modules.

Final Design

Aura's final design uses industrial air cleaning technology on a micro scale to extend the lifetime of food while also monitoring the health of the fridge.
It also connects to an app to combat the psychological aspects relating to food waste.

Aura uses a 5-stage air cleaning process



Nylon Gauze Pre-Filter
Filters out large particles and prolongs the life of specialised filters

Ethylene Absorber
Removes the "fruit ripening hormone" from the air prolonging the life of fresh produce

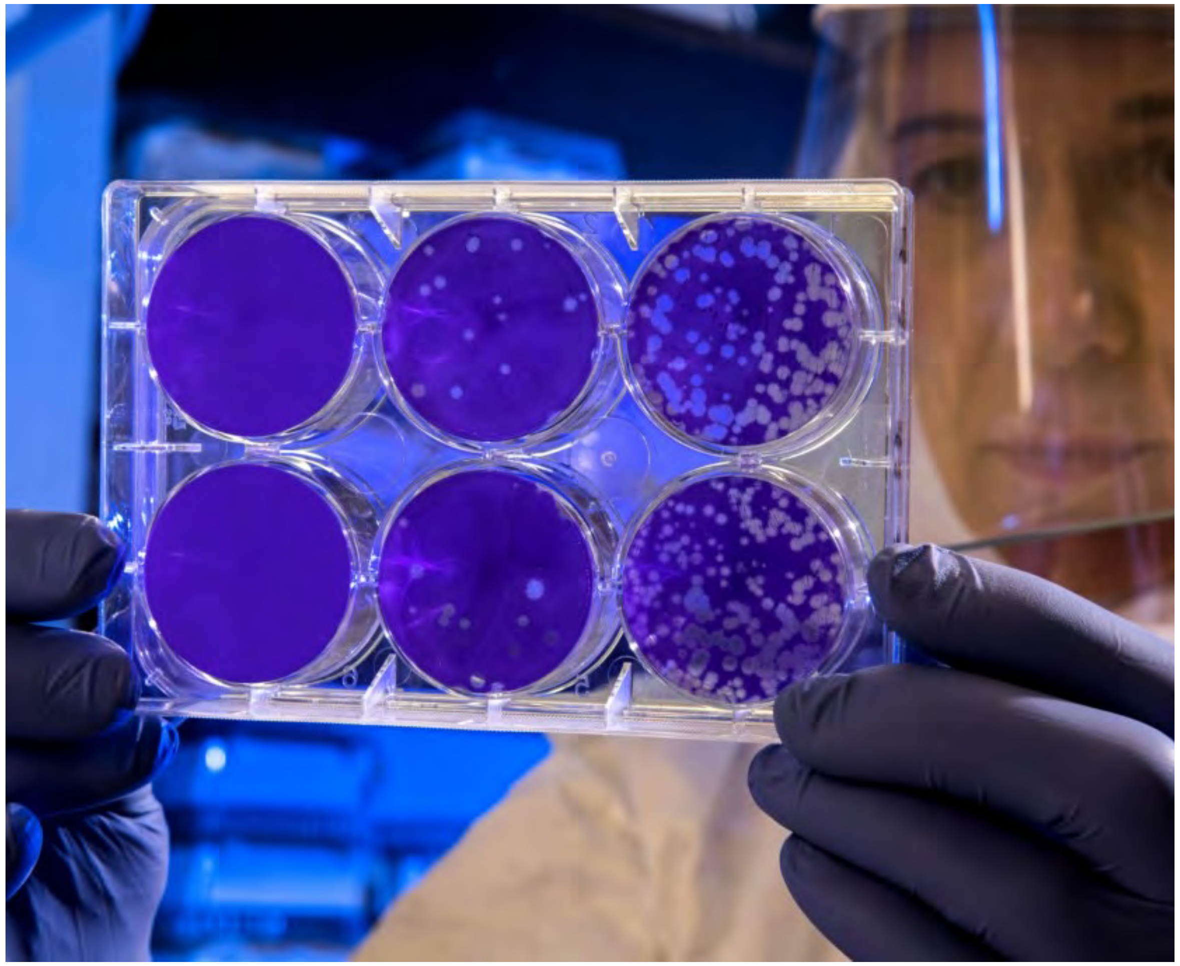
Activated Carbon Filter
Traps gasses, odours and volatile organic compounds (VOCs)

HEPA Filter
Removes dust, pollen, mites, viruses, bacteria and fine particles down to 0.01 millimetre

UVC Light
Deactivates and kills microorganisms and pathogens using photodimerisation by damaging the base acids that make up DNA

UV Light and Bacteria Populations

The majority of applications that use UV light to kill microbes focus on shining the light onto a surface and evaluating time needed to reduce the microbe population. As Aura uses UV light to clean a column of air, an equation for average UV irradiance over the spherical sector it creates was created. This allowed the cleaning ability of the lights to be modelled.



Average Intensity Equation:

$$\frac{1}{4.6h^3}\int_0^h f(h)\cdot 3\pi h^2\, dh = Average\ Intensity$$

Where:

h: *Distance from UV source*

$f(h)$: *Intensity at distance h*

Bacteria growth happens when one bacterium divides into two daughter cells. Bacteria populations are modelled using their generation (doubling) time. As Aura only cleans a fraction of the air inside the fridge at a time and the data for UV disinfection is given in an amount of seconds to achieve a given log reduction in microbes, combined equivalence equations needed to be made.

Reduction per second:

$$\sqrt[t_{lr}]{100\,(1-\left(\sqrt[\frac{t_D}{t_{lr}}]{2}-lr\frac{V_D}{V_T}\right))} = \%\ reduction\ /second$$

Reduction Time:

$$\log_{\sqrt[t_{lr}]{\sqrt[\frac{t_D}{t_{lr}}]{2}-lr\frac{V_D}{V_T}}}(1-lr) = time\ to\ reduction$$

Where:

t_D: *doubling time*

t_{lr}: log *reduction time*

lr: log *reduction*

V_D: *volume within device*

V_T: *total volume*

A "UV Kill Table" was created to evaluate Aura's cleaning ability against common pathogens inside fridges.

This table used the average intensity calculated in the equation to find the length of time required under the lights to achieve different log reductions in the population of these pathogens.

Pathogen	Type	Size (µm)		Log Reduction					
				1 (90%)		2 (99%)		3 (99.9%)	
		Min	Max	Dose (mJ/cm2)	Time Average (s)	Dose (mJ/cm2)	Time Average (s)	Dose (mJ/cm2)	Time Average (s)
Bacillus Cereus ATCC	Spore	0.8	1.1	52.0	56.5	93.0	101.1	140.0	152.2
Bacillus Cereus T	Spore	0.8	1.1	23.0	25.0	30.0	32.6	35.0	38.0
Aeromonas Hydrophila	Bacteria	1.0	3.5	1.1	1.2	2.5	2.7	4.0	4.3
Bacillus Cereus	Bacteria	3.0	4.0	6.0	6.5	7.0	7.6	9.0	9.8
Klebsiella Pneumoniae	Bacteria	0.3	6.0	5.0	5.4	7.0	7.6	10.0	10.9
Listeria Monocytogenes	Bacteria	0.5	4.0	2.2	2.4	3.0	3.3	3.2	3.5
Serratia Marcescens	Bacteria	0.5	2.0	2.2	2.4	NO INFO	NO INFO	NO INFO	NO INFO
Salmonella Typhimurium	Bacteria	0.7	5.0	2.6	2.8	4.5	4.9	5.8	6.3

Prototype Validation & Testing

Validation

Aura's functional prototype was placed inside a fridge to check these functional requirements:

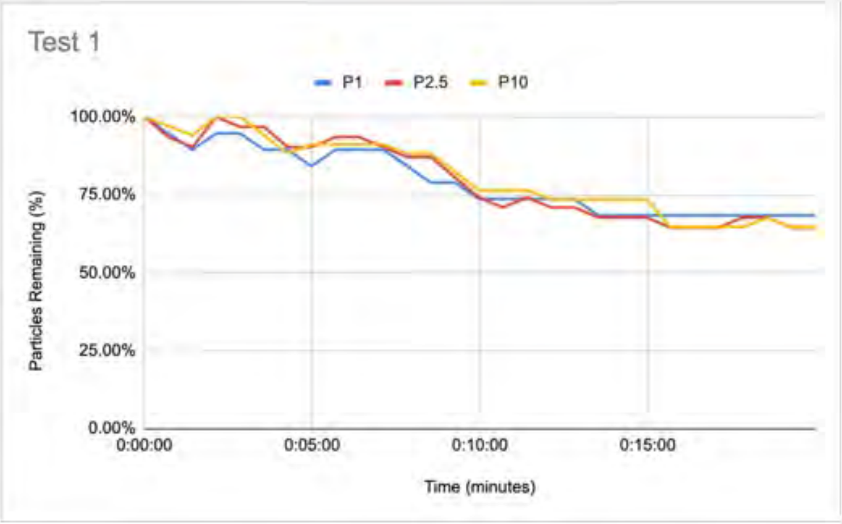
- ✓ Secure mounting in the fridge
- ✓ Turning on and off
- ✓ Connecting to WiFi
- ✓ Taking sensor readings
- ✓ Sending readings to the cloud
- ✓ Drawing air through the filters
- ✓ Holding WiFi strength inside the fridge

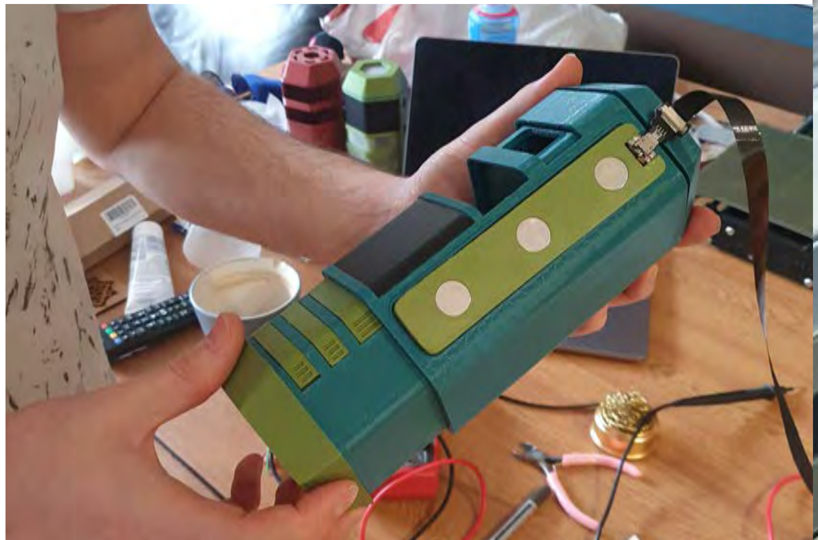
Testing

Aura's filters were tested inside a fridge to validate their cleaning ability.

The levels of 3 different sized particles were measured over the course of the 20 minutes. These were then graphed and adjusted for percentage reduction.

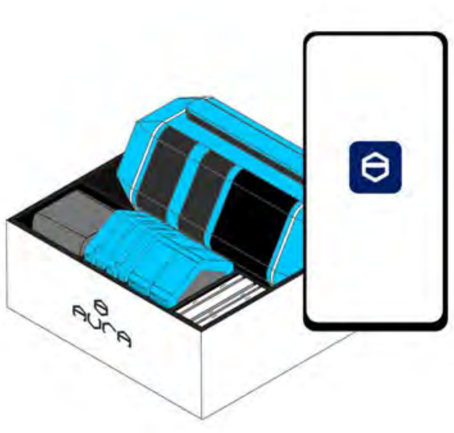
In all three experiments, all three subdivided size brackets of particles reduced significantly. All three of the graphs have a strong negative trend and over the 20 minute period, each of the subdivided size brackets had a 25% reduction in the number of particles.



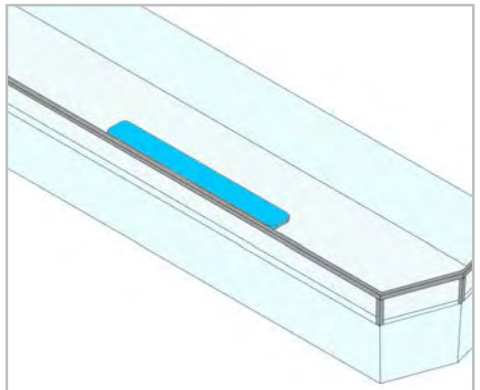


User Interaction

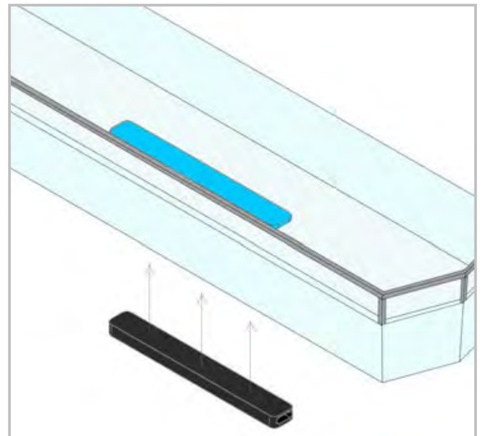
Set Up



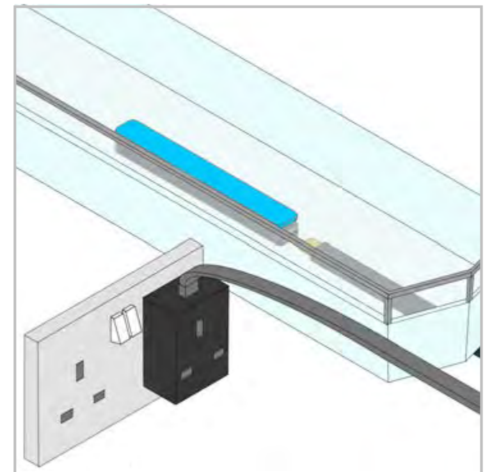
In the box, the manual instructs the user to download the app which has a step by step guide.



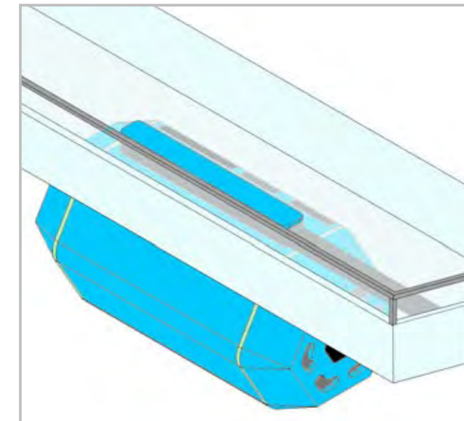
The mount in the desired tray in user's fridge door. This should be placed roughly centrally.



The dock is then magnetised to the mount on the underside of the tray.



The power cable is connected to the dock and run to a plug socket.



Aura will automatically start trying to pair and will glow green when successful.

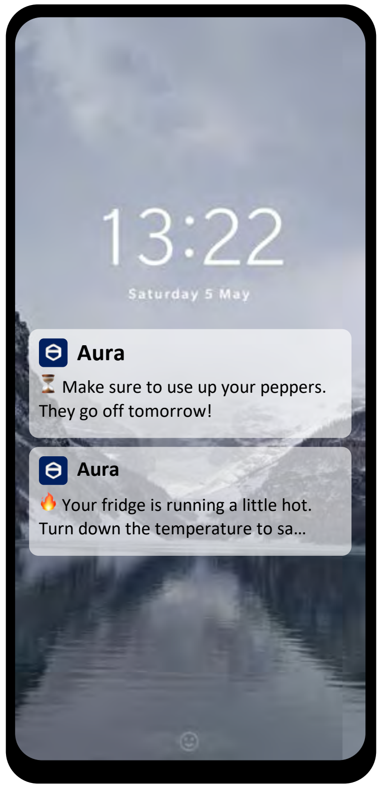
In Use

While in use, Aura autonomously monitors and cleans the user's fridge requiring no interaction with the product itself.

The accompanying app can notify the user of food about to go off and recommend settings changes for the fridge based on the inbuilt sensors.

The app can be used to scan food entering and leaving the fridge to track expiry dates, make shopping lists and track the user's food waste.

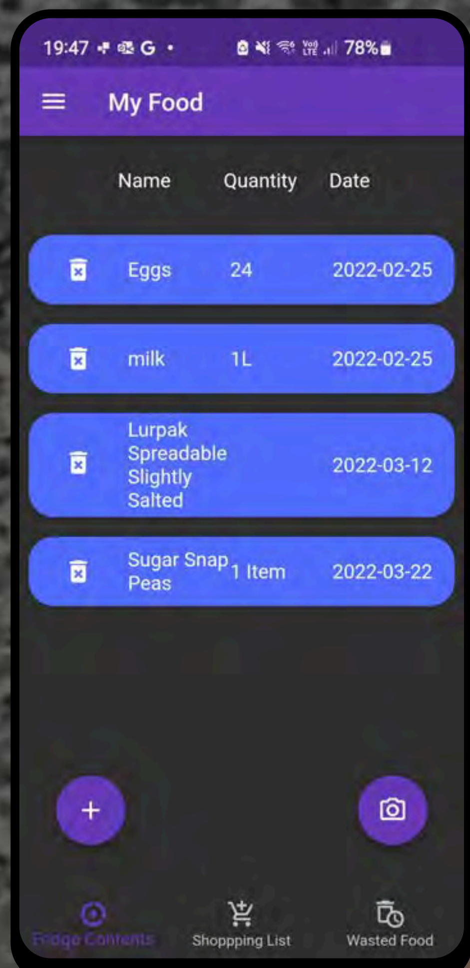
With the camera module, Aura takes a picture of the last time the fridge was opened so user's can check what they have in while at the shops.



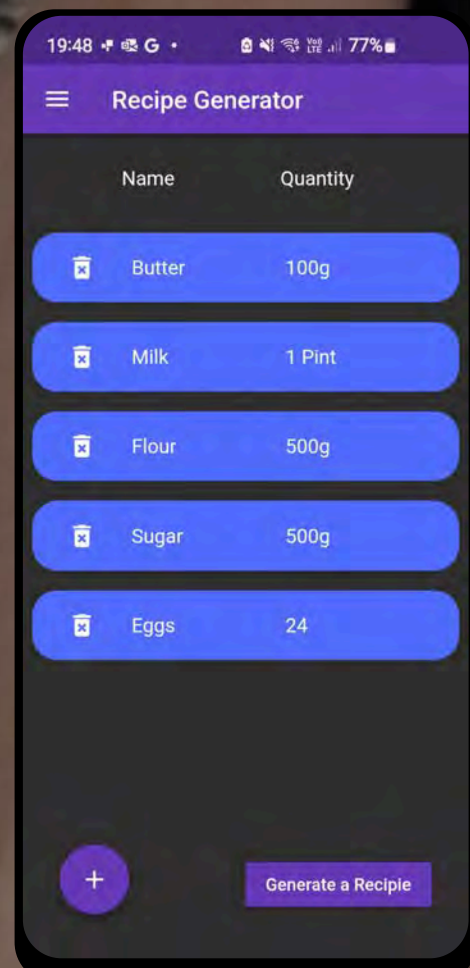
Accompanying App

Aura links to an app to help focus on some of the psychological aspects resulting in food waste.

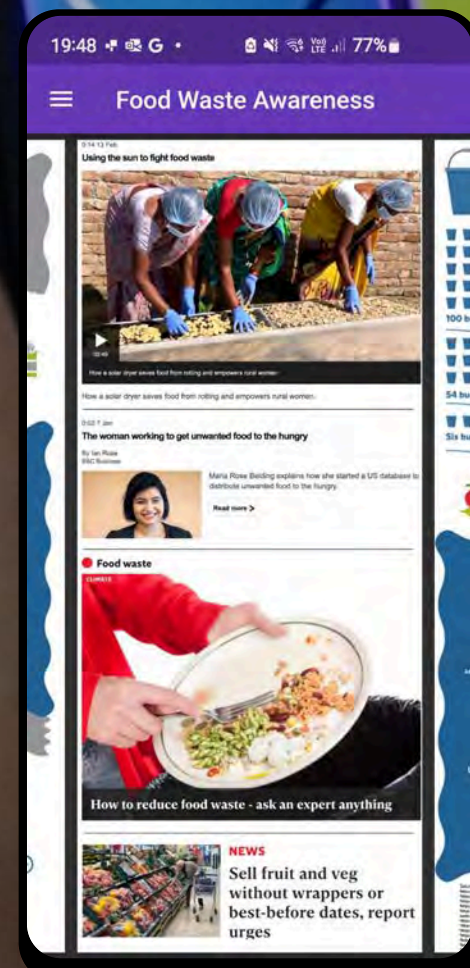
Dashboard
Live monitoring of fridge health



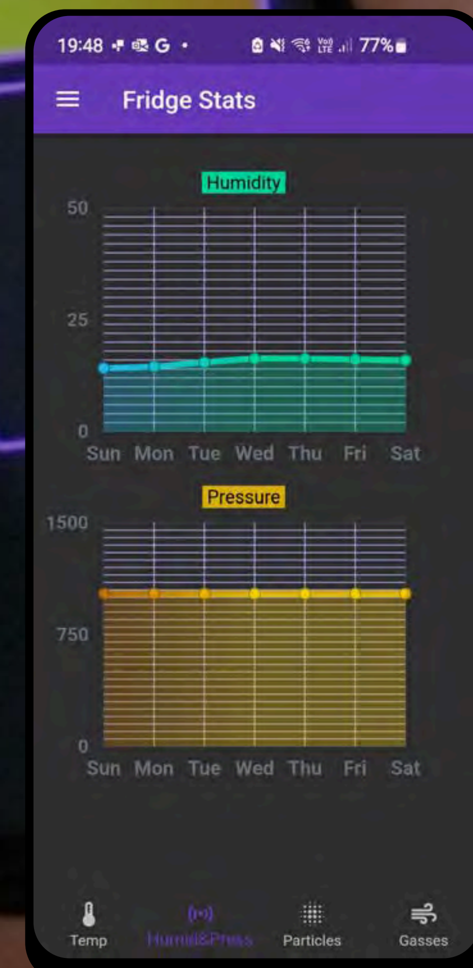
My Food
Track expiry dates, make shopping lists and record food waste



Recipe Generator
Get inspiration of what to eat and how to use up food about to go off



Food Waste Awareness
Top facts, tips and news about food waste



Fridge Stats
Historical sensor readings and push notification alerts

Material & Manufacture

Material: Bio-PET

To reduce the environmental impact of creating the product, the entire housing is made from Bio-PET. PET is made from 70% terephthalic acid and 30% monoethylene glycol (MEG). Bio-PET replaces the 30% MEG with renewable raw material bio-MEG. This bio-MEG is made using ethanol from sugar cane.

Unlike biodegradable plastics, Bio-PET can be recycled in the same way as generic PET which is the most widely recycled plastic in the world. Bio-PET is a "Drop in solution" meaning it can be used in the place of PET with no alterations needed to machinery or processing.

Antimicrobial Additives

Antimicrobial additives are added to the Bio-PET during the manufacturing process. The antimicrobial additives imbue the material with inherently resistant to the growth of microbes. This kills additional microbes in the and stop the build up of microbes within the device. The additives chosen are: Silver Ion, Zinc, Copper and Quaternary Ammonium Compounds (QAC).

Injection Moulding: Mutant Screw

The housing is manufactured using an injection moulding machine with a reverse ring mutant screw due to its high surface hardness and wear resistance.

Injection moulding facilitates rapid mass production with incredibly high levels of detail. This process is able to produce high quality surface finishes and low cost per part.