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DIPARTIMENTO DI DESIGN

EAT SMART

A nutrition management system design

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## Acknowledgement

After few months intense work, this thesis finally comes to an end. Thinking back to the past few months and there are a lot of people that I want to thank:

My deepest gratitude goes first and foremost to my parents, who feed me and alway trust in me in any time of my life. They tried their best to provide me good conditions, and guide me become an better man. Without them, I cannot be here, Milan, thousands miles away from my hometown and cannot make my dream finally come true.

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Last my thanks would go to my dear friends and fellow classmates who gave me their hand and time in helping me not only during the difficult course of the thesis, but also in daily life. Because of all of you, living and studying outside country won't be tough.

Thesis has an end, but love will remain.

Ting Jin
Milan, 3rd December, 2017

I:for

Abstract

Under the background of urbanization and growth of global population. New challenges emerge: environmental issue is getting serious, resource become short. Intenser urban living style also brought people new issues. More and more obese people, countless food goes to garbage. Obviously, without food control, it will eventually be a big problem both personal and social. Will there be a way for us to get rid of the drive of blind hunger and taste, to build a real understanding connection between food and body.

EAT SMART: The goal of this project is helping people eat precisely and smarter, manage their body condition, further to improve the relationship between food and human, to avoid food waste and to look forward a sustainable development of our society.

Design background

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PART 1

Design Background

1.1 Development of human society

1.1.1 Urbanization and the growth of global population

Urbanization refers to the population shift from rural to urban areas, "the gradual increase in the proportion of people living in urban areas", and the ways in which each society adapts to the change.[1] Urbanization is an inevitable process of human social development. Especially under nowadays situation: the global population is constantly increasing. City is not only an aggregation of human population, it generates societies in which people exchange informations, share resources, offer opportunities, creates great stuffs together… in general, city is a container in which people work together, live together, fight together. Everything sounds great in a city, but another truth is, the natural resource on this planet is limited. Rapid pace of urbanization causes growth of wealth and, meanwhile, is also changing our nature what it was: land, oil, minerals… It connects with issues of population, resource, energy, food and environment, etc.

“An urban area is a human settlement with high population density and infrastructure of built environment.” [2]

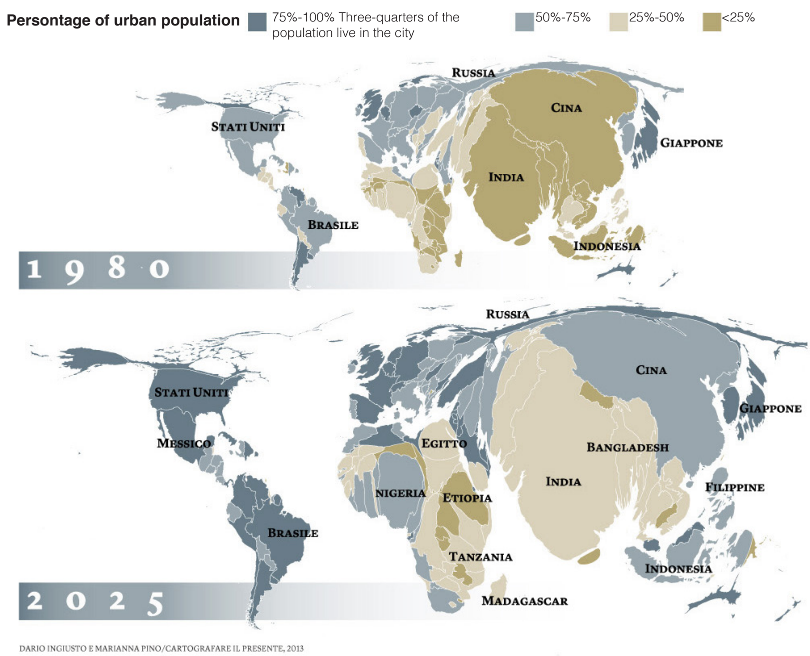
We are in a period of human history which global population is booming, thanks for our peaceful era, and abundant food to feed. In 2017, the global population has reached 7.5 billion and the United Nations estimates it will further increase to 11.2 billion in the year 2100. Follow this tendency, the density of living place’s population will surly increasing, the number and the size of city will also grow, nowadays, urban population has historically surpassed the rural population, about 54 % of the global population lives in urban areas (2014), considering that the urban population in 1950 was 30% of total global population.

1.*MeSH browser. "Urbanization". National Library of Medicine. Retrieved 5 November 2014.*

2. Wikipedia. "Urban area". Retrieved September 1 2017

3.United Nations. World Urbanization Prospects: The 2014 Revision, Key facts. 2014

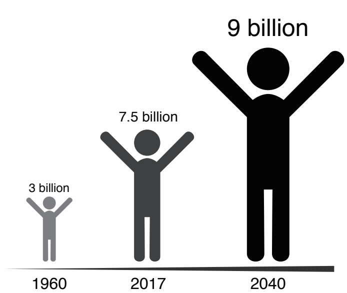
Figure1.1 Development of world urbanization

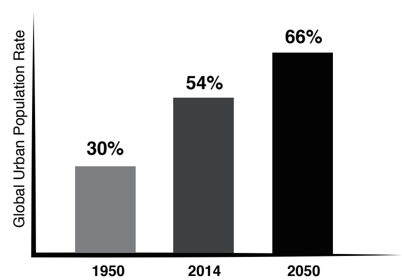


> 66% if the global population is projected to live in urban areas until 2050 and is equivalent to add approximately 2.5 billion urbanites, the majority of which will occur in Africa and Asia.[3]

Figure1.2 Growth of global population

Figure1.3 Growth of global urban population rate





Chicago 1910

Chicago 2010

Shibuya Crossing, Tokyo, Japan

Tokyo 2012

Figure1.4 Pollution by Samedin Latifi

1.1.2
Environmental challenges

Pollution

Pollution is a wide range environmental problem, it is happening in many aspects of our urban life: with the development of industrialization, large-scale machineries and factories emerge; fuel waste, chemical waste, generated by-products in the production. Liquid thing, pollute land and rivers; gas thing, then pollute our atmosphere. Cars on the road, moving energy burner, release heat and harmful gases into the air. Global warming, another obvious impact caused by greenhouse gases. Due to human activities, excessive greenhouse gas generated: in the period from 1880 to 2012, the global average (land and ocean) surface temperature has increased by 0.85 [0.65 to 1.06] °C, and the trend will continue to rise. And smog, common dangerous scenes in cities of developing countries…[4]

4.*IPCC. Climate Change 2013: The Physical Science Basis, IPCC Fifth Assessment Report. 2013*

Municipal solid waste

Waste, one of the most important by-products of an urban lifestyle, is going even faster than the rate of urbanization. Global waste production has doubled over the past ten years. Current MSW(Municipal Solid Waste) generation levels are approximately 1.3 billion tonnes per year. By 2025, is expected to produce garbage at a rate of 2.2 billion tonnes per year. [5]

MSW generation rates are in uenced by economic development, the degree of industrialization, public habits, and local climate. Generally, the higher the economic development and rate of urbanization, the greater the amount of solid waste produced. Income level and urbanization are highly correlated and as disposable incomes and living standards increase, consumption of goods and services corre- spondingly increases, as does the amount of waste generated. Urban residents produce about twice as much waste as their rural counterparts.

In the municipal solid waste stream, waste is broadly classified into organic and inorganic. In this study, waste composition is categorized as organic, paper, plastic, glass, metals, and 'other.' These categories can be further refined, however, these six categories are usually sufficient for general solid waste planning purposes. Figure? describes the different types of waste and their sources.

5.*The World Bank. What a waste. 2012*

Figure1.5 Trend of urban population and waste

	Urban Population (Billion)	Waste per Capita (kg/person/day)	Waste quantity (Billion tonnes/year)
2002	2.9	0.64	0.68
2012	3	1.2	1.3
2025	4.3	1.4	2.2

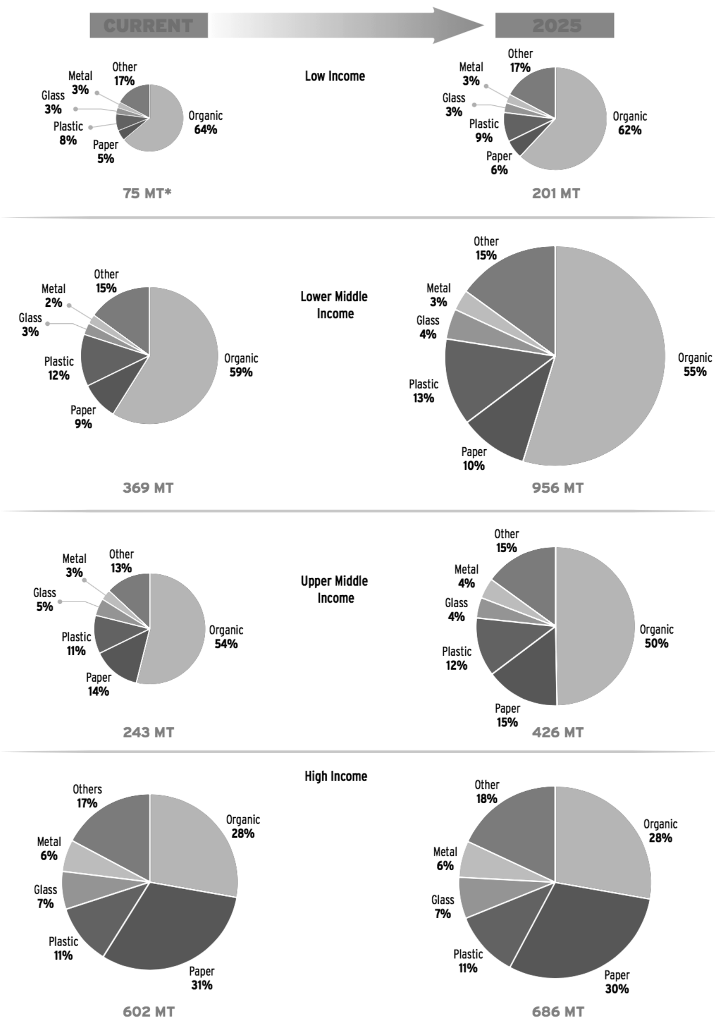
Recource:The World Bank. What a Waste, 2012


SDLG

Table1.6 Types of waste and their sources

Type	Sources
Organic	Food scraps, yard (leaves, grass, brush) waste, wood, process residues
Paper	Paper scraps, cardboard, newspapers, magazines, bags, boxes, wrapping paper, telephone books, shredded paper, paper beverage cups. Strictly speaking paper is organic but unless it is contaminated by food residue, paper is not classified as organic.
Plastic	Bottles, packaging, containers, bags, lids, cups
Glass	Bottles, broken glassware, light bulbs, colored glass
Metal	Cans, foil, tins, non-hazardous aerosol cans, appliances (white goods), railings, bicycles
Other	Textiles, leather, rubber, multi-laminates, e-waste, appliances, ash, other inert materials

Figure1.7 Solid waste composition by income and year



* Total annual waste volume in millions of tonnes

Source:The World Bank. *What a Waste*, 2012

Waste composition

Waste composition is influenced by many factors, such as level of economic development, cultural norms, geographical location, energy sources, and climate. As a country urbanizes and populations become wealthier, consumption of inorganic materials (such as plastics, paper, and aluminum) increases, while the relative organic fraction decreases. Generally, low- and middle-income countries have a high percentage of organic matter in the urban waste stream, ranging from 40 to 85% of the total. Paper, plastic, glass, and metal fractions increase in the waste stream of middle- and high-income countries.

As Figures a-d show, the organic fraction tends to be highest in low-income countries and lowest in high-income countries. Total amount of organic waste tends to increase steadily as affluence increases at a slower rate than the non-organic fraction. Low-income countries have an organic fraction of 64% compared to 28% in high-income countries. The data presented on the right of Figure ? illustrates solid waste composition by income as compared between current values and values projected for 2025. [5]

Current disposals of waste

According to the quantity, the major disposal of waste are: landfilling, recycling, WTE(waste to energy), dump, compost and other. Figure ? shows global MSW disposal for the entire world in 2012. And figure? illustrates the difference in MSW disposal methods according to country income level, in particular and upper middle-income countries. In any income level, the majority of waste is disposed by landfills. Landfills is burying waste in a specific site, a landfill site. Landfills are often the most cost-efficient way to dispose of waste, especially in countries like the United States with large open spaces. While resource recovery and incineration both require extensive investments in infrastructure, and material recovery also requires extensive manpower to maintain, landfills have fewer fixed—or ongoing—costs, allowing them to compete favorably.

Landfills also have its environmental impact. landfills have the potential to cause a number of issues. Infrastructur e disruption, such as damage to access roads by heavy vehicles, may occur. Pollution of the local environment, such as contamination of groundwater or aquifers or soi l contamination may occur, as well. [6] Importantly, landfills need a large open space, and need time to totally dispose waste. With the rate of urbanization, the contradiction of population and waste on a limit land would be more severe.

6. *Wikipedia. "landfill". Retrieved September 17 2017.*

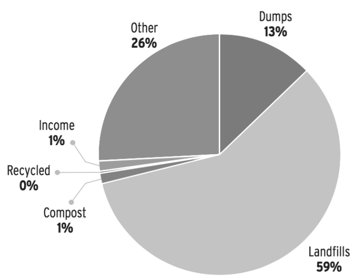


Figure1.8 Low-income countries waste disposal

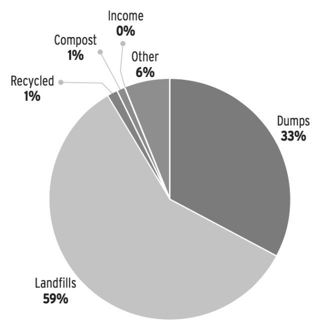


Figure1.9.Upper middle-income countries waste disposal

Source:The World Bank. What a Waste, 2012

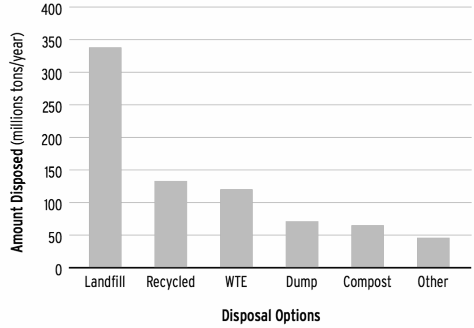


Figure1.10 Total MSW disposed of worldwide

Figure1.11 "Landfill" process

1.1.3
Urban lifestyle and health risk

Urban life , differs from rural life, is the presence of a great number of very different people in a very limited space—-most of them are strangers to each other. [7] Due to the great density of population, shared resources and social division of labor become the main features of urban life. Sharing commodious road, convenient public transport, a series of facilities and services .. ; working in the distributed and selected field to do their own thing. The greater and the more developed the city is, and the higher the degree of division of labor would be. People like gears in a big machine, cooperate efforts together and constantly, so that this big machine, city, could run in a high-speed.

In the city, when different people came together and enriched our culture, various types of subcultures generated, and of course, various lifestyles emerges. People can choose what they like to do in almost any part of life, and there always have fresh lifestyles to try. Different sports: from a small one like billiards to a big one like football; different cuisine: African, Asian..

With the population grows, also the density of citizens, the pressure of living in a city became heavier: the price of eating, clothing, moving, staying. It is an inevitable result, due to the rise of various requirements of resource. Citizens only to need to work hard and harder to earn these resources. When a human doing some certain jobs for a long time, so called “occupational diseases” emerge. And due to the unique living environment, there are some “urban diseases”. And which with our society develops are becoming more and more severe.

7.Jacobs,Jane.The death and life of great America cities,1961

As WHO reported, urbanization is one of the leading global trends of the 21st century that has a significant impact on health. By 2050, over 70% of the world's population will live in cities. The factors influencing urban health include urban governance; population characteristics; the natural and built environment; social and economic development; services and health emergency management; and food security.

While cities can bring opportunities, they can also bring challenges for better health. Today's cities and those of tomorrow are facing a triple threat: infectious diseases like HIV/AIDS, TB, pneumownia, diarrhoeal diseases; noncommunicable diseases like asthma, heart disease, cancer and diabetes; and violence and injuries, including road traffic injuries.[8]

8. *Retrieved from WHO website, "Urban health",september 2017*

1.2 Obesity

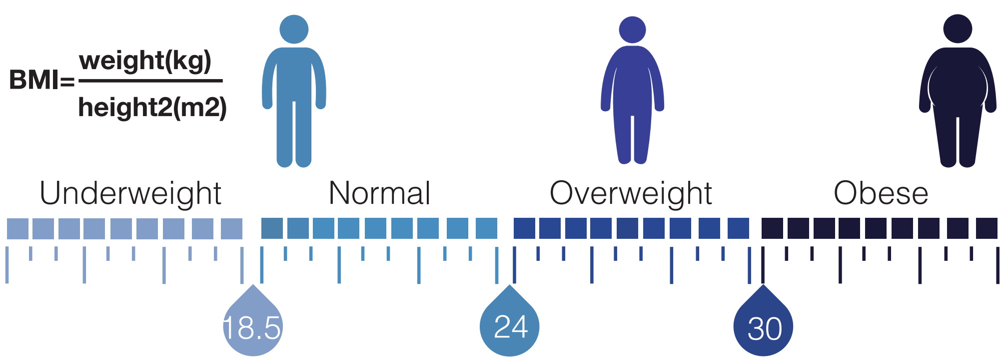


Figure1.12 Body mass index

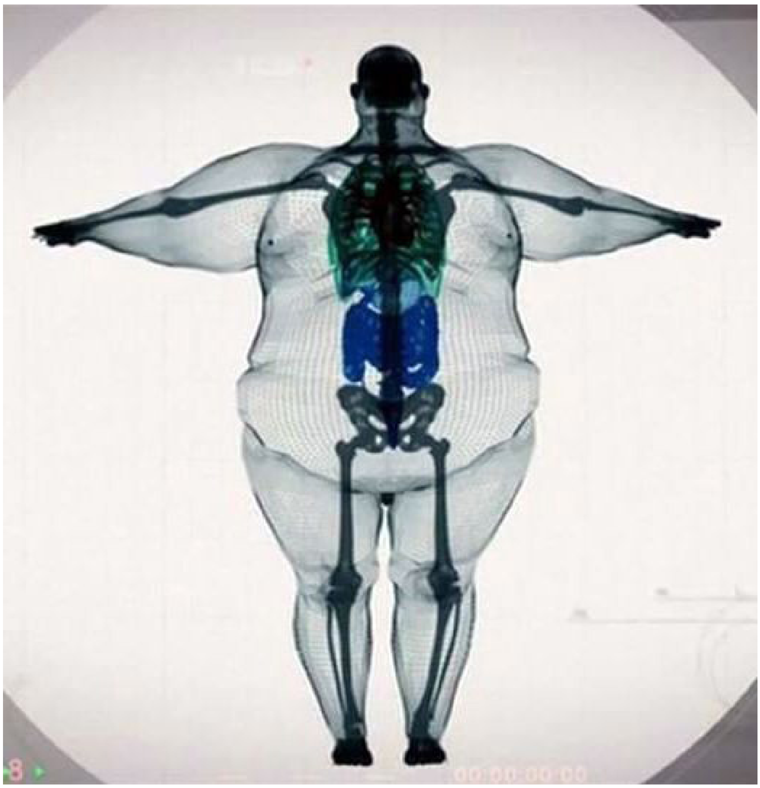
1.2.1
The prevalence of obesity

Obesity is one of the most important social problems in our era. Obesity is a medical condition in which excess body fat has accumulated to the extent that it may have a negative effect on health. Defined by the individual's figure of Body Mass Index(BMI). With the range of 25-29, is defined "overweight", when equals or over 30, is defined “obesity”.

The main reasons for obesity are the excessive intake of calories and the lack of proper exercise, and of course this is also closely related to modern lifestyles. For many reasons, the average BMI of modern people is gradually rising, reaching a unique phenomenon in history.

The frequency of seeing an obese people in the crowd is not low. According to WHO's latest data: More than 1.9 billion adults were overweight in 2015, and more than 700 milion obese (frequency 12%) . 39% of adults aged 18 years and over (38% of men and 40% of women) were overweight.[9]

9. *World Health Organization. "obesity and overweight". Updated June 2016.*



1.2.2
The trend of obesity

Learn from the latest statistics and we can see the steady increase in obesity rate in recent years, and OECD predict the steady increase would continue until at least 2030. Obesity levels are expected to be particularly high in the United States, Mexico and England, where 47%, 39% and 35% of the population respectively are projected to be obese in 2030. Obesity would always be one of the important health issue in recent future.[10]

In the majority of countries, women are more obese than men – however, in most OECD countries for which data are available, male obesity has been growing more rapidly.

Less-educated women are two to three times more likely to be overweight than those with a higher level of education in about half of the eight countries. Disparities are smaller for men, although they are growing.

Inequalities have grown in Italy, Spain, Korea, and England between 2010 and 2014, for both men and women. They have lessened for both genders in Canada, and for men only in France and Hungary. Obesity has been rising more rapidly in less- educated men and in average-educated women, in most countries. However, in the United States, rates have been increasing most rapidly among high- educated people.

Education and socio-economic background affect obesity. Reciprocally, obesity damages labour market outcomes that, in turn, contribute to reinforcing existing social

10. *OECD. Obesity update 2017. 2017*

inequalities (Devaux and Sassi, 2015). Obese people have poorer job prospects compared to normal-weight people, they are less likely to be employed and have more dif culty re-entering the labour market (OECD/EU, 2016). Obese people are less productive at work due to more sick days and fewer worked hours, and they earn about 10% less than non-obese people. Addressing obesity and the associated negative labour market outcomes would help break the vicious circle of social and health inequalities.

Figure1.13 Rising overweight (including obesity) rates in adults aged 15-74 years

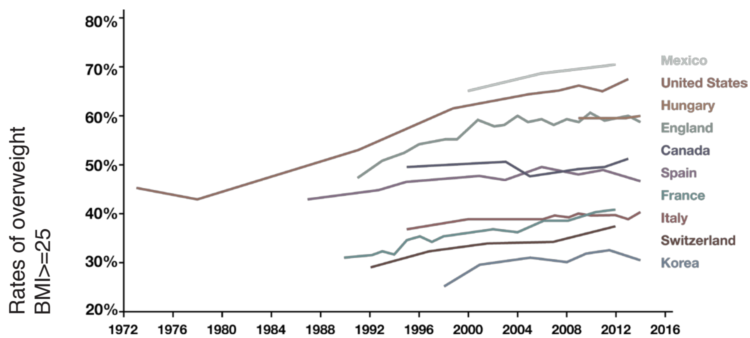
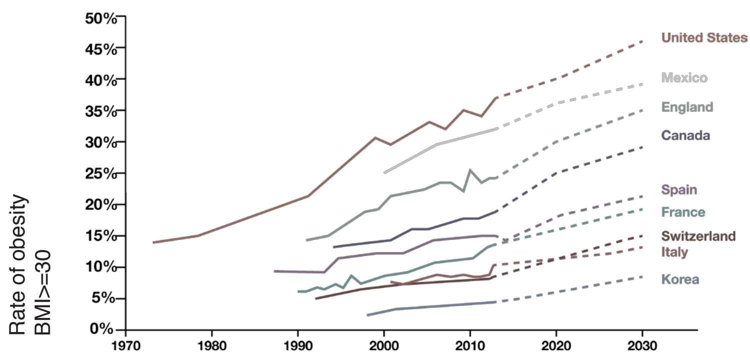


Figure1.14 Projected rates of obesity



Source: OECD. Obesity update 2017, pg 4-6. 2017

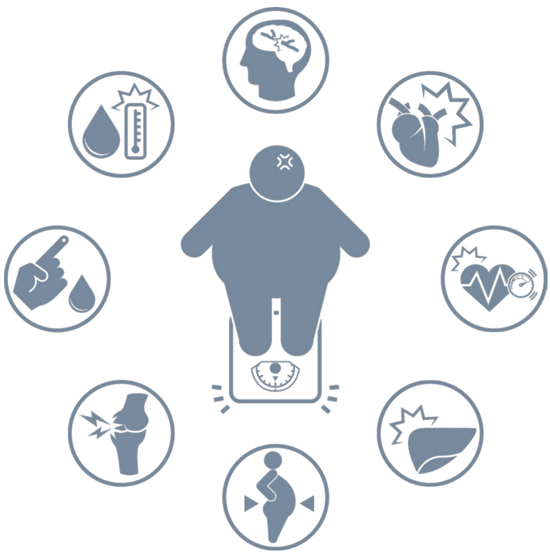
1.2.3
Health risk of obesity

Obese people is not only a bigger size than others. Obesity may represents more than you could see. Ancient Greek medicine recognizes obesity as a medical disorder, and records that the Ancient Egyptians saw it in the same way. Hippocrates wrote that "Corpulence is not only a disease itself, but the harbinger of others”. [11] Study(Haslam DW & James WP) shows that: Excessive body weight is associated with various diseases and conditions, particularly cardiovascular diseases, diabetes mellitus type 2, obstructive sleep apnea, certain types of cancer, osteoarthritis and asthma. As a result, obesity has been found to reduce life expectancy. [12]Even more, compared with underweight, overweight and obesity are linked to more deaths worldwide.

11. *Wikipedia. "Obesity". Retrieved September 17 2017*

12. Haslam DW, James WP."Obesity" Lancet 366(9492): 1197–209. doi:10.1016/S0140-6736(05)67483-1. PMID 16198769. 2005

Figure1.15 Health risk of obesity



1.2.4
Causes of obesity

The fundamental cause of obesity and overweight is an energy imbalance between calories consumed and calories expended. Globally, there has been:
1) an increased intake of energy-dense foods that are high in fat;
2) an increase in physical inactivity due to the increasingly sedentary nature of many forms of work, changing modes of transportation, and increasing urbanization.

Changes in dietary and physical activity patterns are often the result of environmental and societal changes associated with development and lack of supportive policies in sectors such as health, agriculture, transport, urban planning, environment, food processing, distribution, marketing, and education.

A 2006 review identified ten other possible contributors to the recent increase of obesity: (1) insufficient sleep, (2) endocrine disruptors (environmental pollutants that interfere with lipid metabolism), (3) decreased variability in ambient temperature, (4) decreased rates of smoking, because smoking suppresses appetite, (5) increased use of medications that can cause weight gain (e.g., atypical antipsychotics), (6) proportional increases in ethnic and age groups that tend to be heavier, (7) pregnancy at a later age (which may cause susceptibility to obesity in children), (8) epigenetic risk factors passed on generationally, (9) natural selection for higher BMI, and (10) assortative mating leading to increased concentration of obesity risk factors (this would increase the number of obese people by increasing population variance in weight).[13] While there is substantial evidence supporting the influence of these mechanisms on the increased prevalence of obesity, the evidence is still inconclusive, and the authors state that these are probably less influential than the ones discussed in the previous paragraph.

13 .*Keith SW et al. "Putative contributors to the secular increase in obesity: Exploring the roads less traveled". 2006*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1.3 Food waste

1.3.1
Current situation

Food waste or food loss is food that is discarded or lost uneaten. Food from farm to fork usually has four main stages: harvest, processing, retail and consumer. The food waste or loss would occur in each stage: if food is lost at the harvest and processing stage, this is called food loss. If food is lost at the retail or consumer stage, throwing away food that is not bought at stores or food that is not eaten at home, restaurants and cafeterias, this is called food waste. The causes of food waste or loss are numerous, and occur at any stage.

14. *FAO."food loss and food waste". retrieved by September, 2017.*

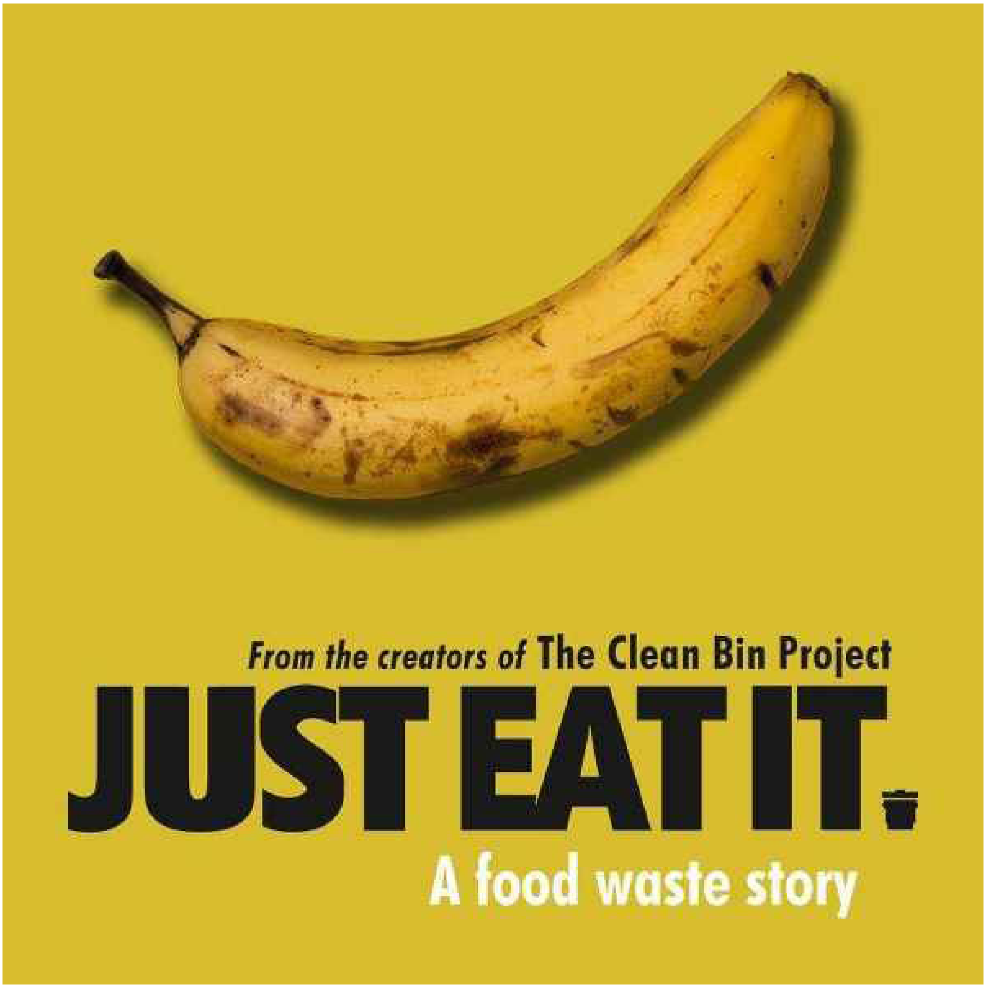
Up to 40 percent of food is losing.

Each year, about one-third to one-half of the food we produce globally is lost or wasted. In developing countries, a large part of this food (40%) is lost at the harvest or processing stage. In developed countries, this same percentage (40%) is lost at the consumer or retail stage.[14] In America, all told, America throws out more than 1,250 calories per day per person, or more than 400 pounds of food per person annually.[15] That's a loss of up to $218 billion each year, costing a household of four an average of $1,800 annually.[16] At the same time, 42 million Americans face food insecurity—and less than one-third of the food we throw out would be enough to feed this population completely.[17]

15 .*Jean C. Buzby et al. "The Estimated Amount, Value, and Calories of Postharvest Food Losses at the Retail and Consumer Levels in the United States".USDA. February 2014*

16 .*ReFED, "A Roadmap to Reduce US Food Waste by 20 Percent". 2016*

17 .*Alisha Coleman-Jensen, et al., "Household Food Security in the United States in 2015". USDA. 2015*


From the creators of The Clean Bin Project
JUST EAT IT.
A food waste story

NRDC

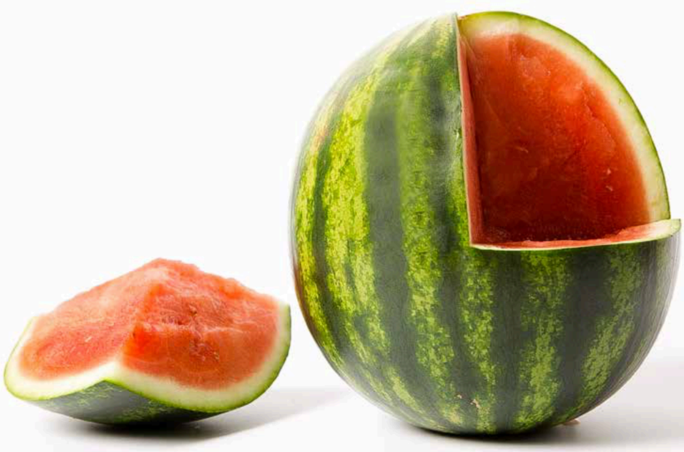
AUGUST 2017
R: 17-05-A

REPORT

WASTED:

HOW AMERICA IS LOSING UP TO 40 PERCENT OF ITS FOOD FROM FARM TO FORK TO LANDFILL

SECOND EDITION OF NRDC'S ORIGINAL 2012 REPORT



1.3.2 Ecological impacts of food waste

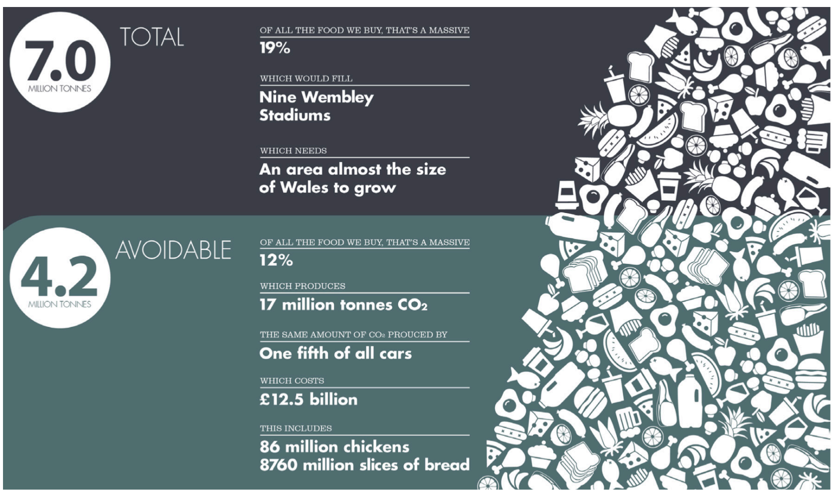
Food waste is a major environmental problem globally. The global carbon footprint of food waste per year is 3.3G tonnes CO_2e. The top 3 of whole countries which led the total carbon footprints are the US, China and the UK. The greenhouse gases (CO_2, as well as methane CH_4 and nitrous oxide N_2O, which have a weighting factor of 25 and 298 times CO_2 respectively)[18] produced in the production, transport, storage and decomposition of food, are significant: UK as an example, food and drink waste in the UK causes 900 million tonnes CO_2e per year.[19] The cost estimate for the average family of four is $1,800 annually. [16] This is not only waste of money, it also has serious implications for wasted energy. A McKinsey study reports that household losses are responsible for eight times the energy waste of post-harvest losses on average due to the energy used along the supply chain and in food preparation.[20]

18 .*FAO. "Food wastage footprint – Impacts on natural resources." 2013*

19 .*Quested, T., Ingles, R. & Parry, "A. Household Food and drink waste in the United Kingdom 2012, Banbury: WRAP." 2013*

20 .*R. Dobbs et al., "Resource Revolution: Meeting the World's energy, Materials, Food, and Water Needs," McKinsey Global Institute, November 2011.*

Figure1.16 Domestic food waste in the UK per year



Quested, T., Ingles, R.& Parry, A. (2013) Household food and drink waste in the United Kingdom 2012, Banbury: WRAP

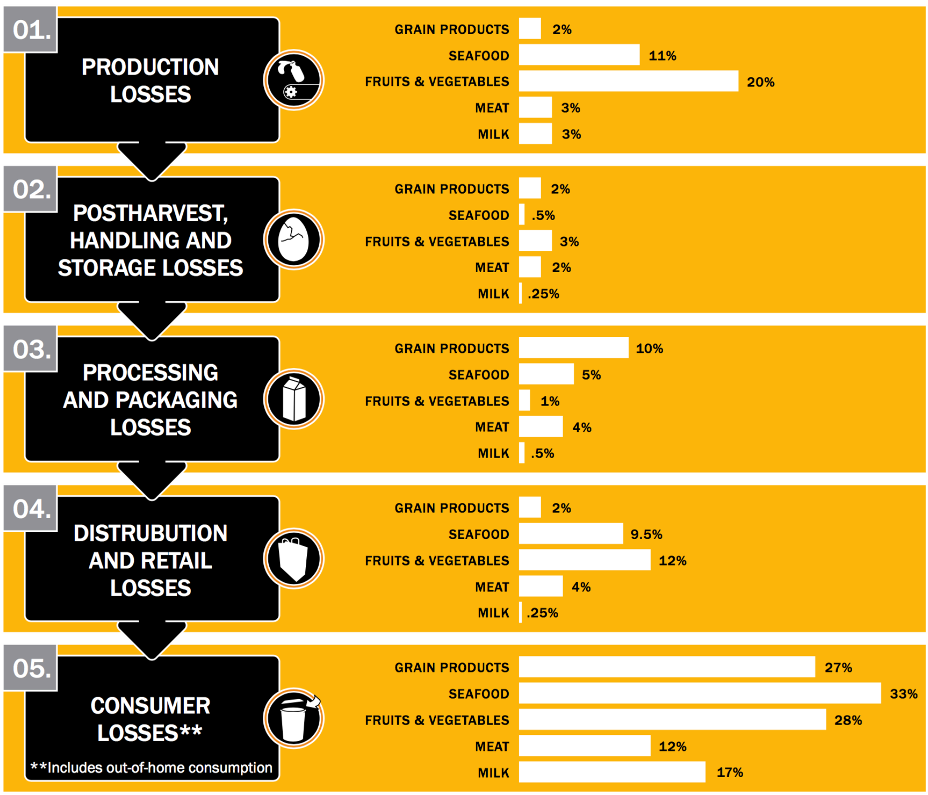
1.3.3
Food waste at home.

21. *NRDC. "Wasted: How America Is Losing Up to 40 Percent of Its Food from Farm to Fork to Landfill". 2012*

The biggest part of food waste is at home. As shown in the ReFED estimate, households collectively generate the largest share of food waste, followed by restaurants and other food service institutions, and then farms and supermarkets. American families throw out approximately 25 percent of the food and beverages they buy. The cost estimate for the average family of four is $1,800 annually. 3 About two-thirds of household waste is due to food spoilage from not being used in time, whereas the other one-third is caused by people cooking or serving too much.6 At the retail and end-consumer stages of the supply chain, perishables make up the majority of food losses due to the high volume of consumption and the food's tendency to spoil. In terms of total mass, fresh fruits and vegetables account for the largest losses, followed closely by dairy, and meat/poultry/fish. Note that loss numbers are based on mass and include loss in mass due to cooking but exclude inedible portions such as bones and peels. Again, data of this nature for losses from farm to retail are not available.

Of the food and drink that is wasted, 60% (by weight) is deemed 'avoidable', as it could have been eaten at some point prior to throwing away. It is this domestic, avoidable waste we should be focused on.[21]

Figure1.17 North American food losses at each step in the supply chain



Source: Food and agriculture organization 2011

Figure1.18 Banana, photograph by Alamy

1.3.4 Causes of food waste at home

According to the report of NRDC, some evidence suggests that drivers for household losses might include:

Lack of awareness and undervaluing of foods. Cheap, available food has created behaviors that do not place high value on utilizing what is purchased. As a result, the issue of wasted food is simply not on the radar of many Americans, even those who consider themselves environment- or cost- conscious.

Confusion over label dates. Label dates on food are generally not regulated and do not indicate food safety. Multiple dates, inconsistent usage, and lack of education around date labels cause consumers to discard food prematurely. In the U.K., an estimated 20 percent of avoidable food waste in households is discarded because of date labeling confusion.[22]

Spoilage. Food spoils in homes due to improper or suboptimal storage, poor visibility in refrigerators, partially used ingredients, and misjudged food needs.

Impulse and bulk purchases. Store promotions leading to bulk purchases or purchases of unusual products often result in consumers buying foods outside their typical meal planning, which then gets discarded.

Poor planning. Lack of meal planning and shopping lists, inaccurate estimates of meal preparation, and impromptu restaurant meals can lead to purchased food spoiling before being used.

22. WRAP, "Consumer Insight: Date Labels and Storage Guidance". 2011

23 .B.Wansink et al. "Portion Size Me: Downsizing Our Consumption Norms," Journal of the American Dietetic Association, July 2007

Over-preparation. Cooking portions have increased over time and large portions can lead to uneaten leftovers. In fact, the surface area of the average dinner plate expanded by 36 percent between 1960 and 2007.[23]

Household waste is not inevitable, nor has it always been common. A study conducted in 1987 found that people over 65, many of whom lived through either the Great Depression or World War II, wasted half as much food as other age groups.[24] Similarly, developing countries do not waste
nearly the same amount of food at the consumer level as do Europeans or Americans. As mentioned above, the average American consumer discards 10 times as much as the average Southeast Asian. There are many steps consumers can take to make their food budget go further and reduce their household waste.

24.*Bloom, "American Wasteland."2010*

PART 2
Idea & Research

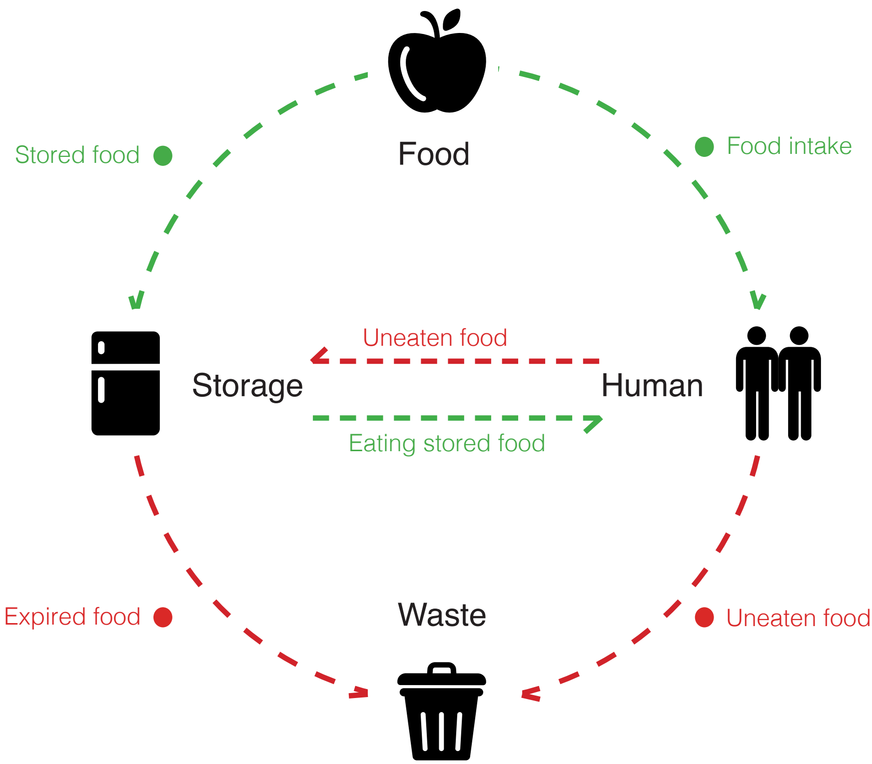


Figure2.1 Common domestic food journey. By Jin

2.1 Idea generation

2.1.1 Food journey at home

As showed in figure, domestic food flow commonly has two circles, green circle and red circle. The green circle refers projected or ideal food flow, which stars from food source, market, farming, fishing.. and then food would goes two directions, being eaten in time or being stored for the next period of time and then would be eaten by human. Besides, the red circle refers the part unplanted or unwanted. Uneaten food resulted from over-preparation or other reasons, and expired food result from forgetting, all goes to the same result, food waste.

we can see, there are lots of lines connected to human, which means there are too much thing should be considered by human, and everything is a kind of calculation, when food calculated or estimated precisely, the green circle would be bigger than red circle, vice versa. In our real life, we have too much things to consider, food just a part of them. And the relation between food and human is complicated. People can eat much or less, and there is also a tradeoff between food waste and weight gain. What is the nutritions of different food?…. could we have a easy way to manage our food? no more endless pre-meal calculation, and as a result, manage our body shape?

Figure2.2 "Energilization" By Jin

IDEA : "Energilize" food, quantification of body and food energy. A visible, interactive, easy-understood way to help people know their body requirement and manage their food.

2.1.2 "Common language"

The most difficult part of understanding food nutrition and body requirement is that are no “common language” to let them connect. Traditionally and technically, your feeling of your body is the media, sense of hungry or full, and everything depends on your personal experience which in some sense is unreliable. The government and organization are alway trying different way to show people the knowledge of food, nutrition table on packaging for instance, but most of them are still basic one, can not be used by most people. And people who wants to know more, should learn a lot of nutrition knowledge, which is frustrating. A visible and easy-understood intermediate way is missing. Creating a “common language” seems necessary.

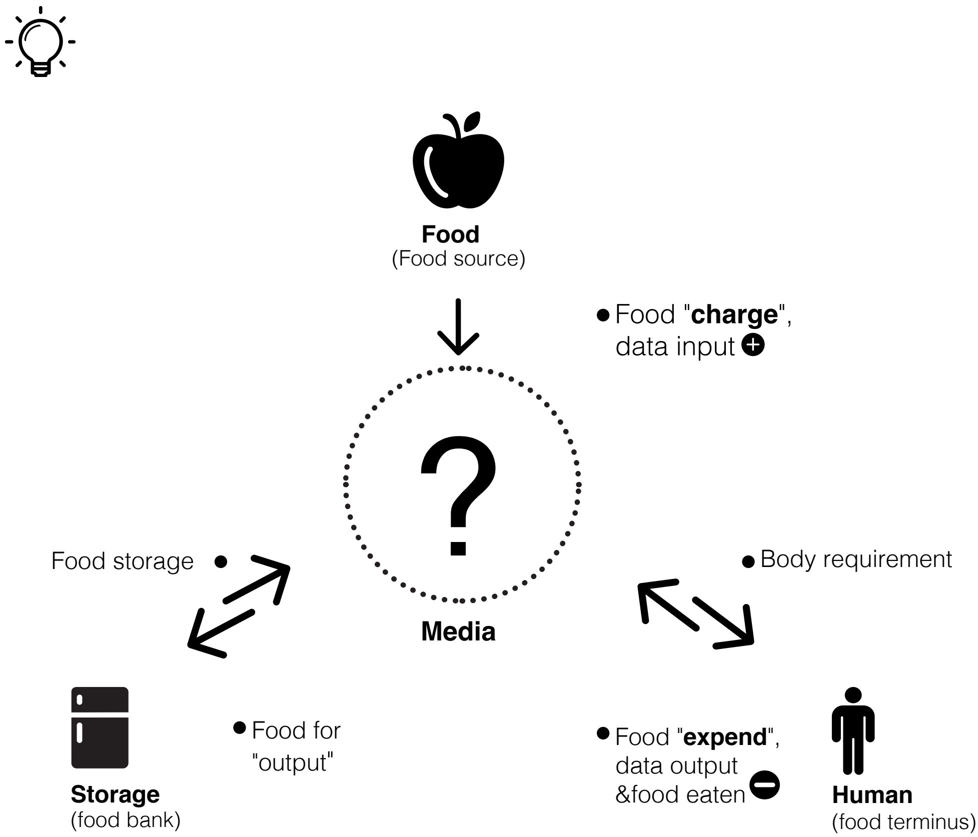


Figure2.3 "Idea projection" By Jin

2.1.3 Idea projection

Follow the design idea, food energy and body requirement could be transferred into a common language. And through a intermediate method, people could really see body information and food information data in the same platform. Simplified information could easily help people know what's in food, how much should take, how much I stored, how much I should take…

This media could be like a rechargeable battery, food from food source be measured and transferred into data be recorded in media. The media would also monitor body activity and transfer body data in it. Food data would meet body data in media, and user could make there food decision. After data inputing, food could be stored at home, and could be checked anytime. Before intaking food, people should do motion like registration phase again, but for outputting data and for monitoring food intake. Thus, the whole eating process could be measured, eventually help user manage food &body scientifically, reasonable.

TRANSFORM: To achieve the ideal result, two essential parts should be fulfilled: knowing, transferring food energy and body energy requirement.

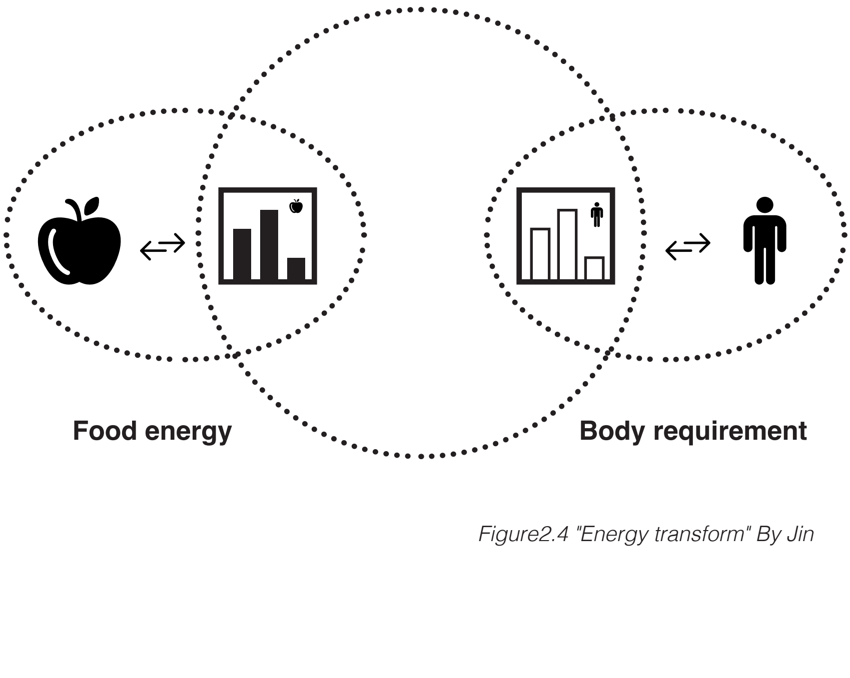


Figure2.4 "Energy transform" By Jin


ENERGY

2.2 Food energy

2.2.1 overall understanding

Food is the our energy resource of human body, but which kind of food components benefit us? and how they provide energy? Those are very difficult problem, cause foods and our bodies are so complicated and hard to figure them out clearly. Theoretically, to understand how food energy translate individual foods, and ultimately diets, into energy intakes that can be compared with the requirement recommendations, two pieces of information are needed:

1) Food analysis: the composition of foods for those components that provide energy, and the measurement of the amounts– i.e. the amounts of protein, fat, carbohydrate, etc.
2) Conversion factors: the calculation of the food energy: what are the energy conversion factors for converting those components into energy content

25. *FAO, "food energy-methods of analysis and conversion factors". 2003*

It has long been recognized that the energy contents of protein, fat and carbohydrate differ, both inherently in the compounds themselves and owing to their different digestion, absorption and metabolism.[25]

Understanding of foods and nutrition has become increasingly sophisticated over recent decades, particularly regarding enhanced understanding of the

relationship between diet and health. Much of the work of the first part of the twentieth century was directed towards understanding the roles of specific nutrients in intermediary metabolism: the goal of an adequate and healthy diet was to prevent energy and nutrient deficiencies. There is now increasing awareness of the key role that diet plays in the induction or prevention of specific diseases, such as heart disease, strokes, cancer and diabetes mellitus (WHO, 2003). Inadequate energy intake still limits the potential of individuals in many developing countries, while excess energy intakes are increasingly leading to very high prevalence of obesity (with its attendant complications) across all socio-economic strata in both developing and developed countries.

2.2.2 Food analysis theory

Basically, food sample will be tested through laboratory analysis, its commonly a precise method for nutrition analysis. Normally, food analyzed in laboratory would be in destructive methods: typical analysis includes: moisture (water) by loss of mass at 102C, Protein by analysis of total nitrogen...

Protein

For many years, the protein content of foods has been determined on the basis of total nitrogen content, while the Kjeldahl (or similar) method has been almost universally applied to determine nitrogen content (AOAC, 2000). Nitrogen content is then multiplied by a factor to arrive at protein content. This approach is based on two assumptions: that dietary carbohydrates and fats do not contain nitrogen, and that nearly all of the nitrogen in the diet is present as amino acids in proteins. On the basis of early determinations, the average nitrogen (N) content of proteins was found to be about 16 percent, which led to use of the calculation N x 6.25 (1/0.16 = 6.25) to convert nitrogen content into protein content.
For getting a more precise analysis, some conditions should be considered: not all nitrogen in foods is found in proteins; the nitrogen content of specific amino acids (as a percentage of weight) is various. Based on these facts, and the different amino acid compositions of various proteins, the nitrogen content of proteins actually varies from about 13 to 19 percent. This would equate to

Table2.5 Specific (Jones) factors for the conversion of nitrogen content to protein content (selected foods)

Source: Adapted and modified from Merrill and Watt(1973).

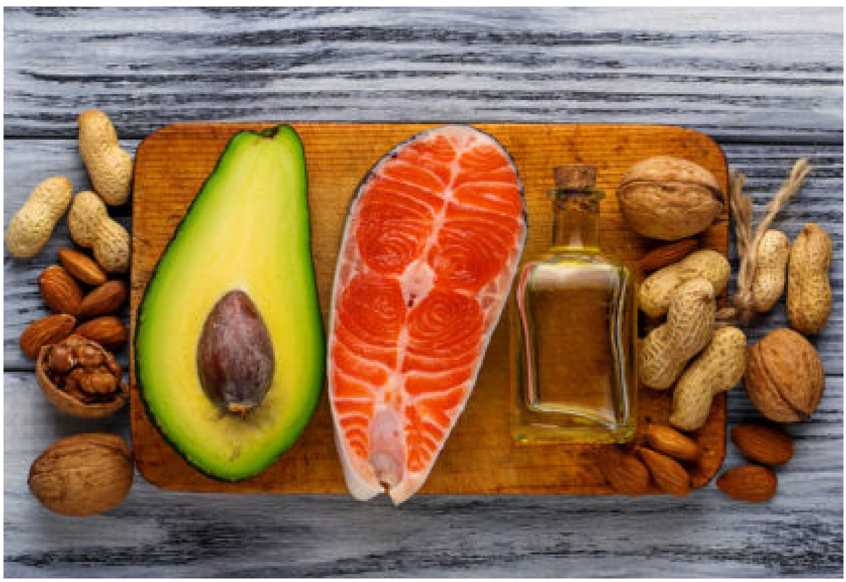
Food	Factor
Animal origin	
Eggs	6.25
Meat	6.25
Milk	6.38
Vegetable origin	
Barley	5.83
Corn (maize)	6.25
Millets	5.83
Oats	5.83
Rice	5.95
Rye	5.83
Sorghums	6.25
Wheat: Whole kernel	5.83
Bran	6.31
Endosperm	5.70
Beans: Castor	5.30
Jack, lima, navy, mung	6.25
Soybean	5.71
Velvet beans	6.25
Peanuts	5.46

Figure2.6 Foods contain protein

nitrogen conversion factors ranging from 5.26 (1/0.19) to 7.69 (1/0.13).

In response to these considerations, Jones (1941) suggested that N x 6.25 be abandoned and replaced by N x a factor specific for the food in question. These specific factors, now referred to as “Jones factors”, have been widely adopted.

Figure2.7 Foods contain fat



Fat

Most fat in the diet is in the form of triglyceride (three fatty acids esterified to a glycerol molecule backbone). There are also non-glyceride components such as sterols, e.g. cholesterol. While there is considerable interest in the roles that these non-glyceride components may play in metabolism, they are not important sources of energy in the diet (FAO, 1994).

There are accepted AOAC gravimetric methods for crude fat, which includes phospholipids and wax esters, as well as minor amounts of non- fatty material (AOAC, 2000). Total fat can be expressed as triglyceride equivalents determined as the sum of individual fatty acids and expressed as triglycerides (FAO, 1994). This method is satisfactory for the determination of fat in a wide variety of foods.

Figure2.8 Foods contain carbs.

Carbohydrates

Total carbohydrate content of foods has, for many years, been calculated by difference, rather than analyzed directly. Under this approach, the other constituents in the food (protein, fat, water, alcohol, ash) are determined individually, summed and subtracted from the total weight of the food. This is referred to as total carbohydrate by difference and is calculated by the following formula:

100 – (weight in grams [protein + fat + water + ash + alcohol] in 100 g of food)

It should be clear that carbohydrate estimated in this way includes fibre, as well as some components that are not strictly speaking carbohydrate, e.g. organic acids (Merrill and Watt, 1973). Total carbohydrate can also be calculated from the sum of the weights of individual carbohydrates and fibre after each has been directly analyzed.

Table2.9 Total and available carbohydrate

Total carbohydrate:	
	By difference: 100 – (weight in grams [protein + fat + water + ash + alcohol] in 100 g of food)
	By direct analysis: weight in grams (mono- + disaccharides + oligsaccharides + polysaccharides, including fibre)
Available carbohydrate:	
	By difference: 100 – (weight in grams [protein + fat + water + ash + alcohol + fibre] in 100 g of food)
	By direct analysis: weight in grams (mono- + disaccharides + oligosaccharides + polysaccharides, excluding fibre)*

* May be expressed as weight (anhydrous form) or as the monosaccharide equivalents (hydrous form including water).

Available carbohydrate represents that fraction of carbohydrate that can be digested by human enzymes, is absorbed and enters into intermediary metabolism. (It does not include dietary fibre, which can be a source of energy only after fermentation – see the following subsections.) Available carbohydrate can be arrived at in two different ways: it can be estimated by difference, or analysed directly. To calculate available carbohydrate by difference, the amount of dietary fibre is analysed and subtracted from total carbohydrate, thus:

100 – (weight in grams [protein + fat + water + ash + alcohol + dietary fibre] in 100 g of food)

This yields the estimated weight of available carbohydrate, but gives no indication of the composition of the various saccharides comprising available carbohydrate. Alternatively, available carbohydrate can be derived by summing the analysed weights of individual available carbohydrates. In either case, available carbohydrate can be expressed as the weight of the carbohydrate or as monosaccharide equivalents. For a summary of all these methods, see Table.

2.2.3 Food analysis method

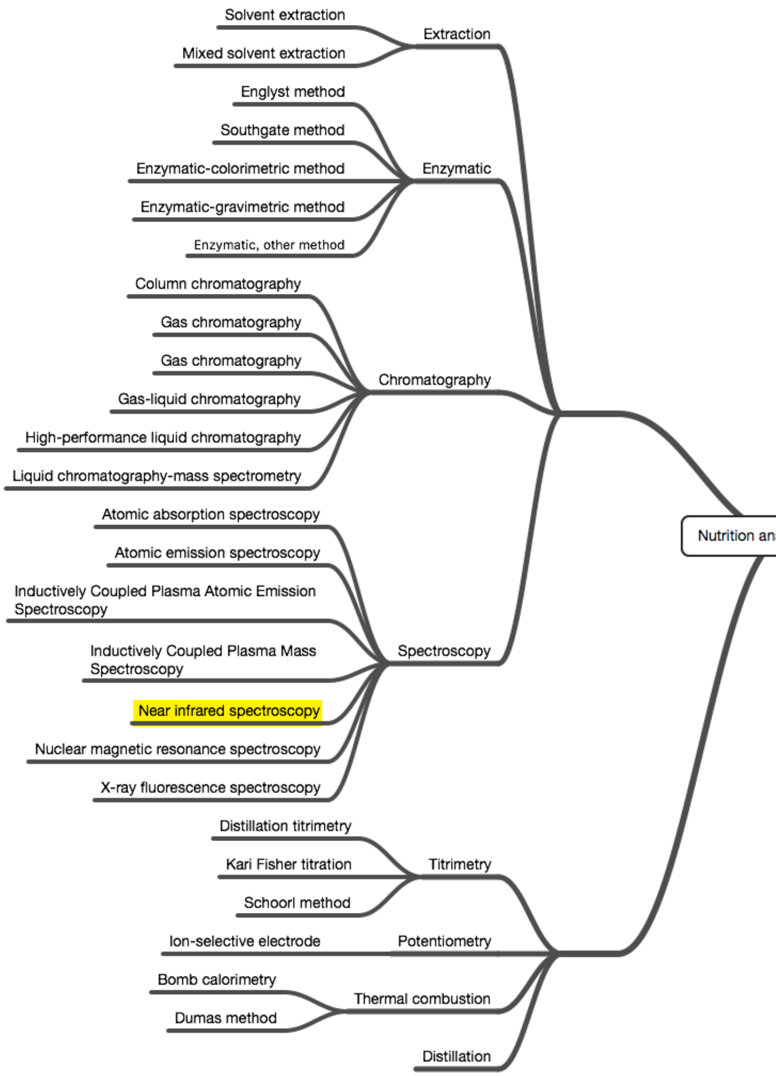
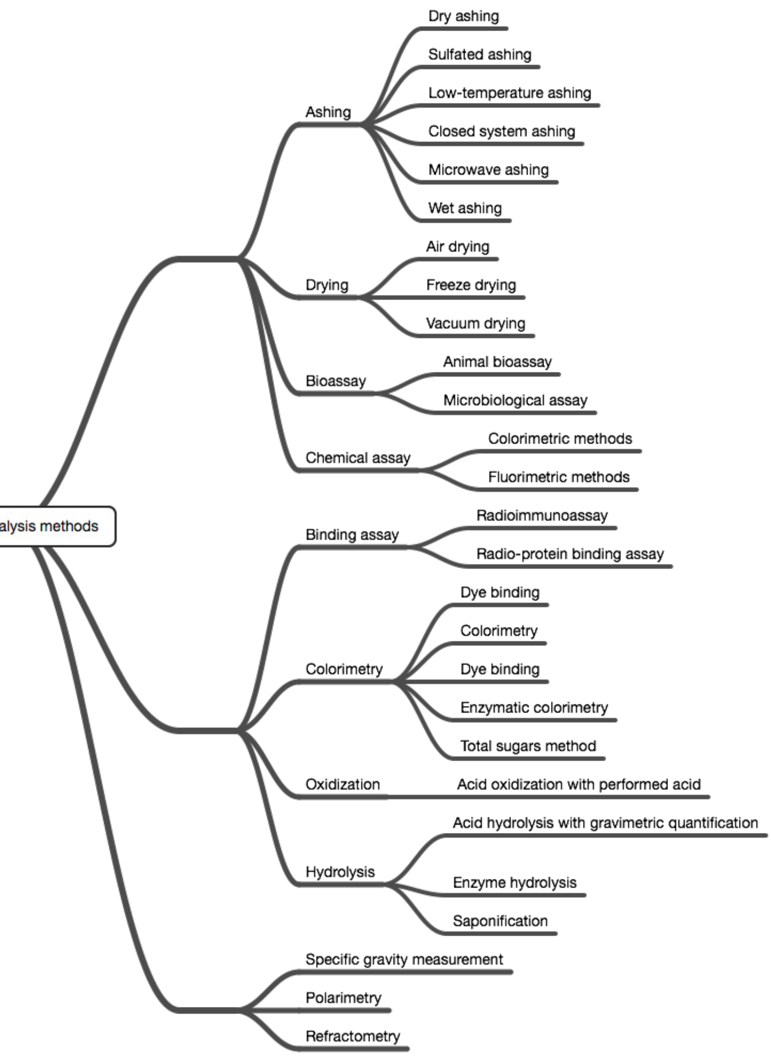


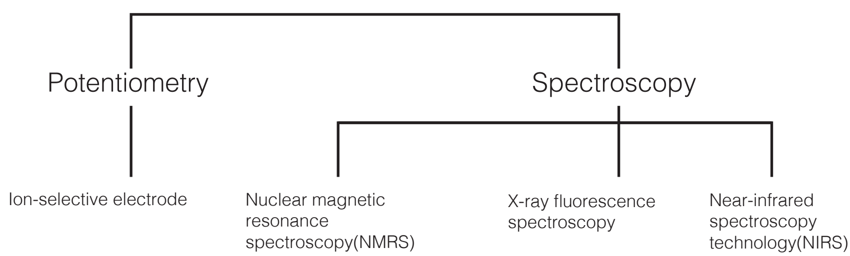
Figure2.10 Nutrition analysis methods taxonomy



Source: USDA nutrition database

Non destructive methods (candidate technologies)

Connecting our idea projection and food analysis methods, obviously traditional destructive methods are not suitable for the project. With the demand of nondestructive food analysis methods, only few method been remained.


Potentiometry
Spectroscopy
Ion-selective electrode
Nuclear magnetic resonance spectroscopy(NMRS)
X-ray fluorescence spectroscopy
Near-infrared spectroscopy technology(NIRS)

Indirect analysis methods and related applications

Excepting directly sending food to laboratory and waiting for testing nutrition, there are also other methods for this purpose.

Software
Software is available as an alternative to laboratory nutrition analysis. This software typically utilizes a database of ingredients that have previously been laboratory tested. The user can input ingredient data by matching their ingredients to ingredients found in the database; the analysis can then be calculated.

Online Nutrition Analysis
In recent years, web-based nutrition analysis software services have become more popular. Online nutrition analysis allows users to access online databases and draw from certified ingredients to produce instant nutrition information.

Turn-Key Nutrition Analysis Services
Another emerging trend is the use of nutritional analysis services that do a complete analysis of any recipe by using their proprietary database. Users provide recipes, cooking methods and serving sizes. In turn, the service provides a complete nutritional analysis.[26]

26. *Wikipedia. "nutrition analysis". retrieved by September. 2017*

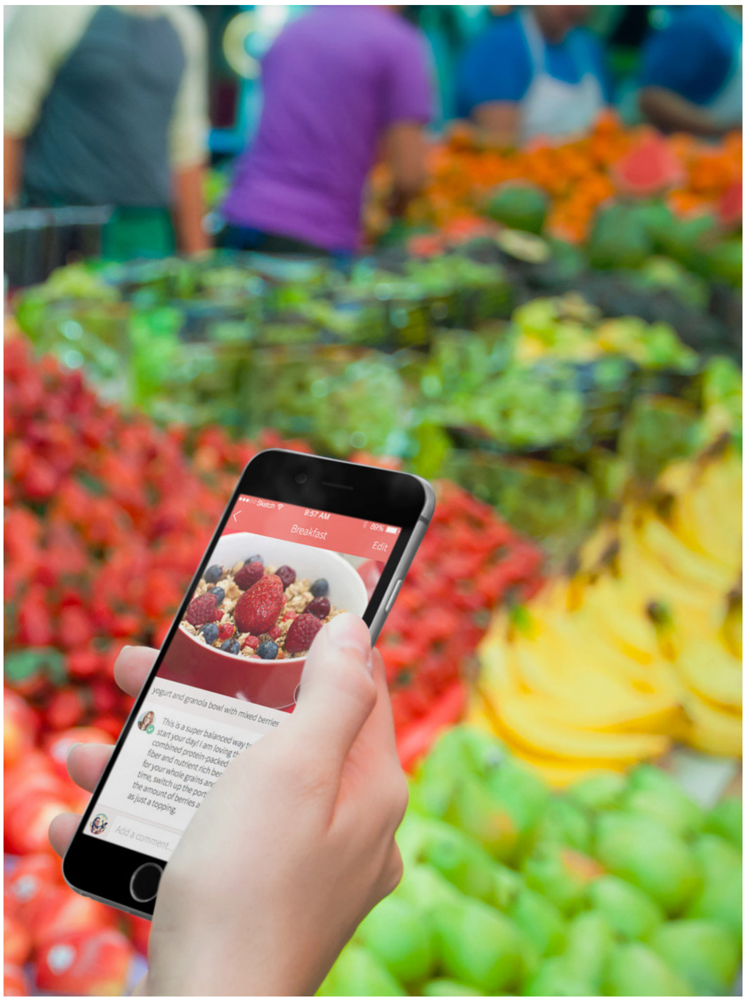


Figure2.11 Nutrition analysis App.

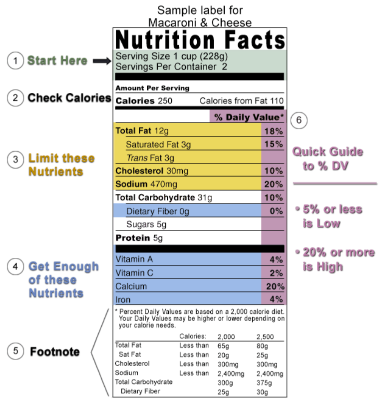


Figure2.12 Nutrition facts on food packaging

Direct data acquirement

For providing people more knowledge about food nutrition, government and related department still trying some work. In the United States, nutrition information is required on packaged retail foods in the form of nutrition facts panels as a result of food labeling regulations. In recent years, many restaurants have begun posting nutrition information as a result of both customer demand and menu-labeling laws.

Menu-labeling
The nutrition-disclosure provision requires chain restaurants, similar retail food establishments and vending machines, etc to provide specific nutrition labeling information.

Nutrition facts label
The nutrition facts label is a label required on most packaged food in many countries.It provedes food nutrition details about each nutrient.

Figure2.13 Barcode in fish shape

Indirect data acquirement

AIDC
Automatic identification and data capture (AIDC) refers to the methods of automatically identifying objects, collecting data about them, and entering them directly into computer systems, without human involvement.

Barcode
A barcode is an optical, machine-readable, representation of data; the data usually describes something about the object that carries the barcode.

Radio frequency identification (RFID)
RFID uses electromagnetic fields to automatically identify and track tags attached to objects. The tags contain electronically stored information. More commonly used in clothes and other items, cause it doesn't need be posted under scanner's vision, and doesn't need be printed on product.[27]

27. *Wikipedia. "automatic identification and data capture". retrieved by September. 2017*

Future vision

Augmented Reality (AR)
Currently, AR technology is flourishing, it might change the information getting in food industry. Cause almost each of us has smartphone now, it might be an interface between food and us: when you want to know recipe, nutrient or any information of the food in front of you, you can capture those directly on the screen of smart device.

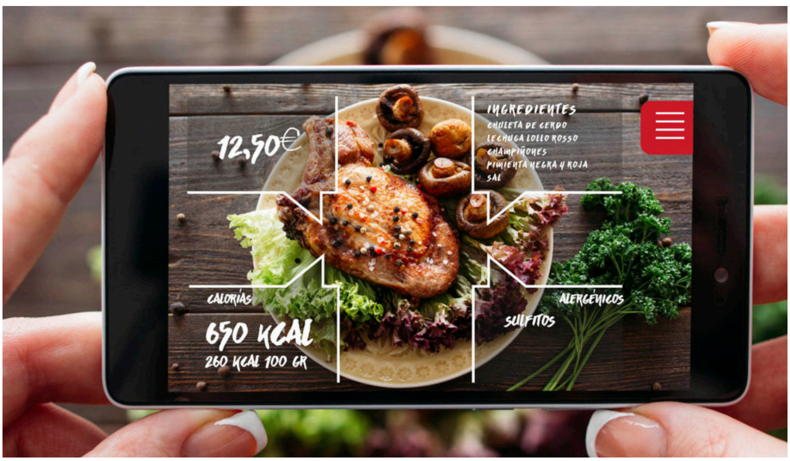


Figure2.14 Future proposal: seeing food nutrition through screen


f(x) ≥ 0
F(x) = G(x)
y = kx + b
y = x
y = 1/x
y = √x
P = ρgh
y = 2·cos(3·x+1)

2.2.5 Energy conversion factors &body requirement

The translation of human energy requirements into recommended intakes of food and the assessment of how well the available food supplies or diets of populations (or even of individuals) satisfy these requirements require knowledge of the amounts of available energy in individual foods.
Determining the energy content of foods depends on the following:

1) the components of food that provide energy (protein, fat, carbohydrate, alcohol, polyols, organic acids and novel compounds) should be determined by appropriate analytical methods;

2) the quantity of each individual component must be converted to food energy using a generally accepted factor that expresses the amount of available energy per unit of weight; and

3) the food energies of all components must be added together to represent the nutritional energy value of the food for humans.

The energy conversion factors and the models currently used assume that each component of a food has an energy factor that is fixed and that does not vary according to the proportions of other components in the food or diet.

Energy unit: Joules & Calories

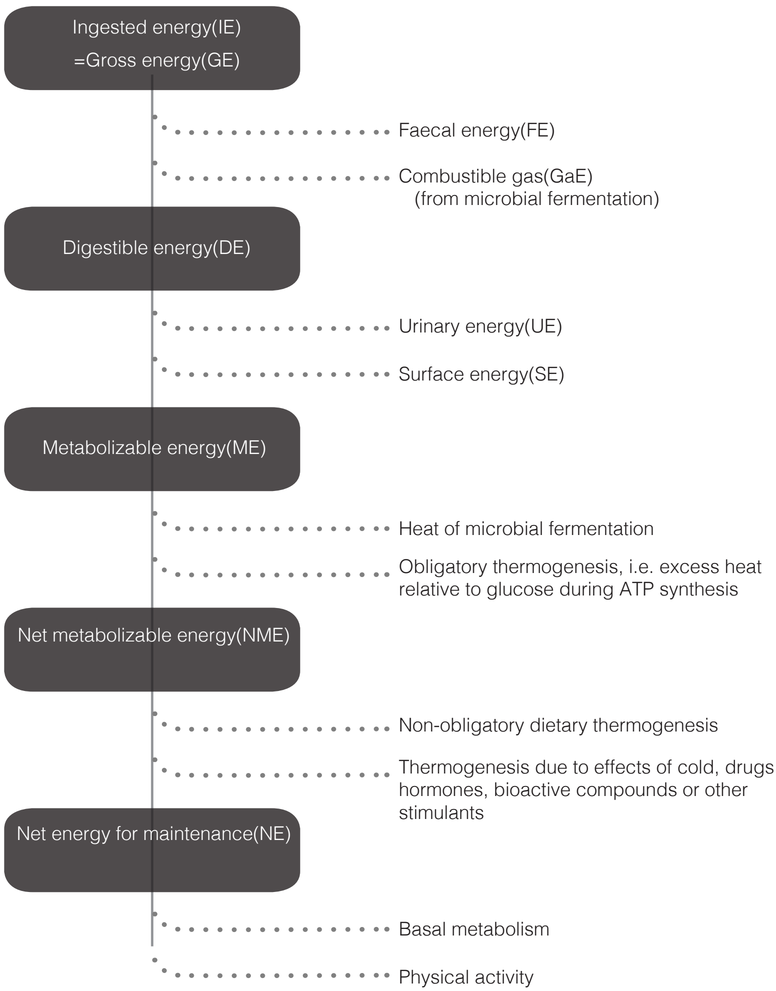
The unit of energy in the International System of Units (SI) is the joule (J). A joule is the energy expended when 1 kg is moved 1 m by a force of 1 Newton. This is the accepted standard unit of energy used in human energetics and it should also be used for the expression of energy in foods. Because nutritionists and food scientists are concerned with large amounts of energy, they generally use kiloJoules (kJ = 103 J) or megaJoules (MJ = 106 J). For many decades, many scientists, non-scientists and consumers are get used to the use of calories, which is not a coherent unit although. So that both joules (kJ) and calories (kcal) are used side by side in most regulatory frameworks. The conversion factors for joules and calories are: 1 kJ = 0.239 kcal; and 1 kcal = 4.184 kJ.[28]

28. *Wikipedia. "Calorie". retrieved by September. 2017*

1 Kj = 0.239Kcal
1 Kcal = 4.184 Kj

Flow of energy through the body

Figure2.15 Overview of food energy flow through the body for maintenance of energy balance



Source: Adapted from Warwick and Baines (2000) and Livesey

Food that is ingested contains energy – the maximum amount being reflected in the heat that is measured after complete combustion to carbon dioxide (CO2) and water in a bomb calorimeter.

This energy is referred to as ingested energy (IE) or gross energy (GE). Incomplete digestion of food in the small intestine, and fermentation of unabsorbed carbohydrate in the colon, results in losses of energy as faecal energy (FE) and gaseous energy (GaE) in the form of combustible gases (e.g. hydrogen and methane) and even short-chain (volatile) fatty acids are formed. Most of the energy that is absorbed is available to human metabolism, but some is lost as urinary energy (UE), which derived from incomplete catabolism of protein. A small amount of energy is also lost from the body surface (surface energy [SE]). The energy that remains after accounting for the important losses is known as "metabolizable energy" (ME).

Not all metabolizable energy is available for the production of ATP. Some energy is utilized during the metabolic processes associated with digestion and can be measured as heat production; this is referred to as dietary-induced thermogenesis (DIT). This can be considered an obligatory energy expenditure and, theoretically, it can be related to the energy factors assigned to foods. When the energy lost to microbial fermentation and obligatory thermogenesis are subtracted from ME, the result is an expression of the energy content of food, which is referred to as net metabolizable energy (NME).

Some energy is also lost as the heat produced by metabolic processes associated with other forms of thermogenesis, such as the effects of cold, hormones, certain drugs, bioactive compounds and stimulants. The energy that remains after subtracting these heat losses from NME is referred to as net energy for maintenance (NE), which is the energy that can be used by the human to support basal metabolism, physical activity and the energy needed for growth, pregnancy and lactation. [25]

25. *FAO, "food energy-methods of analysis and conversion factors". 2003*

Food energy conversion factors

PROTEIN	17kJ/g (4.0 kcal/g)
FAT	37kJ/g (9.0 kcal/g)
CARBOHYDRATES	17kJ/g (4.0 kcal/g)

Figure2.16 The Atwater general food energy conversion factor

Just as a large number of analytical methods for food analysis have been developed, so have a variety of different energy conversion factors for foods. In general, three systems are in use: the Atwater general factor system; the extensive general factor system; and the Atwater specific factor system. [25]

It is important to note that all of these systems relate conceptually to (ME) as defined in the previous section. A

25. *FAO, "food energy-methods of analysis and conversion factors". 2003*

general factor system based on NME has been proposed by Livesey (2001) as an alternative to these systems.

The Atwater general factor system

The Atwater general factor system was developed by W.O. Atwater and his colleagues at the United States Department of Agriculture (USDA) Agricultural Experiment Station in Storrs, Connecticut at the end of the nineteenth century (Atwater and Woods, 1896). It uses a single factor for each of the energy-yielding substrates (protein, fat, carbohydrate), regardless of the food in which it is found. The energy values are 17 kJ/g (4.0 kcal/g) for protein, 37 kJ/g (9.0 kcal/g) for fat and 17 kJ/g (4.0 kcal/g) for carbohydrates. Also includes alcohol with a rounded value of 29 kJ/g (7.0 kcal/g) (Atwater and Benedict, 1902). As originally described by Atwater, carbohydrate is determined by difference, and thus includes fibre. The Atwater system has been widely used, in part because of its obvious simplicity.

The extensive general factor system

A more extensive general factor system has been derived by modifying, refining and making additions to the Atwater general factor system. For example, separate factors were needed so that the division of total carbohydrate into available carbohydrate and fibre could be taken into account.

In arriving at this factor, fibre is assumed to be 70 percent fermentable. It should also be recognized that some of the energy generated by fermentation is lost as gas and lost in the faeces.

The Atwater specific factor system

The Atwater specific factor system, a refinement based on reexamination of the Atwater system, was introduced in 1955 by Merrill and Watt (1955). It integrates the results of 50 years of research and derives different factors for proteins, fats and carbohydrates, depending on the foods in which they are found. Whereas Atwater used average values. For example:

1) Because proteins differ in their amino acid composition, they also differ in their heats of combustion. Thus, the heat of combustion of protein in rice is approximately 20 percent higher than that of protein in potatoes, and different energy factors should be used for each. 2) Digestibility (and fibre content) of a grain may be affected by how it is milled. Thus, the available energy from equal amounts (weight) of whole-wheat flour (100 percent extraction) and extensively milled wheat flour (70 percent extraction) will be different.

Table2.17 Atwater specific factors for selected foods

	Protein *kcal/g* (kJ/g)[§]	Fat *kcal/g* (kJ/g)[§]	Total carbohydrate *kcal/g* (kJ/g)[§]
Eggs, meat products, milk products:			
Eggs	*4.36* (18.2)	*9.02* (37.7)	*3.68* (15.4)
Meat/fish	*4.27* (17.9)	*9.02* (37.7)	*
Milk/milk products	*4.27* (17.9)	*8.79* (36.8)	*3.87* (16.2)
Fats – separated:			
Butter	*4.27* (17.9)	*8.79* (36.8)	*3.87* (16.2)
Margarine, vegetable	*4.27* (17.9)	*8.84* (37.0)	*3.87* (16.2)
Other vegetable fats and oils	--	*8.84* (37.0)	--
Fruits :			
All, except lemons, limes	*3.36* (14.1)	*8.37* (35.0)	*3.60* (15.1)
Fruit juice, except lemon, lime[#]	*3.36* (14.1)	*8.37* (35.0)	*3.92* (15.1)
Lemon, limes	*3.36* (14.1)	*8.37* (35.0)	*2.48* (10.4)
Lemon juice, lime juice[#]	*3.36* (14.1)	*8.37* (35.0)	*2.70* (11.3)
Grain products:			
Barley, pearled	*3.55* (14.9)	*8.37* (35.0)	*3.95* (16.5)
Cornmeal, whole ground	*2.73* (11.4)	*8.37* (35.0)	*4.03* (16.9)
Macaroni, spaghetti	*3.91* (16.4)	*8.37* (35.0)	*4.12* (17.2)
Oatmeal – rolled oats	*3.46* (14.5)	*8.37* (35.0)	*4.12* (17.2)
Rice, brown	*3.41* (14.3)	*8.37* (35.0)	*4.12* (17.2)
Rice, white or polished	*3.82* (16.0)	*8.37* (35.0)	*4.16* (17.4)
Rye flour – whole grain	*3.05* (12.8)	*8.37* (35.0)	*3.86* (16.2)
Rye flour – light	*3.41* (14.3)	*8.37* (35.0)	*4.07* (17.0)
Sorghum – wholemeal	*0.91* (3.8)	*8.37* (35.0)	*4.03* (16.9)
Wheat – 97–100% extraction	*3.59* (14.0)	*8.37* (35.0)	*3.78* (15.8)
Wheat t – 70–74% extraction	*4.05* (17.0)	*8.37* (35.0)	*4.12* (17.2)
Other cereals – refined	*3.87* (16.2)	*8.37* (35.0)	*4.12* (17.2)
Legumes, nuts:			
Mature dry beans, peas, nuts	*3.47* (14.5)	*8.37* (35.0)	*4.07* (17.0)
Soybeans	*3.47* (14.5)	*8.37* (35.0)	*4.07* (17.0)

Source: *FAO, "food energy- methods of analysis and conversion factors". 2003*

The Atwater specific factor system appears to be superior to the original Atwater general system, which took only protein, fat, total carbohydrate and alcohol into account. However, it may not be vastly superior to the more extensive general factor system, which takes into account the differentiation between available carbohydrate and dietary fibre, and recognizes sources of energy other than protein, carbohydrates and fat.

Different uses between metabolizable energy(ME) and net metabolizable energy(NME)

ME has traditionally been defined as “food energy available for heat production (= energy expenditure) and body gains” (Atwater and Bryant, 1900). By contrast, net metabolizable energy (NME) is thought of as the “food energy available for body functions that require ATP”, which is based on the ATP-producing capacity of foods and their components, rather than on the total heat-producing capacity of foods.

So when using different concept, there will be a different value for each nutrient of food. The lower NME values for dietary fibre are due to a higher assumed loss of energy through heat of fermentation. And the discrepancy between energy values calculated using ME and those using NME conversion factors will be greatest for diets that are high in protein and dietary fibre, as well as for some novel food components.

There are clearly circumstances in which it is desirable to know with greater precision which specific foods will ultimately contribute to maintaining energy balance – for example: in the management of obesity through weight-loss diets that are high in protein or fibre, which will not be completely metabolized to yield energy; in diabetes mellitus with concomitant renal disease, when protein intake may be low, and therefore makes only a small contribution to total

Table2.18 Comparison of ME general factors and NME factors for the major energy-producing constituents of foods

	ME as general Atwater factors kJ/g *(kcal/g)*	**Modified ME factors#** kJ/g *(kcal/g)*	**NME factors*** [1] kJ/g *(kcal/g)*
Protein	17 (*4.0*)	17 (*4.0*)	13 (*3.2*)
Fat	37 (*9.0*)	37 (*9.0*)	37 (*9.0*)
Carbohydrate			
Available – monosaccharides	16 (*3.75*)[2]	16 (*3.75*)	16 (*3.8*)
Available – by difference, sum	17 (*4.0*)	17 (*4.0*)	17 (*4.0*)
Total	17 (*4.0*)	17 (*4.0*)	
Dietary fibre			
Fermentable		11 (*2.6*)*** [1]	8 (*1.9*)
Non-fermentable		0 (*0.0*)*** [1]	0 (*0.0*)
In conventional foods**		8 (*2*)*** [3]	6 (*1.4*)
Alcohol	29 (*7*)*	29 (*6.9*)[4]	26 (*6.3*)
Total polyols		10 (*2.4*)[5]	
Organic acids[+]		13 (*3*)[6]	9 (*2.1*)

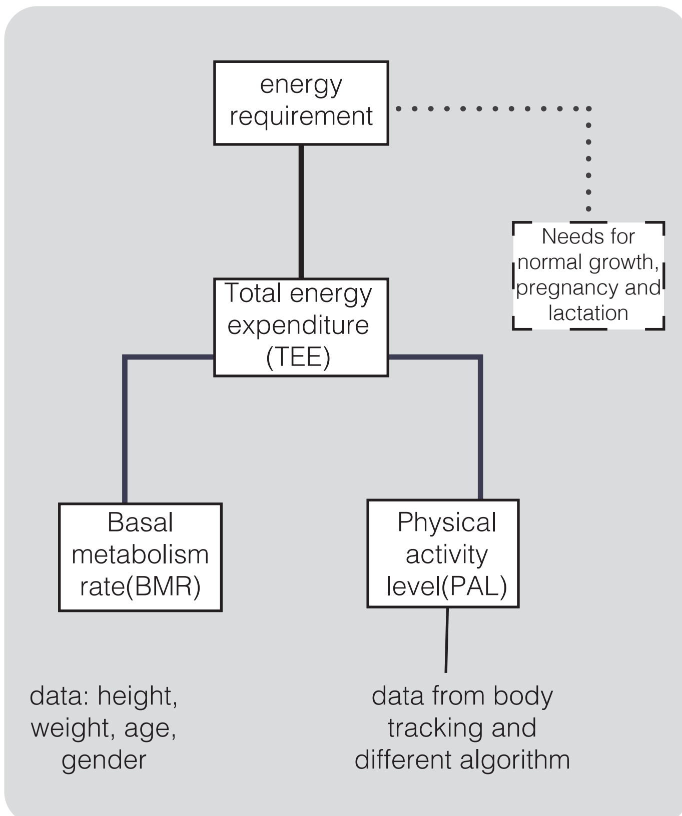
* Rounded values are used.
# Based on general Atwater factors.
** Assumes that 70 percent of the fibre in traditional foods is fermentable.
*** Proposed factors.
Sources: [1] Livesey (in press [b]); [2] Southgate and Durnin (1970); [3] FAO (1998); [4] Merrill and Watt (1973); [5] EC (1990); [6] Codex Alimentarius (2001).

energy intake; or when using novel foods that may or may not be fully metabolized. It should be noted that in situations where NME conversion factors for food energy are used, guidance on “reduced” energy requirements based on NME factors must be provided so that requirements and intakes are expressed in the same fashion. Nevertheless, in most cases the error incurred will be about 5 percent, which is within the usually accepted limits of measurement error or biological variation.

2.3 Body requirement

▌2.3.1 Calculation structure of body energy requirements

Figure2.19 Calculation structure of body energy requirement



source:FAO database, human energy requirement, 2004

Because energy factors are used to assess how well foods and diets meet the recommended energy requirements, it is desirable that values for requirements and those for food energy be expressed in comparable terms. The ME based-on use of energy conversion factors is related to the way in which estimations of energy requirement recommendations are currently derived.

Requirements for all ages are now based on measurements of energy expenditure, plus the energy needs for normal growth, pregnancy and lactation.[29] Energy expenditure data have been obtained by a variety of techniques, including the use of doubly labelled water, heart rate monitoring and standard Basal Metabolic Rate (BMR) measurements. Regardless of the technique used, the energy values obtained are related to oxygen consumption or CO2 production and (through indirect calorimetry calculations) heat production. The current estimates of energy requirements and dietary energy recommendations relate more closely to ME, and the use of ME conversion factors allows a direct comparison between the values for food intakes and the values for energy requirements. This was perceived as desirable for both professionals and consumers alike.

29. FAO. Human energy requirement, report of a Joint FAO/WHO/UNU Expert Consultation. Rome, 17-24 October 2001. 2004

2.3.2 Energy expenditure

● Total energy expenditure (TEE)

BMR constitutes about 45 to 70 percent of TEE in adults, and is determined principally by gender, body size, body composition and age. It can be measured accurately with small intra-individual variation by direct or indirect calorimetry under standard conditions, which include being awake in the supine position, ten to 12 hours after a meal, following eight hours of physical rest and no strenuous exercise in the preceding day, and being in a state of mental relaxation and an ambient environmental temperature that does not evoke shivering or sweating. BMR can be measured only under laboratory conditions

Figure2.20 Equation of total energy expenditure

Total energy expenditure (TEE) = Basal metabolic rate(BMR) x Physical activity level(PAL)

and in small groups of representative individuals. There is a need to estimate BMR at the population level when using the factorial approach to estimate TEE from the average BMR and PAL value attributable to that population. Hence, the alternative has been to estimate a group's mean BMR using predictive equations based on measurements that are easier to obtain, such as body weight and/or height.

Basal Metabolic Rate(BMR)

30. Wikipedia. "Basal metabolic rate". retrieved by September. 2017

Basal metabolic rate (BMR) is the minimal rate of energy expenditure per unit time by endothermic animals at rest.It is reported in energy units per unit time ranging from watt (joule/second) to ml O2/min or joule per hour per kg body mass J/(h·kg). Proper measurement requires a strict set of criteria be met.[30]

Metabolism comprises the processes that the body needs to function. Basal metabolic rate is the amount of energy expressed in calories that a person needs to keep the body functioning at rest. Some of those processes are breathing, blood circulation, controlling body temperature, cell growth, brain and nerve function, and contraction of muscles. Basal metabolic rate (BMR) affects the rate that a person burns calories and ultimately whether that individual maintains, gains, or loses weight. The basal metabolic rate accounts for about 60 to 75% of the daily calorie expenditure by individuals. It is influenced by several factors.

BMR estimation formulas

Several prediction equations exist. Historically, the most notable one was the Harris–Benedict equation, which was created in 1919.

The Original Harris-Benedict Equation

$$\text{for men, } P = \left(\frac{13.7516m}{1\text{ kg}} + \frac{5.0033h}{1\text{ cm}} - \frac{6.7550a}{1\text{ year}} + 66.4730\right)\frac{\text{kcal}}{\text{day}}$$

$$\text{for women, } P = \left(\frac{9.5634m}{1\text{ kg}} + \frac{1.8496h}{1\text{ cm}} - \frac{4.6756a}{1\text{ year}} + 655.0955\right)\frac{\text{kcal}}{\text{day}}$$

The difference in BMR for men and women is mainly due to differences in body weight.
In 1984, the original Harris-Benedict equations were revised[7] using new data. In comparisons with actual expenditure, the revised equations were found to be more accurate.

The Revised Harris-Benedict Equation

$$\text{for men, } P = \left(\frac{13.397m}{1\text{ kg}} + \frac{4.799h}{1\text{ cm}} - \frac{5.677a}{1\text{ year}} + 88.362\right)\frac{\text{kcal}}{\text{day}}$$

$$\text{for women, } P = \left(\frac{9.247m}{1\text{ kg}} + \frac{3.098h}{1\text{ cm}} - \frac{4.330a}{1\text{ year}} + 447.593\right)\frac{\text{kcal}}{\text{day}}$$

It was the best prediction equation until 1990, when Mifflin introduced the equation:

The Mifflin St Jeor Equation

$$P = \left(\frac{10.0m}{1\text{ kg}} + \frac{6.25h}{1\text{ cm}} - \frac{5.0a}{1\text{ year}} + s\right)\frac{\text{kcal}}{\text{day}}$$, where s is +5 for males and −161 for females.

These formulas are based on body weight, which does not take into account the difference in metabolic activity between lean body mass and body fat. Other formulas exist which take into account lean body mass, two of which are the Katch-McArdle formula, and Cunningham formula. The Katch-McArdle formula is used to predict Resting Daily Energy Expenditure (RDEE). The Cunningham formula is commonly attributed as being used to predict RMR instead of BMR, however the formulas provided by Katch-McArdle and Cunningham are the same.

$P = \mathbf{370} + (\mathbf{21.6} \cdot LBM)$, where *LBM* is the lean body mass in kg.

● Physical activity level(PAL)

The physical activity level (PAL) is a way to express a person's daily physical activity as a number, and is used to estimate a person's total energy expenditure.[1] In combination with the basal metabolic rate, it can be used to compute the amount of food energy a person needs to consume in order to maintain a particular lifestyle.

Table2.21 Classification of lifestyles in relation to the intensity of habitual physical activity

category	PAL value
Sedentary or light activity lifestyle	1.40-1.69
Active or moderately active lifestyle	1.70-1.99
Vigorous or vigorously active lifestyle	2.00-2.40*

* PAL values > 2.40 are difficult to maintain over a long period of time.

PART 3

Design thinking

3.1 Personas

BILL

Age: 25
Gender: Male
Profession: College student
Key words: Overweight

“I don’t like my current body, because you know that, I’m very busy on school task, I have no time to plan the a diet for myself. Besides, I hate do paper work before each meal, that’s disaster. Eating fast, prepared food around school for me is a reasonable choice, even I know its not much healthy.”

As students, we started learning how to live alone without parents. Managing life between school and home is tough: studying, having fun, eating, shopping… everything should be considered. Eating, as the most essential part of life, annoys me everyday. “What to eat?” is humorously be considered as the most difficult question in the universe. We all know good eating builds our bodies, but I mean, it is hard to know and use those knowledges.

ANNA

Age: 21
Gender: Female
Profession: College student
Key words: Type 1 diabetes

"I have had Type 1 diabetes for 11 years, 5 months and 10 days. I have had over 30,000 blood sugar tests and 18,000 injections/site changes. I am only 21. In 1974, researchers claimed that a cure was only 5 years away. It's now 2017. I don't wish to live another 11 years, 5 months and 10 days with diabetes. Diabetes is hard; however, we are more than a disease, a disorder or a sickness. "

As a diabetic, we're allowed to have good days and bad days; just like everyone else. We just need to be prepared. Even on our bad days, we are still diabetics. We still have to stop and test our blood sugars and give insulin. We have highs (fun fact: we don't understand how odd it sounds to others when we're in public and say, "I think I'm high") and then we also have lows (literally). Our blood sugars can jump to 25.4 mmol/l (457 mg/dl) then plummet to 2.1 mmol/l (38 mg/dl). We deal with the unquenchable thirst, headaches and emotional meltdowns when we're high, then later deal with the ravenous hunger when we're low. Diabetes is in absolutely no way, "easy" to manage. In fact, sometimes it feels like you can't manage at all.

	Eating around school; Fast, easy food; No time cooking; Eating same food; Eating snacks.	Once or twice a week; Bulk purchase for low price; Buy same food; Buy a lot of snacks.	Bulk purchased food strored; Stored food out of date; Storing uneaten food.
Analysis	Unbalanced diet; Bad diet choice; Lacking of cooking skill; No learning food knowledge.	Low shopping frequency; Easy to overpurchase food; Unbalanced eating; Bad nutrition chioce.	Too much food stored; Easy to forget stored food; Each food has different duration.
MOTIVATION	Time saving; Fast food relatively cheep; Preference of taste than health.	No shopping list; Impulse; Saving money.	Food accessible; No cooking plan; Too lazy.
Results	● Overweight&obesity	● Money waste	● Food waste

USER NEEDS

● Easy way to know food quality	● Remind and easy to check food storage	● Know how much food should prepare	● Recipe advisor &imformation for exploring new food

No red meat diet;
Eat several times during a day;
Eating various food;

Read carefully before buying;
Have shopping list;
Buy different types of food;

Test blood eight to ten times a day,even night;
Alway keep monitor aside;

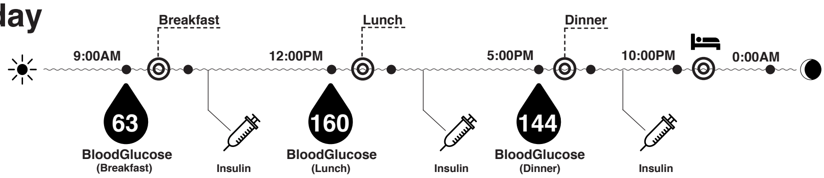
Analysis

Certain foods bad for diabetic;
Control blood glucose through eating;
Requirement of balanced nutrition.

Check nutrition table to avoid bad components;
Need regular and healthy diet;
Need plan a wide range eating.

Always need to know blood glucose;
Not easy to know blood glucose trend;
Diabetes is dangerous even night

My typical day



USER NEEDS

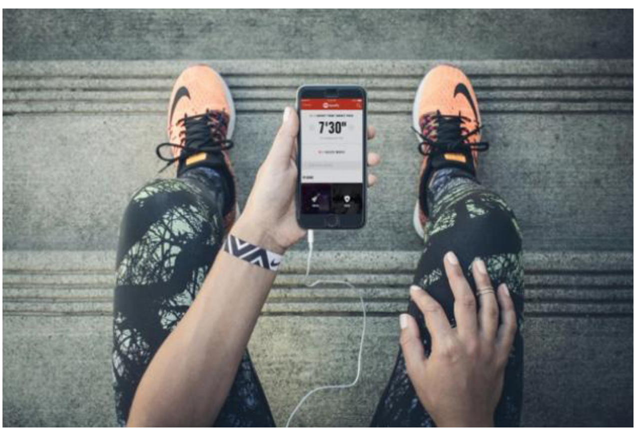
• Easy to know glucose trend	• A painless way to test blood	• Food advisor: identify foods to avoid or limit

3.2 Body monitoring device research

3.2.1 Body monitoring market

Body monitoring devices are the devices used for tracking and monitoring fitness related metrics including calorie consumption, distance covered, heartbeat rate, sleep time, sweat rate, body temperature, brain activity etc. These devices are usually wirelessly synced with a smartphone or computer to achieve long term data tracking. Body monitoring devices are a part of Internet of Things and are embedded with software, sensors, electronics etc. to enable the connected objects to share and exchange data without requiring human intervention. Body monitoring devices are widely used in sports and medical sciences to monitor unforeseen situations and physiological symptoms and parameters.

The world body monitoring device market is currently at magnification due to increase in adoption of monitoring devices especially among the youngsters across the globe. Increasing per capita disposable income and spending power are some key factors fueling the growth of the market. Moreover, increase in advancements in technology, rising awareness for health and fitness among consumers and increasing demand for monitoring devices from sports clubs are some major factors driving the overall market. However, high costs and rising competition from local players are some key elements hampering the growth of the market.


7'30"

3.2.2 Forms of body monitoring device

Figure3.1 Applewatch

Current types of smart trackers are divided into three types: **wristbands**, **sports watch** and **others**. Wristbands are more focus on the functions of fitness track things, basic functions start from pedometer, time alarm, calorie counting, heart rate monitoring, sleep monitoring… Sports watch is a more capable device than wristband, more multifunctional, of course, relativity more expensive. Beside functions of wristband, sports watch also can reply phone calls, messages, GPS, and the display from monochrome to LED/LCD display. Others fitness tracker devices, compare to the first two devices, would be a more professional exist, they are very precise products for professional and high-trained users. For example, smart belt which is placed very close to user’s heart via a adjustable band, can more precisely, directly monitor user’s hear rate (wristband and sports watch

Figure3.2 Fitbit collection

use indirectly method to measure hear rate, so they are relatively not accurate). Smart suit, which uses EmG technology to monitor the precise muscle you are training for getting a better result.

Technically, wristband uses relative low technologies. Pedometer is basic element for pace counting. Calorie counting function, is an algorithm mainly based on the result of pedometer and some other concerning. Every company has its own specific algorithm for calorie counting, and usually are business secrets, so we don't know how the result comes from and there are differences between two products from different company for a totally same activity. Activity detecting and sleep monitoring are more or less based on algorithm and analysis of heart rate changes, then predict users's status. Study shows that, current wristband on the market have 20% or more error compared to a precise lab device. For sports watches, they have functions could connect with your smartphone, reading messages, knowing or receive phone call. They free your hands when you are doing sport without missing important calls. And both current wristband and sports watch, they have a APP or software to easily transfer datas and user could use for a long-time monitoring.

Figure3.3 Comparison of body monitoring devices. By Jin

	POSITION	COMFORT	PRECISION
	wrist	good	medium
	wrist	good	medium
	wrist	great	great
	wrist	great	great
	chest	good	great
	chest	bad	great
	whole body	good	great
	not wearable	great	good
	back head	medium	great

ANALYSIS METHOD	TECHNOLOGY	COMPONENT
monitoring pace	electromechanism	accelerometer
predicting expenditure based on pace counting	electromechanism	accelerometer
more accurate prediction based on various data monitoring	electromechanism/ photoplethysmography(PPG)	accelerometer/ gyroscope/ infrared and visible-light LEDs/GPS chip ...
monitoring convulsive seizures and alerting caregivers	electrodermal activity(EDA)	EDA sensor/ gyroscope/ accelerometer/ peripheral temperature sensor
heart rate monitoring	electrocardiogram(EKG)	electrodes
heart rate monitoring	electrocardiogram(EKG)	electrodes
muscle activities monitoring	electromyography	eletromechanical sensor
attached on device like skateboard, monitoring data	electromechanism	accelerometer/ gyroscope/GPS chip
monitoring brainwave for preventing consussion	electroencephalogram	electrodes

3.2.3 Functionality analysis

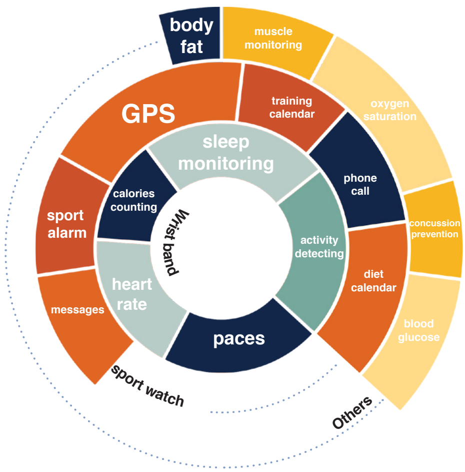
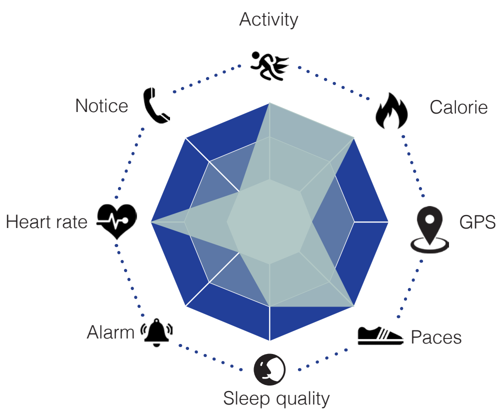


Figure3.4 Main functions for fitness tracker in the market. By Jin

Figure3.5 Most popular functions for fitness tracker. By Jin




POLAR

3.3 Diabetes mellitus

3.3.1 Diabetes nowadays

Diabetes or diabetes mellitus is a long-term metabolic pathological condition in which blood glucose level fluctuates outside the normal range (90–120 mg/dL). Glucose is the main source of energy in biological cells. [31]Insulin, a hormone secreted by the pancreas, helps in glucose absorption by cells, which in turn regulates the blood glucose level. [32,33]

According to a survey made by the International Diabetes Federation (IDF)[34], it was estimated that 8.3% of adults (382 million) were suffering from diabetes in 2013, which may rise to 592 million in 2030. It shows there will be 55% rise in people with diabetes in next 25 years. The number of diabetic people in various regions in 2013 by IDF survey is shown in figure 3.7. Poorly managed diabetes leads to serious complications such as cardiovascular diseases, damage of blood vessels, stroke, blindness, chronic kidney failure, nervous system diseases and even amputation of the foot due to ulceration in extreme cases. [35-38] Health spending on diabetes accounted for 10.8%

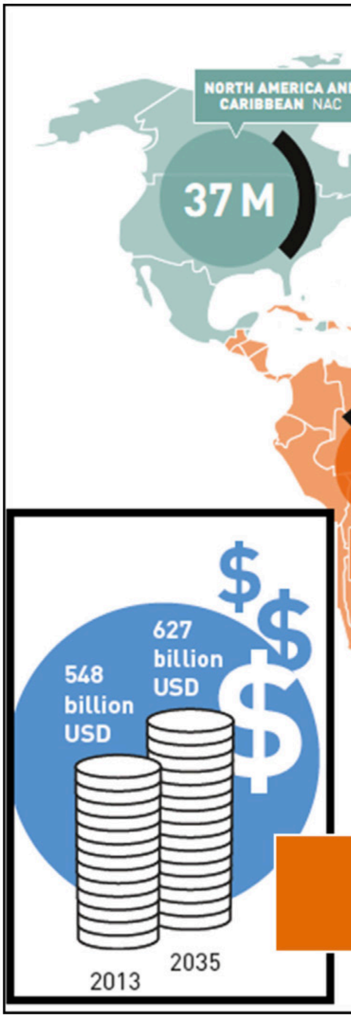
Figure3.6 Universal blue circle symbol for diabetes

world diabetes day

14 November

(548 billion USD) of total health expenditure worldwide in 2013. It is expected that expenditure on diabetes will be 627 billion USD in 2035. These escalating figures show that diabetes is a huge and growing global problem leading to an economic burden on the society. However, regular monitoring of blood glucose level plays a key role in reducing and preventing complications of diabetes.[39,40]

Figure. common equipments for diabetes



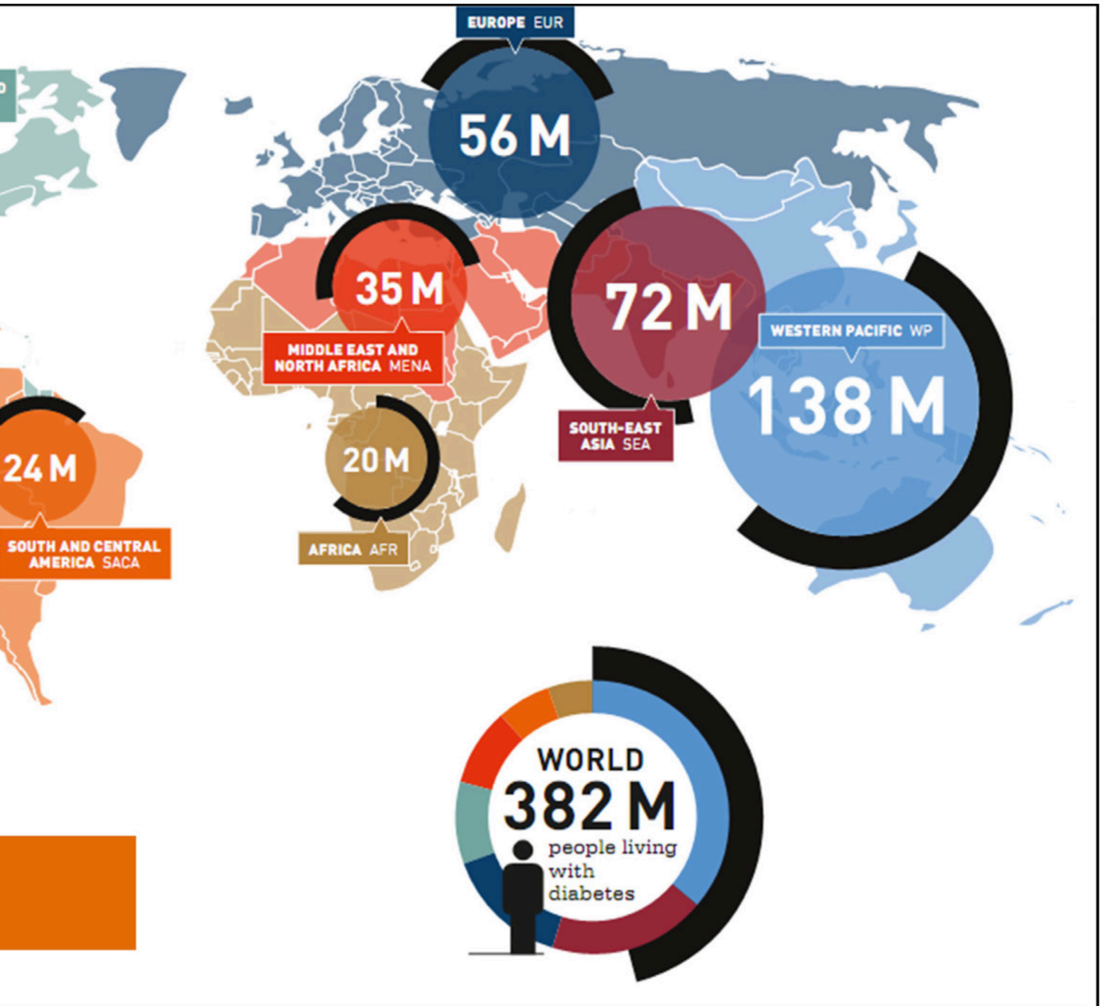


Figure3.7 Number of diabetic people in various regions in 2013

Source: IDF, Diabetes Atlas, sixth ed., International Diabetes Federation, 2013

3.3.2 Type 1 &type 2 diabetes

41. www.healthline.com , "What's the Difference Between Type 1 and Type 2 Diabetes?". August. 2017

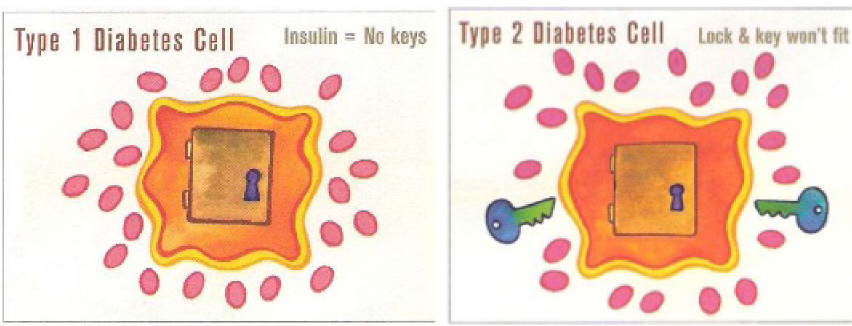
There are two main types of diabetes: type 1 and type 2. Both types of diabetes are chronic diseases that affect the way your body regulates blood sugar, or glucose. Glucose is the fuel that feeds your body's cells, but to enter your cells it needs a key. Insulin is that key.

People with type 1 diabetes don't produce insulin. You can think of it as not having a key.

People with type 2 diabetes don't respond to insulin as well as they should and later in the disease often don't make enough insulin. You can think of this as having a broken key.

Both types of diabetes can lead to chronically high blood sugar levels. That increases the risk of diabetes complications.[41]

Figure3.8 Type 1 vs. type 2 diabetes



No insulin (key) means that sugar cannot enter the cell.

Insulin (key) cannot unlock the cell door. Insulin resistance or inability of body to use insulin

3.3.3 Different methods for blood glucose monitoring

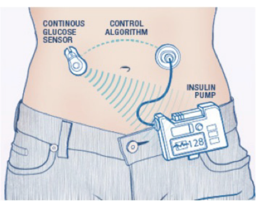
Invasive

Most widely used blood glucose devices are invasive which are painful to the patient, carry the risk of infection and also disturb the daily life of diabetic patient. Testing with conventional methods is made by piercing the finger or other areas of the skin and drawing a small amount (50 L) of blood. The blood is then applied on a testing strip where an estimation of glucose is produced by electrochemical, colorimetric or optical methods. Repeated drawing of blood is painful and creates a risk of infection. Further, one time enzyme based strips are costly, which limits the frequent testing.

Great effort is made by researchers to develop non-invasive or minimally invasive devices that can monitor blood glucose level continuously. A Continuous Glucose Monitoring (CGM) device enables to monitor the glucose trends and helps in efficient management of diabetes. It can provide the information every 5–10 min and can also give the alarms of any hyper or hypoglycemia event even at night. However, presently CGM devices are not as accurate as conventional glucose meters.

42. J. Yadav et al. Prospects and limitations of non-invasive blood glucose monitoring using near-infrared spectroscopy, on Biomedical Signal Processing and Control 18 (2015) 214–227

Minimally invasive



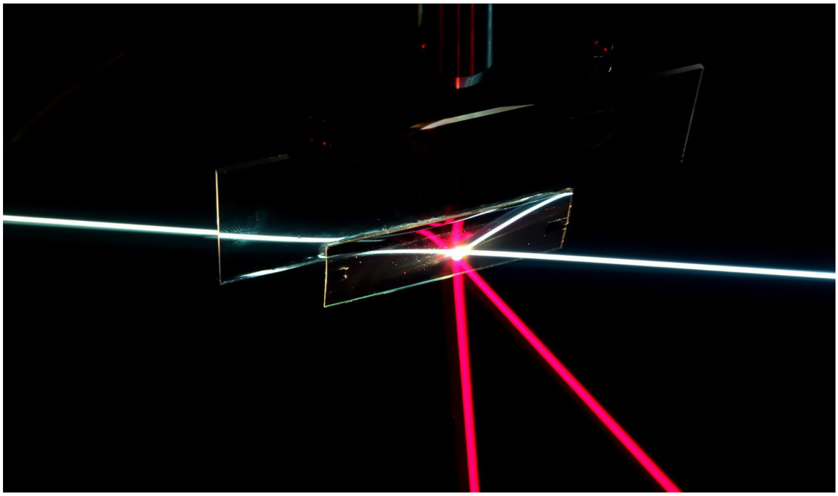
The minimally invasive monitoring is an alternative method in which skin injury is minimal. Human skin consists of several layers therefore different technologies need various transduction mechanisms to get sufficient blood samples for analysis. Several techniques have been proposed for minimal invasive measurements such as subcutaneous implantable biosensor, iontophoresis, sonophoresis and microdialysis which cause very less damage to the skin. Studies have shown that under the steady state condition, the glucose concentration in Interstitial Fluids (ISF) and intracellular is same as the glucose concentration in the blood.

In subcutaneous measurement the sensing part is implanted beneath the skin to sense glucose level in ISF. Interfacing of sensor with external control circuitry is carried out via radio frequency or optical means. These devices show unpredictable drift and glucose levels of ISF lag by several minutes to glucose values of blood. Therefore the frequent calibration is needed with a conventional blood glucose measurement. Further the lifetime of these devices is few days, after that they need replacement, which limits the widespread use of such devices. Thus, various researchers are working to develop innovative technologies for reliable non-invasive blood glucose measurement devices. Among them only a few are in advanced stages of development.

Non-invasive

Future trend. Non-invasive methods for glucose monitoring are more desirable and excellent alternatives to the above discussed technologies. This could make millions of people more relaxed and comfortable about regular blood glucose testing. Although a large number of research works have already been carried out in this area, the search of a successful non-invasive technique still continues. None of the non-invasive techniques, presently available, give the same accuracy as invasive methods. Besides blood glucose testing, non-invasive glucose testing has been tried on biofluids such as saliva, urine, sweat or tears. Continuous monitoring of glucose is not possible using these biofluids. It can be carried out by measurement through tissue sites such as tongue, oral mucosa, lip, tympanic membrane and skin. Measurement through the oral mucosa and lip shows good correlation, but the pressure applied by the device disturbs the glucose specific peaks. Moreover residual food in the mouth also causes interferences while having measurement using any oral site.

Non-invasive glucose measurement through the skin has been studied at various sites, i.e. finger, palm, forearm, ear lobe, cheek and arm. The lag between blood and alternative sites, glucose levels can contribute significantly to minimize error in current and predicted blood glucose monitoring. It is suggested that arm-to-alternative site blood glucose differences may be minimized by rubbing the test site before blood collection.



Sometimes small delay can cause complications, while blood glucose is dropping fast. There is a high density of the capillary network in finger, no time lag and hair free site; therefore it is most convenient site for measurement. Other factors, such as subject age, BMI, diabetes type, and insulin dependence did not have a significant impact on site differences. Several non-invasive technologies using Raman spectroscopy, polarimetry, optical coherence tomography, photoacoustic spectroscopy, impedance spectroscopy, thermal emission spectroscopy, NIRS and mid infrared spectroscopy have been reported for blood glucose monitoring. Among all these techniques NIRS has shown its potential for measurement of blood glucose non-invasively.

3.3.4 Blood glucose device research

42. J. Yadav et al. Prospects and limitations of non-invasive blood glucose monitoring using near-infrared spectroscopy, on Biomedical Signal Processing and Control 18 (2015) 214–227

Glucose monitoring methods are classified into three categories: invasive, minimally invasive and non-invasive depending upon transduction mechanism used. Table shows the summary of various glucose monitoring methods.[42]

Table3.9 Various glucose monitoring methods

	Method	Type of method	Sample/continous
1	Invasive method	Finger stick	Sample
2	Minimal invasive	Subcutaneous implanted biosensors Iontophoresis, microdialysis, sonophoresis	Continous Continous
3	Non-invasive	Sweat, saliva, tears, urine Raman spectroscopy, optical coherence tomography, polarimetry, photoacoustic, ultrasound, bio-impedance spectroscopy, mid-infrared spectroscopy, near-infrared spectroscopy	Sample Continous

Source: J. Yadav et al. / Biomedical Signal Processing and Control 18 (2015) 214–227

Table3.10 Different BGM devices research. By Jin

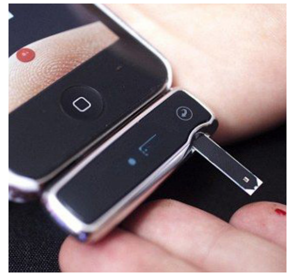
①

Invasive

Testing with conventional methods is made by piercing the finger or other areas of the skin and drawing a small amount of blood.

Blood glucose meter by Accu-Chek

A conventional blood glucose measurement device, test blood by piercing fingers or other skin.



iBGStar blood glucose meter by Sanofi

Using a attachable device on cellphone, can test glucose level on APP.

②

Minimally invasive

Monitoring the glucose concentration in Interstitial Fluids (ISF) and intracellular cause which has the same glucose concentration as that in the blood.

Dexcom G5 Mobile CGM System by Dexcom

A small Sensor that measures glucose levels underneath the skin. Sending data

automatically wirelessly to your compatible smart device or your receiver. Using app to view your glucose trends.

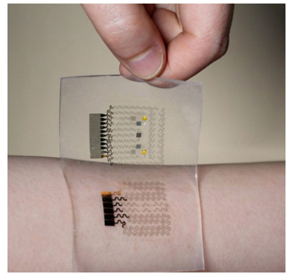
3

Non-invasive

There are various methods for non-invasive blood glucose monitoring: through biofluids(sweat, tear…), tissue sites(tongue, lips…), skin and other site (arm, palm…)

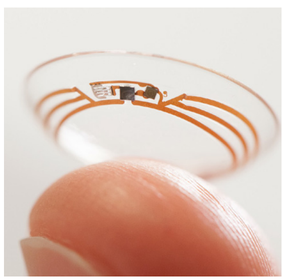
GlucoTrack by Integrity Applications

Combination of 3 technologies (ultrasonic, electromagnetic, thermal) with priority of algorithm. Using a ear clip, which is clipped to the earlobe and contains sensors and calibration electronics, user can read their computed glucose level on the display.



Monitoring patch by Seoul National University.

This see-through patch made of graphene and studded with gold, has sensors that can detect your temperature and the pH/ chemical composition of your sweat.



Smart contact lens by Google

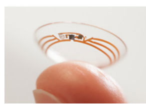
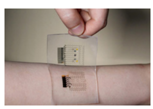
(in development) .

Monitoring blood glucose level by analyzing glucose in tears.

Combo Glucometer by Cnoga

Using optical technology and unique algorithms to know blood glucose levels

Figure3.11 Comparison of different glucose monitoring devices. By Jin

		POSITION	COMFORT
		finger	pain
1		finger	pain
2		skin	medium
3		eye	no pain
		earlobe	no pain
		skin	no pain
		finger	no pain

PRECISION	ANALYSIS METHOD
great	mesuring blood sample
great	mesuring blood sample
good	consitnuosly monitoring blood glucose through inserted sensor
bad	consitnuosly monitoring through analyzing tear
medium	meauring through analyzing blood in earlobe
medium	detecting your temperature and the pH/ chemical composition of your sweat
good	meauring through analyzing blood in finger

3.4 Integrated study of monitoring devivce position

Learned from different monitoring needs and different methods to achieve the goal. I got understanding about which condition is perfect for a certain technology.
Some needed conditions are extremely harsh, so that the devices are forced to place on a certain position.
From previous study, after analyzing main and required functions of fitness tracker. Some functions could be organized in the same requirement, cause they use the same hardware, but through different analysis algorithm.
For example, heart-rate monitoring and activity detecting, the latter could through algorithm and analysis from heart-rate result to get predicting activity. Sleep monitoring in some sense could do as the same. Some devices in the market just use accelerometer, (the one for pedometer, paces), to predict sleep mode.
Different positions may use different methods or have different tissue or blood vessel, so the accuracy of results could exist some errors.

Heart-rate monitoring technologies: blood oxygen method, Optical-based (photoplethysmography, PPG), Electrical (electrocardiography, ECG), and pulse. Blood oxygen method uses the theory, heart-rate and oxygen level have same cycle. Usually be measured through optical methods and monitoring on thin body parts like fingers. ECG directly uses electrical signals produced by heart

activity, it is the most accurate one, be measured close to heart. PPG is an optical methods, uses electrical signals derived from changes in reflected light due to changes in blood flow during heart activity. Due to the need of light penetration, thin body parts also the better choice. Pulse is a mechanical method which needs stay tightly to wrist, it’s not ideal solution for a continuous monitoring.

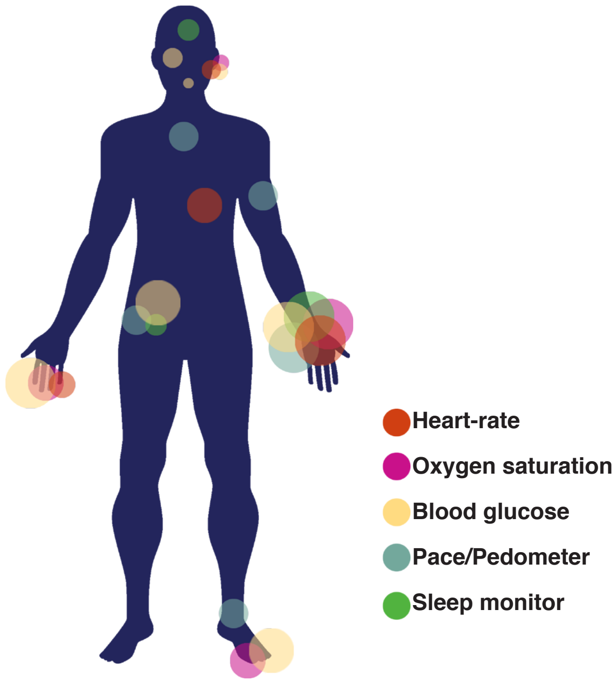
Oxygen saturation, uses the same technologies like pulse oximetry. It is optical method, so needs thin body parts, fingers and earlobe are common choices.

Blood glucose monitoring, previously we have analyzed, it has traditional methods, invasive and minimal-invasive, and future conceptual method non-invasive. Blood sample or biofluids sample are needed, and could be measure in anywhere (eg. blood, sweat..) or specific areas (tears, saliva, urine..). Common method is placing device for continuous monitoring on a non active skin, such as abdomen..

Pace counting, the same technology like pedometer, uses accelerometer inside. It needs to be positioned on a place which could easily sense the move or wave of body. Waist, above hips or arm are common places.

Sleep monitoring, some devices use the technology accelerometer, so the positions just like the previous one to sense the body's movement and relaxation. There are also more accurate technology, electroencephalogram EEG, and directly monitor the brain wave, which generates α wave when people's relaxing.

Figure3.12. Possible positions for fitness track functions.By Jin



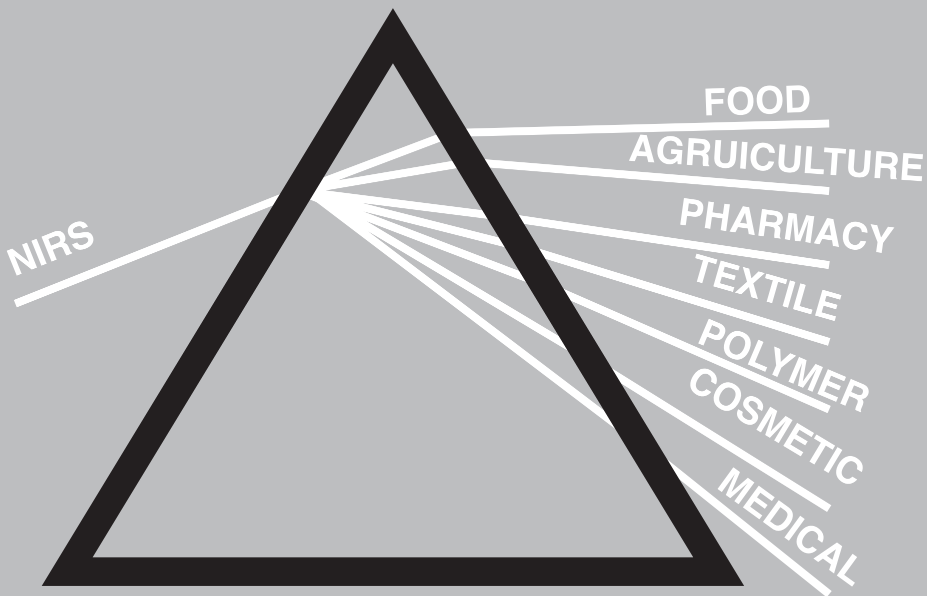


Figure3.13 NIRS, potential fields

3.5 Near-infrared spectroscopy

Visible light could be dispersed according to its wavelength, after passing through a prism. Then would become a series colorful bars which we call it, Spectrum. (common example around us: rainbow).

Spectroscopy is a study of the interaction between matter and electromagnetic radiation(light is an electromagnetic radiation). When a white light emitted to matter, it will be selectively absorbed or reflected some certain light. That's why we can identify its unique color on a matter.

43. Wikipedia. "Spectroscopy." retrieved by September. 2017

44. Wikipedia. "Near-infrared spectroscopy". retrieved by September. 2017

Near-infrared spectroscopy (NIRS) is a spectroscopic method that uses the near-infrared region of the electromagnetic spectrum (from about 700 nm to 2500 nm).

Typical applications include medical and physiological diagnostics and research including blood sugar, pulse oximetry, functional neuroimaging, sports medicine, elite sports training, ergonomics, rehabilitation, neonatal research, brain computer interface, urology (bladder contraction), and neurology (neurovascular coupling). There are also applications in other areas as well such as pharmaceutical, food and agrochemical quality control, atmospheric chemistry, combustion research and astronomy.

3.5.1 NIRS X Nutrition identification

45. Burns, Donald et al. Handbook of Near-Infrared Analysis, Third Edition (Practical Spectroscopy). pp. 349–369. 2007

Near-infrared spectroscopy is widely applied in agriculture for determining the quality of forages, grains, and grain products, oilseeds, coffee, tea, spices, fruits, vegetables, sugarcane, beverages, fats, and oils, dairy products, eggs, meat, and other agricultural products. It is widely used to quantify the composition of agricultural products because it meets the criteria of being accurate, reliable, rapid, non-destructive, and inexpensive.

In the future, with more data for comparison, NIRS will can even analyze prepared food, processed food…

3.5.2 NIRS X Blood glucose monitoring

With the rapid progress of optical technology in the last few decades, NIRS has become a more powerful tool for clinical applications and scientific research. With the recent advancement
in microelectronics, NIRS has become popular for monitoring many physiological parameters because it can provide a simple, economical, safe and convenient on-line monitoring. Since no specific reagents are required for measurement, the repetitive analysis is thus possible at low cost. NIR radiation can pass through different skin layers to subcutaneous space. The technique is successfully applied in non-invasive measurement of oxygenated and deoxygenated hemoglobin.

42. Jyoti Yadav et al. Prospects and limitations of non-invasive blood glucose monitoring using near-infrared spectroscopy. 2015

It is a spectroscopic method which uses radiation in the NIR region of the electromagnetic spectrum (750–2500 nm). There are mainly three bands in NIR range i.e. combination overtone band (2000–2500nm), first overtone

band (1400–2000nm) and second or higher overtone band (750–1400 nm). It allows the glucose measurement under the skin to a depth of few mm in range. The penetration of light into the skin decreases with the increase in wavelength. As the light interacts with tissue, it is partially absorbed and scattered due to interaction with chromophores within the tissue. The combination and first overtone regions are dominated by glucose absorption information while shorter wavelength region mainly carries scattering information. [1]

Figure3.14 Aspects of near-infrared spectroscopy in BGM

KEY WORDS	MERITS
Continuous **Non invasive**	1. Skin penetration up to 1–100 mm 2. The sensitivity of the NIR photoconductive detectors are high 3. High energy signals as compared with MIR spectroscopy 4. Low cost and wide variety of commercial products are available
DRAWBACKS	**MEASUREMENT SITE**
1. Physical parameters (variation in pressure, temperature, and chemical parameters, triglyceride and albumin) interfere in glucose measurement 2. Environmental variations such as changes in temperature, humidity, skin hydration, carbon dioxide, and atmospheric pressure also interfere with measurement	Tongue, oral mucosa, lip, ear lobe, finger, forearm, cheek

Source: J. Yadav et al. / Biomedical Signal Processing and Control 18 (2015) 214–227

BODY TRACK
NIRS
FOOD IDENTIFICATION

3.6 Case study

SCIO

A pocket-sized micro spectrometer, using Near-Infrared(NIR) Spectroscopy technology, helps people analyze components of things and get more invisible information. Its success is be managed to

Figure3.15 Scio, food analyzer

minimize the spectrometer, make it portable and pocketable. Its powerful database is another key part of their product.

Structure sensor

Structure Sensor is a attached device for smart device, which using 3D scanning technology can create digital model directly through scanning real object. It's a depth sensor using an invisible laser projective infrared blast and

Figure3.16 Structure Sensor

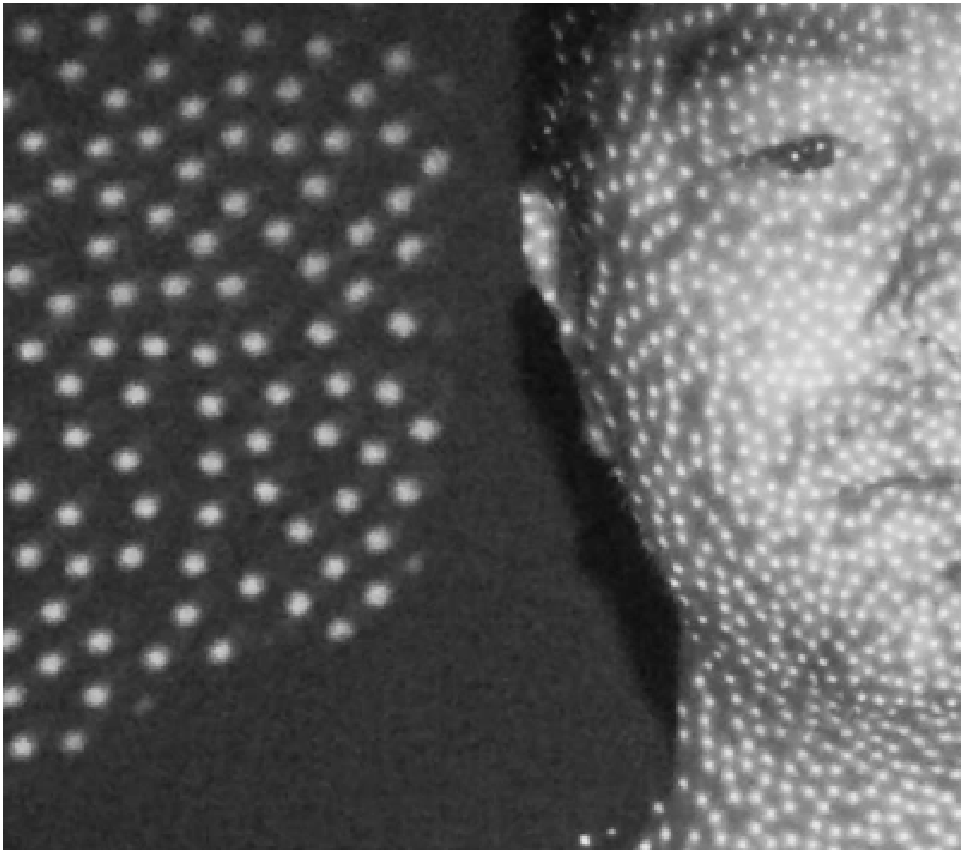
infrared camera to capture and then in conjunction with the smart device's accelerometer gyroscope and compass it can map out a relatively accurate depth map that can be put together into a point cloud and finally modeled.

Habit

Habit aims to create personalized diet. After drinking a special beverage, testing and monitoring blood glucose level, Habit will know which nutrition benefits user most, and will then give user personalized food recipe advices.

Figure3.17 Habit, personalized diet

OUR TESTING PROCESS



Face ID
on Iphone X

Face ID application on iPhone X is an amazing method for unlocking the phone, and could use it also for payment! This application works so well, thanks to the technology of 3d scanning, using infrared dot projector projects 30,000 invisible infrared

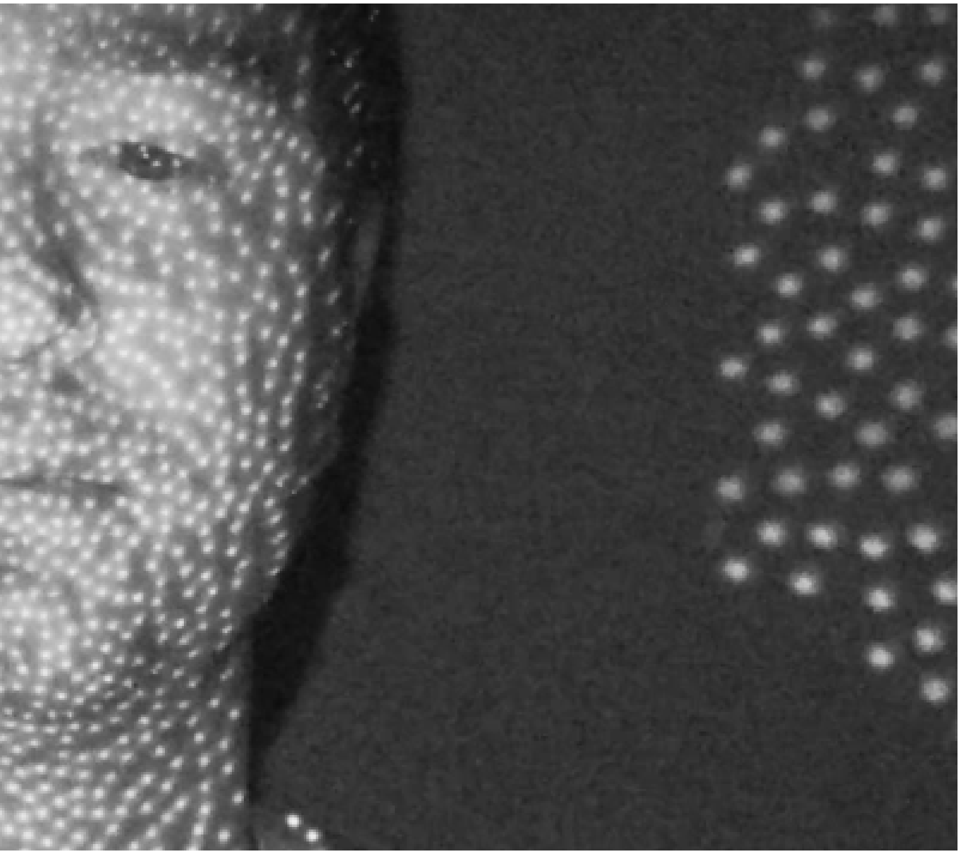


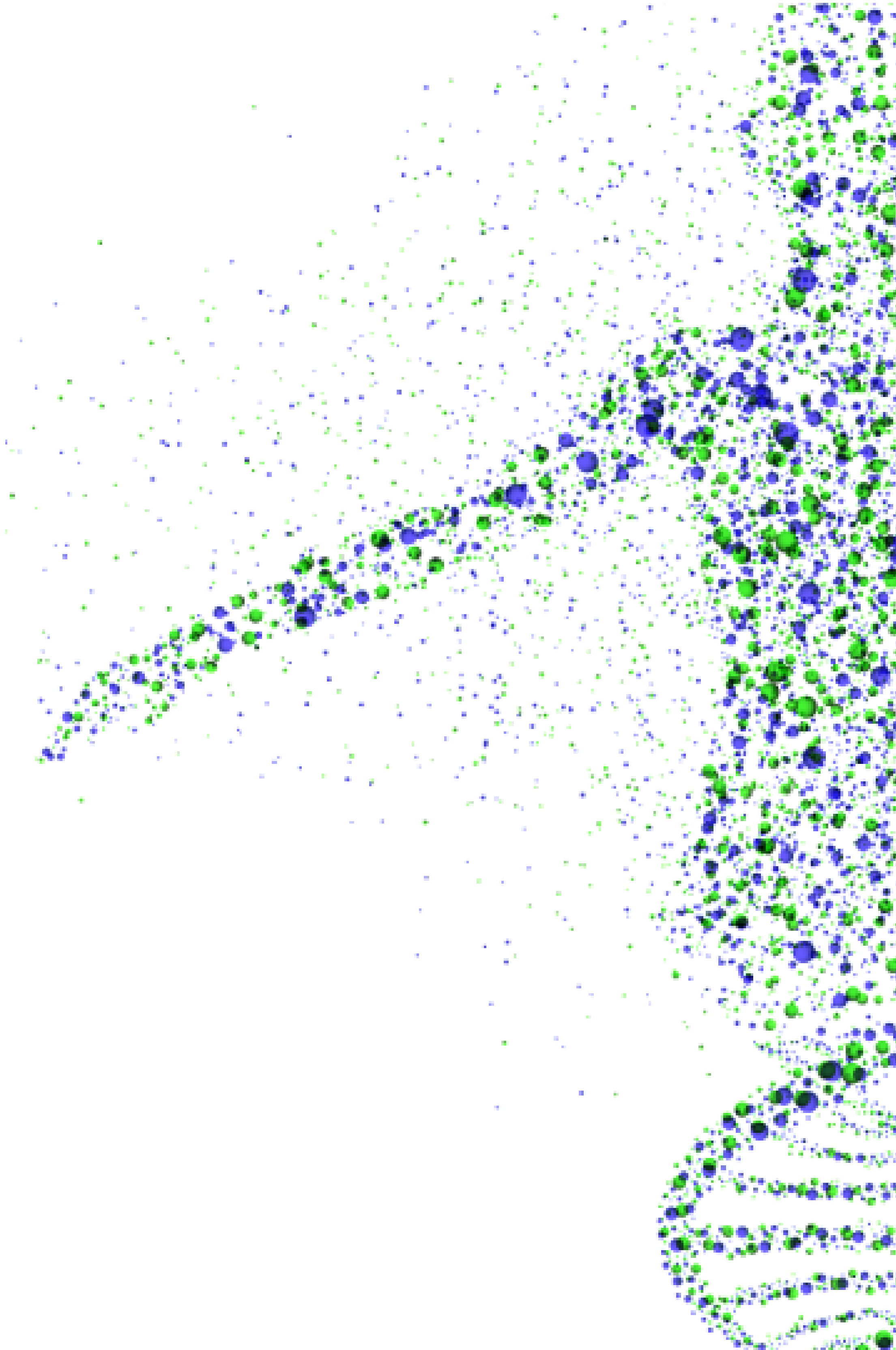
Figure3.18 Face ID, reading face through infrared dot projector

dots on face, and capture the point cloud of dots, creating users face in device.

PART 4
Project

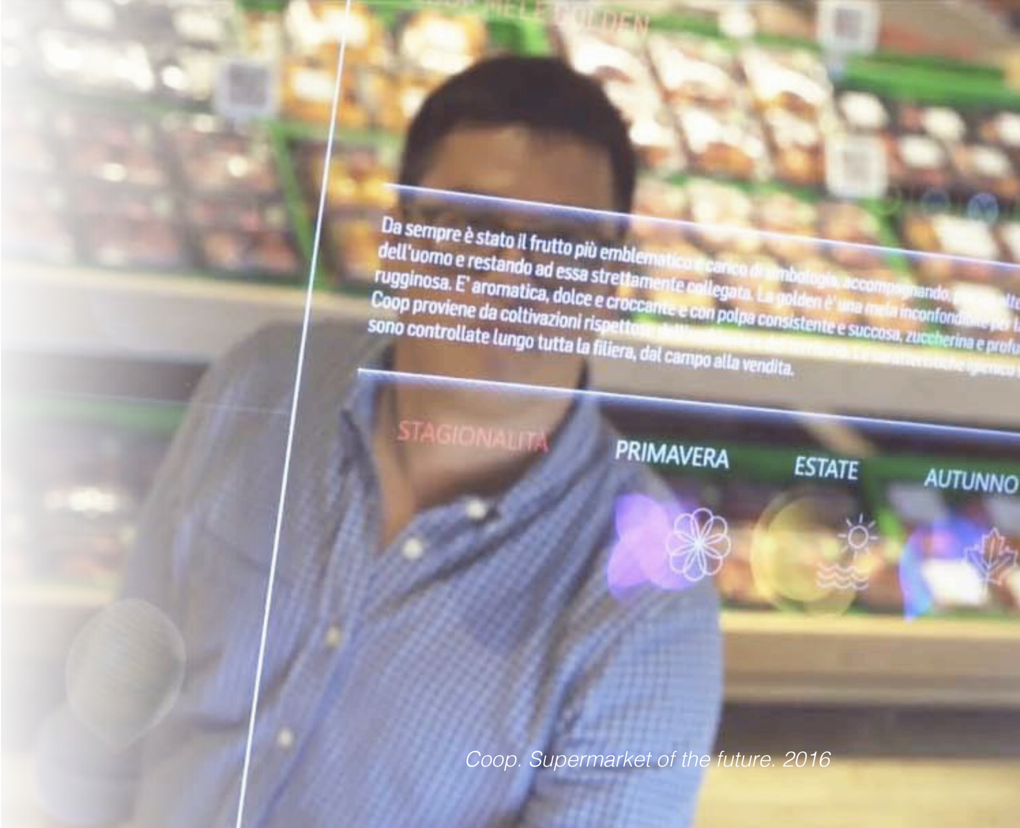
NUTRITION IS FUTURE

how food benefits our body



WE KEEP TRYING TO KNOW

Still need more



Coop. Supermarket of the future. 2016

Milan Expo. Future food district. 2015

4.1 Foreword

The core question is: **how food effects human's body?** To develop this, I did research about both food and body science, and try to connect them...

4.2 Integrated thinking

4.2.1 Peraonas analysis

BILL

Age: 25
Gender: Male
Profession: College student
Key words: Overweight

ANNA

Age: 21
Gender: Female
Profession: College student
Key words: Type 1 diabetes

-Easy way to know food quality

-Remind and easy to check food storage

-Recipe advisor &imformation for exploring new food

-Know how much food should prepare

BILL

-Easy to know glucose trend

-A painless way to test blood

-Food advisor: identify foods to avoid or limit

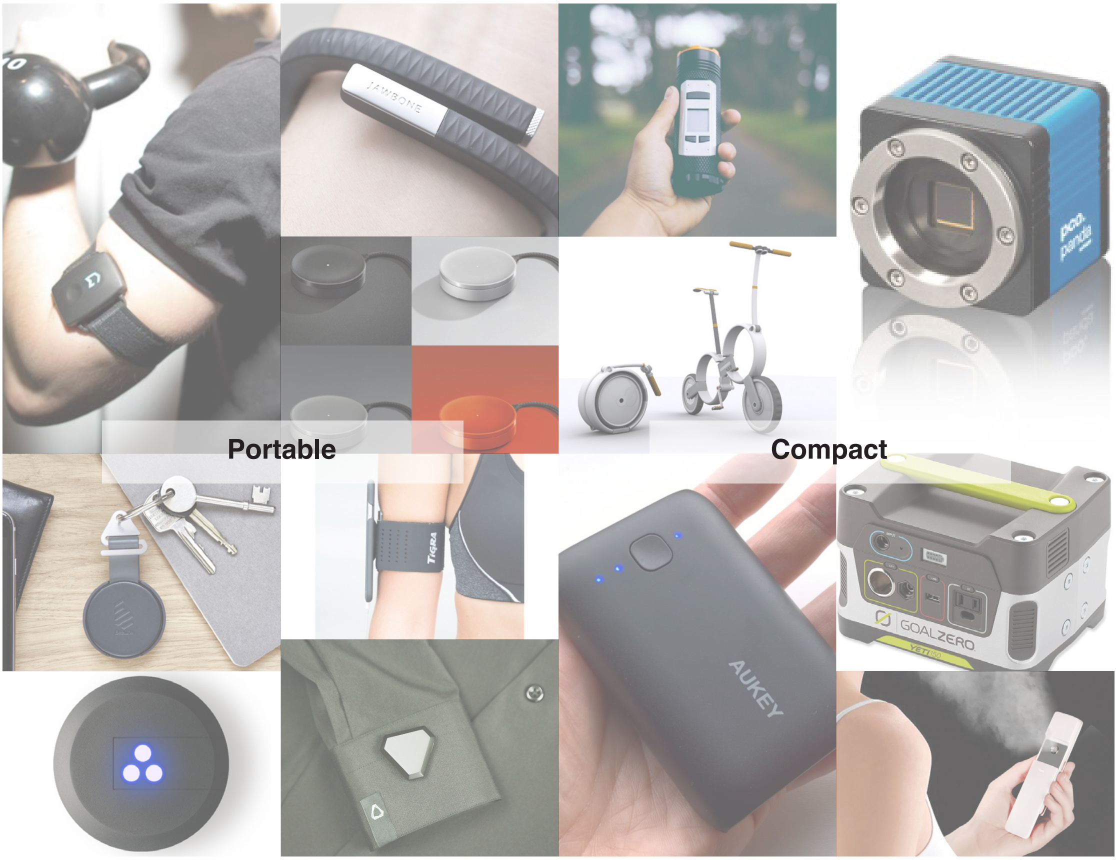
ANNA

4.2.2 Design target

Simplify nutrition	Record food	Track body	Food advisor
"Energylize" food nutritions in a easy-understand way	Visible food intake and in storage	Track and know users body energy requirement	Advice for a certain food based on its nutrition

4.2.3 Form thinking

Portable	**Compact**	**Clear**	**Dividable**
for tracking body movement.	small and easy to use	clear and easy-understand interface	for 24h monitoring / use of scanning

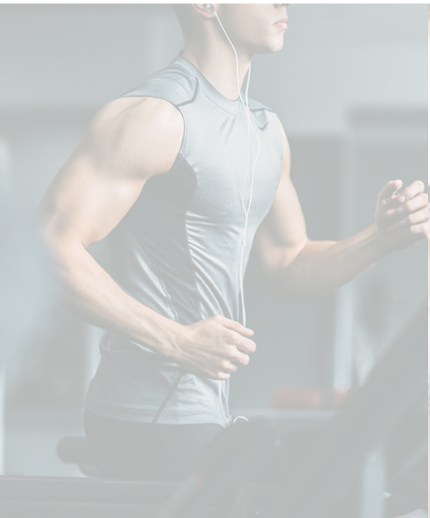

Portable
Compact
JAWBONE
pco.
panda
TIGRA
AUKEY
GOALZERO

Clear

Dividable

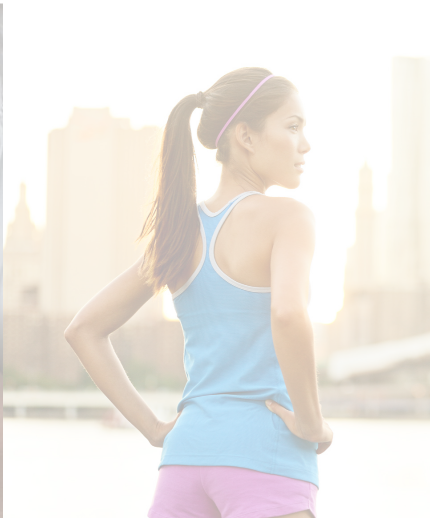


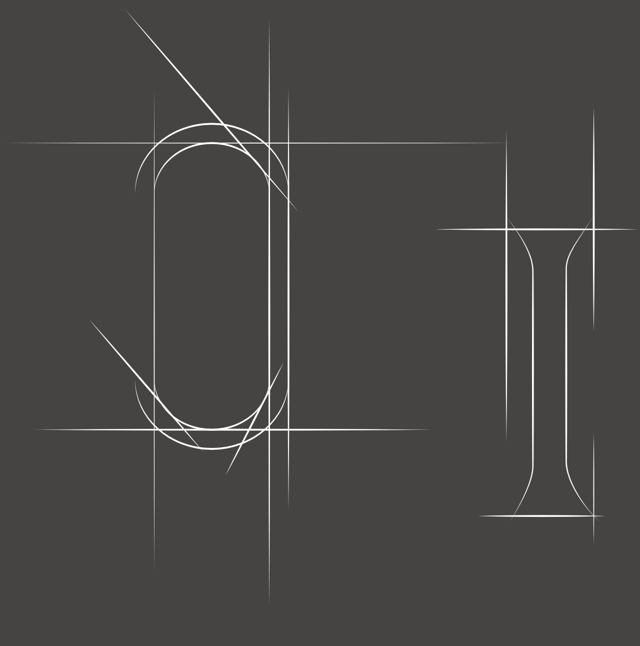
CONNECTION





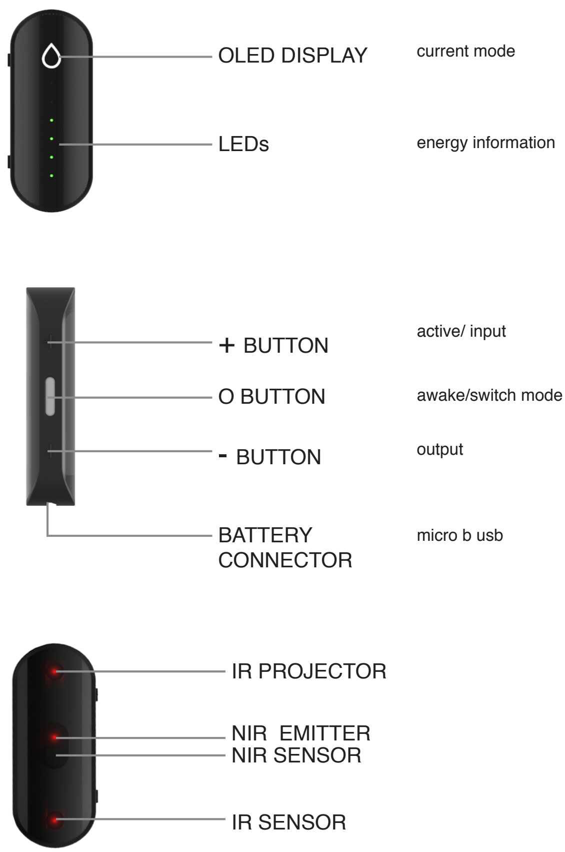
between food and body

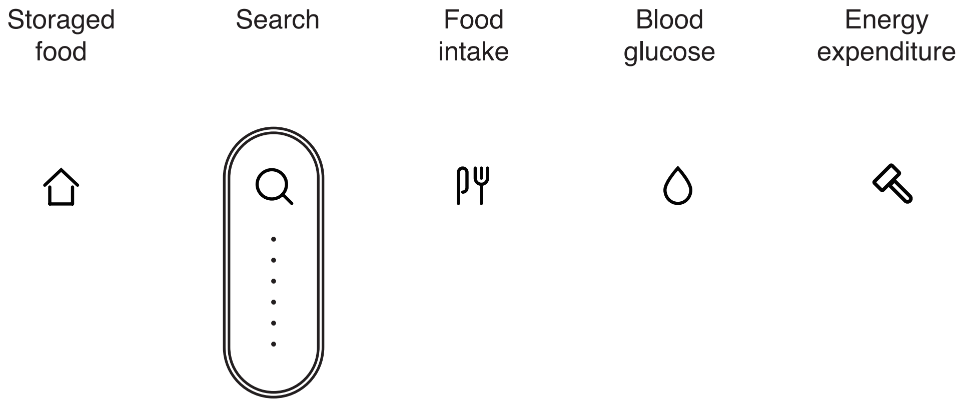
For

4.3 Efor 1.0


OLED DISPLAY
current mode
LEDs
energy information
+ BUTTON
active/ input
O BUTTON
awake/switch mode
- BUTTON
output
BATTERY CONNECTOR
micro b usb
IR PROJECTOR
NIR EMITTER
NIR SENSOR
IR SENSOR

4.3.1 MODE 1.0

Efor 1.0 has four functions: search, storage food, food intake and blood glucose monitoring. Thanks to NIRS, 3D scanning, related body track technologies and nutrition science, they make Efor a possible media between food and body, and for exploring a better relation.


Storaged food
Search
Food intake
Blood glucose
Energy expenditure

#BODYTRACK


3:20 h:min
3380 paces
420 kcal
110 mg/dL

4.3.2 Body track

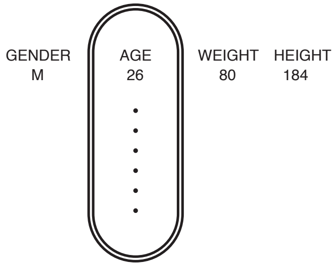
The function of body track will be realized automatically through related technologies and with a little pre-manipulation:

Data will be detected whenever you are:
sitting, walking, sleeping, working, sporting…

The result, energy expenditure, could be read in mode “energy expenditure” and will be used as the reference of “food scanning” functions.

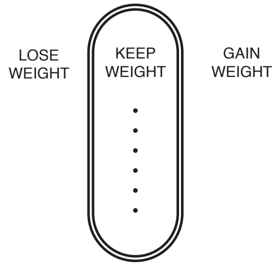
STEP 1 Insert your information

Information for estimate your BMR[1]



STEP 2 Choose health mode

Choose personal preference to give your food advice later



STEP 3 Take Efor with you!

Thanks to equipted inertial module, easy to estimate your PAL[2]

1.BMR: basal metabolism rate; 2.PAL: physical activity level

#FOOD SCANNING

ADVICE

RECORD

STORAGE


Instacart

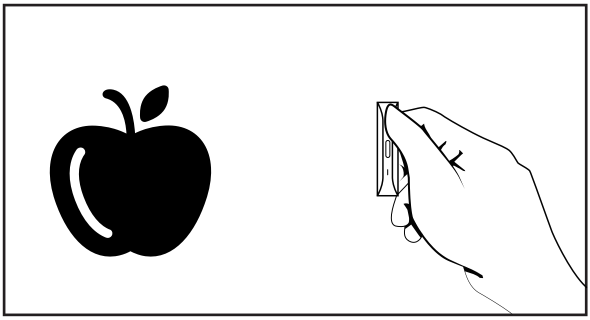
4.3.3 Food scanning

The advices are based on the result of calculation of your personal energy requirement, more precisly is the demands for **protein**, **carbohydrate** and **fat** from food.

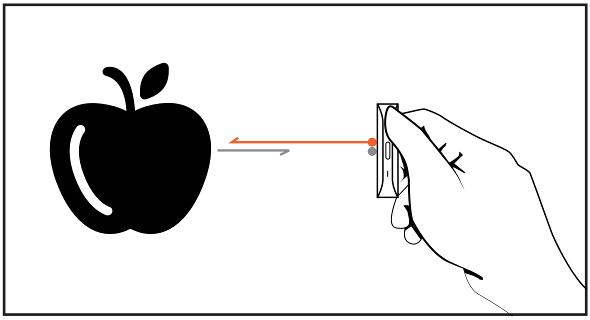
Using those data, could realize functions as in the right:

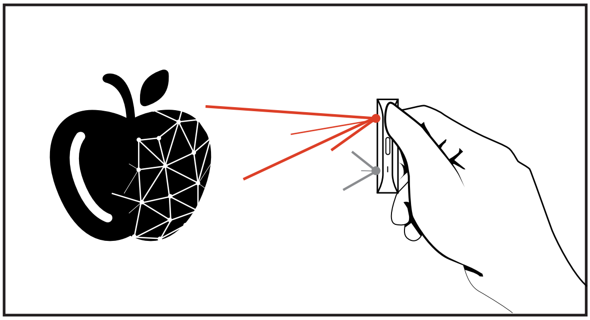
Search	**Advisor**	Green refers both right; yellow refers paying attention on food quantity or food type; red refers more serious than yellow.
Food intake	**Diet manager**	Full six LEDs are bright refers you intaked enough food for today.
Storaged food	**Storaged Food remender**	User can choose the max capacity of stored food, for ex. User chosed "3 days" as the maximun quantity, then each 2 LEDs refers food quantity for you per day.

STEP 1 Select mode, and aim at food.



STEP 2 Press +/- button and scan.





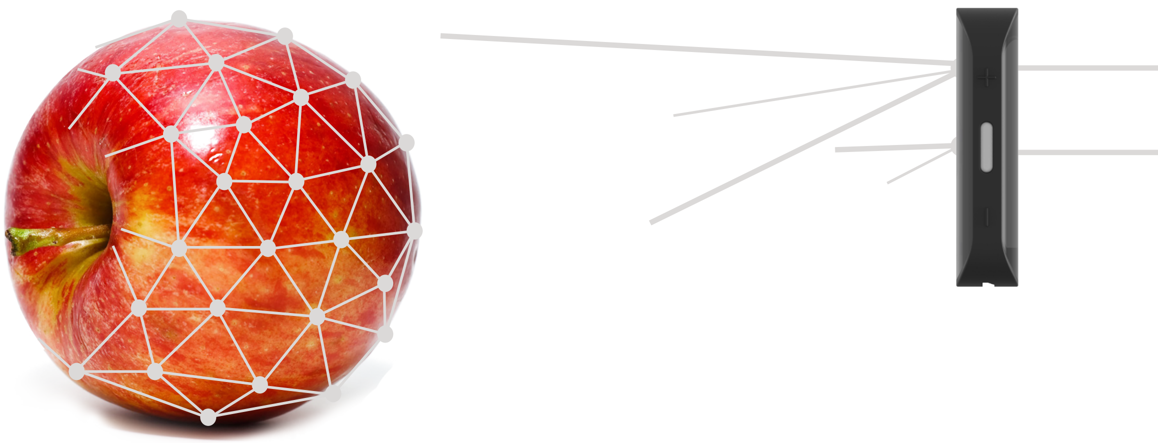
STEP 3 Read LED indicators in different mode.

	Search	**Storaged food**	**Food intake**
	**bad** choice: eat carefully or avoid eat	**full** or **nearly**	**enough** intake or nearly
	general choice: eat carefully	**enough** food	**media** intake
	**ideal** choice	**less** food	**less** intake

*detail information could be read through APP on smart device

#SCANNING PROCESS

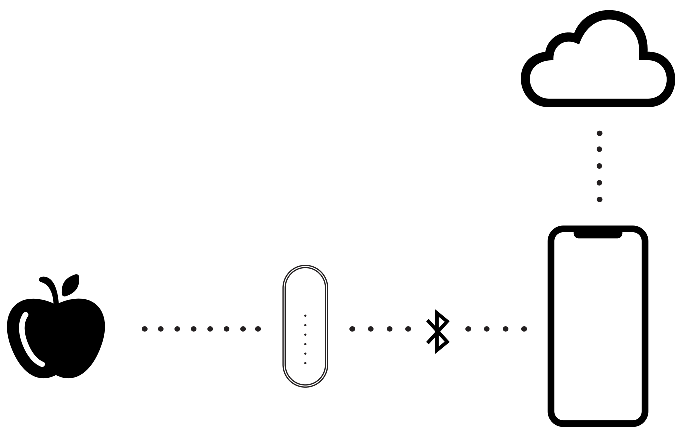
REAL OBJECT



DIGITAL DATA

4.3.4 Food database

Thanks to the **NIRS technology**, people using Efor scan food, the device will create a unique spectroscopy of the item, then the data will be sent online to compare in **database**. The result then will be sent back, with the whole detail of food components: percentages of protein, fat, carbohydrates, sodium..



4.3.5 Food scale

Thanks to the NIRS technology, the food scale is based on the capacity of food sample database. Nowadays, NIRS is commonly used to determine simple food in figure.

With the **expansion** of the food type database, it could also be used to determine the quality of processed food or cooked food.

Database expansion

It is equipped with a **microphone**, users can record unknown food by scanning and voice operations to expand the database

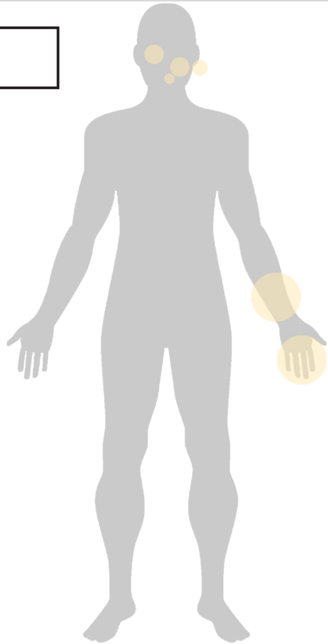

Dairy
Fruits
Beverage
Meat
Vegetables
Grain
Spice
Currently
Eggs
Dolce
Future
Fast food
Ice cream
Street food
Restaurant
Prepared food

#BLOOD GLUCOSE MONITORING


#

-BAND

4.3.6 C-band



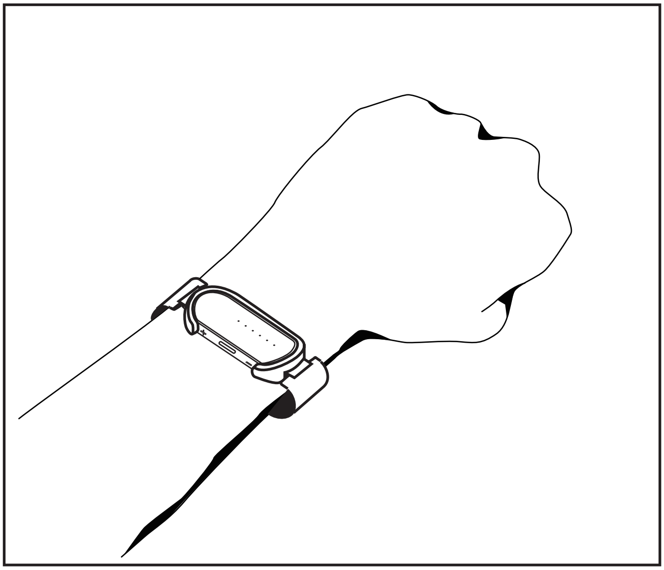
Design for:

- Positon idea place for body monitoring
- Solution for continuous monitoring
- Potability
- Comfortability
- Facility

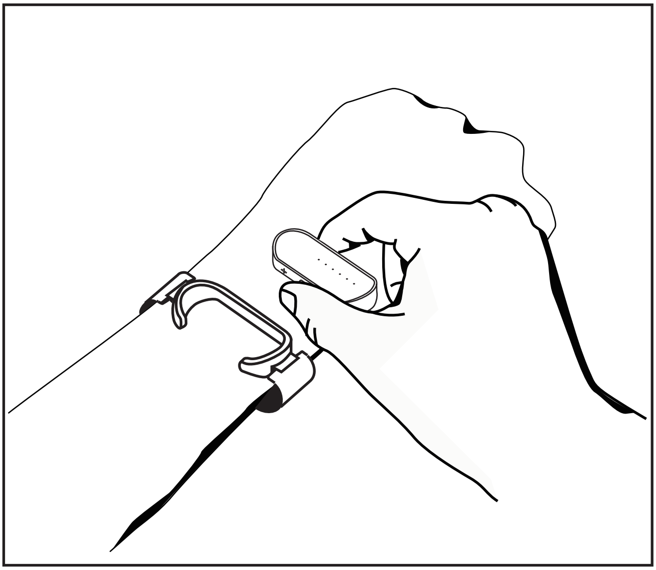
The ideal measurement site of NIRS for monitoring glucose are: Tongue, oral mucosa, lip, ear lobe, finger, forearm, cheek[42]

42. Jyoti Yadav et al. Prospects and limitations of non-invasive blood glucose monitoring using near-infrared spectroscopy. 2015

Use of c-band



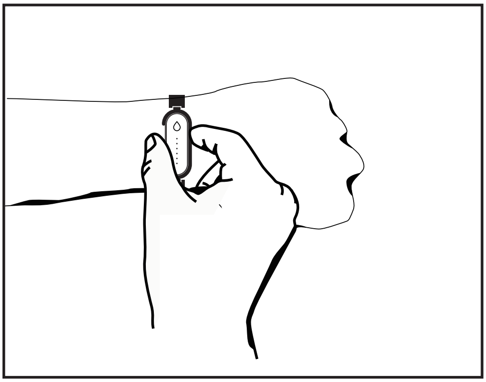
fit



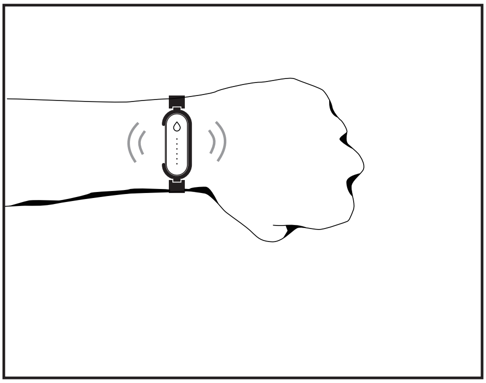
take-off

4.3.7 Blood glucose monitoring

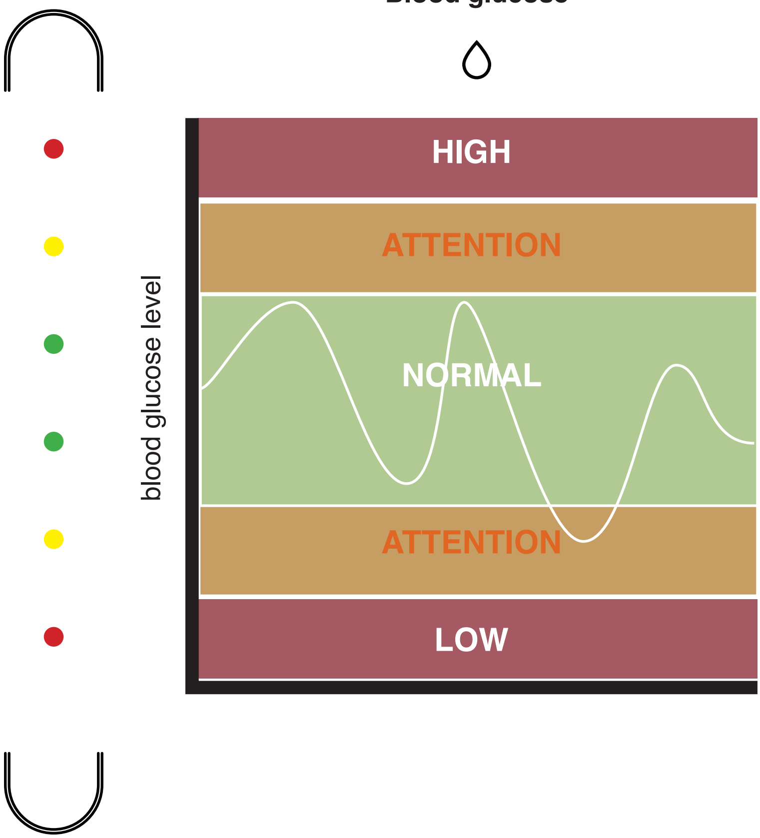
STEP 1 Press O button to select mode, and press + button to activate



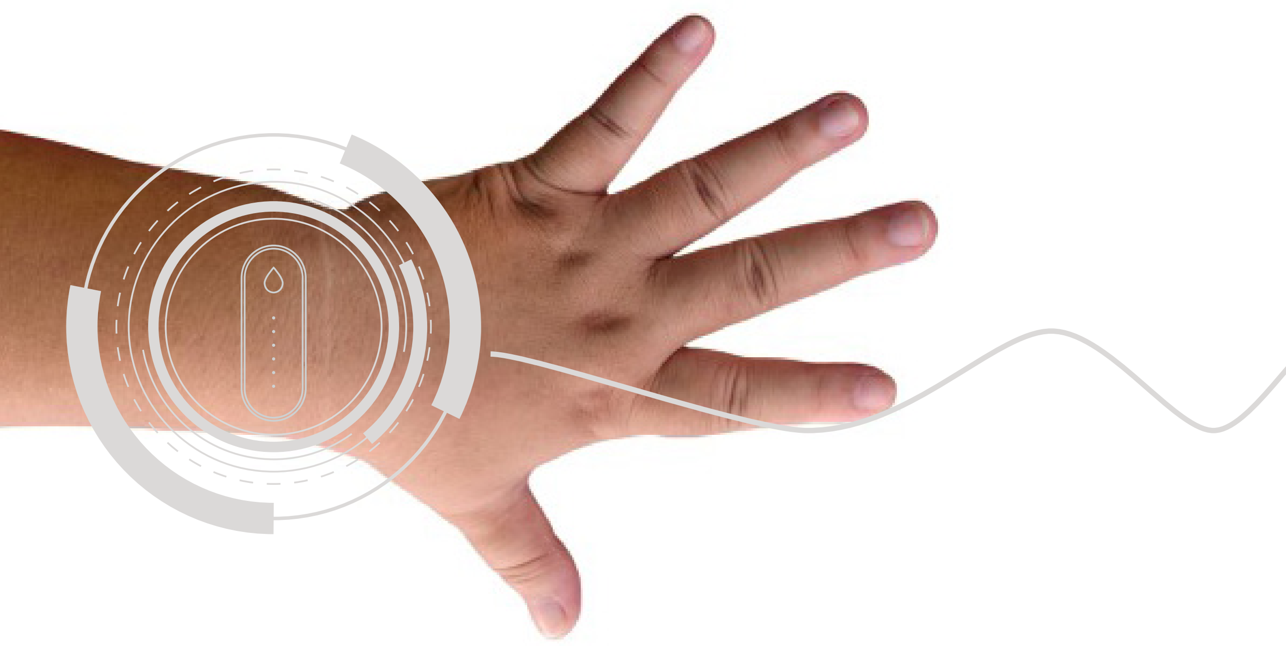
STEP 2 Read LED indicators

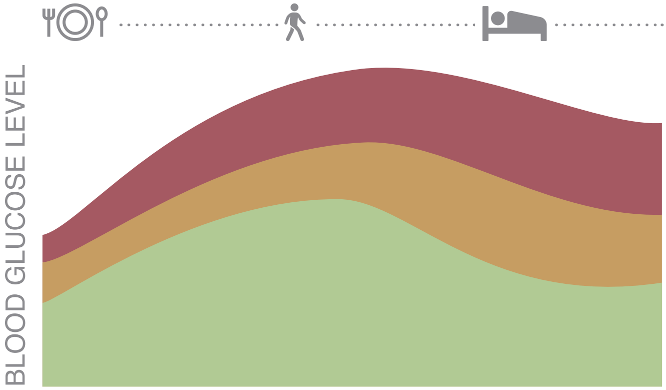


Blood glucose



#BGM PROCESS

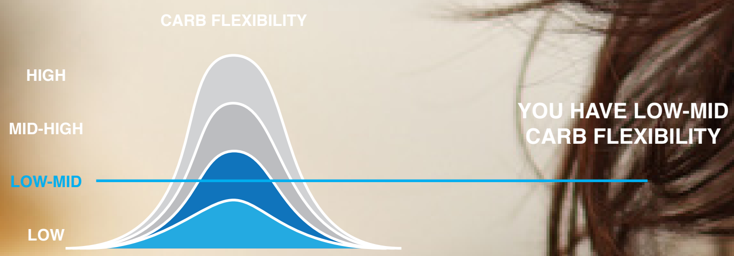



BLOOD GLUCOSE LEVEL

4.3.8 Personalized nutrition

Find it, feed you!

We are individuals, our bodies craves different nutrition ratio. Efor knows your **unique** through monitoring the process that different types food effect your blood glucose level.

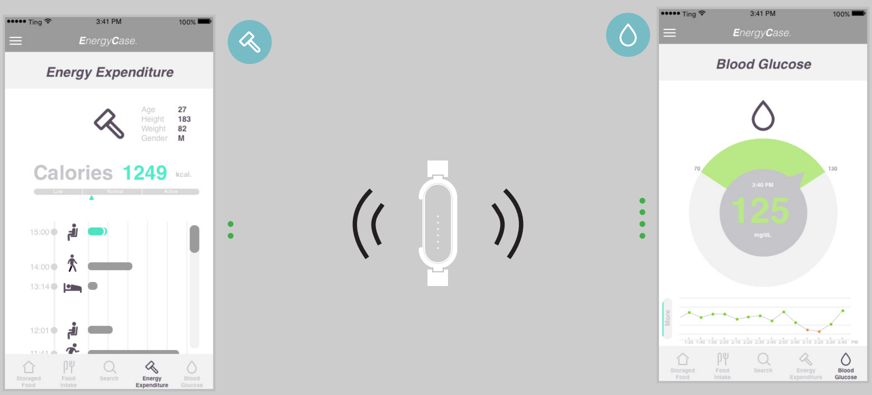


THE IDEAL RATIO OF PROTEINS, CARBS AND FATS

JUST
RIGHT FOR YOU

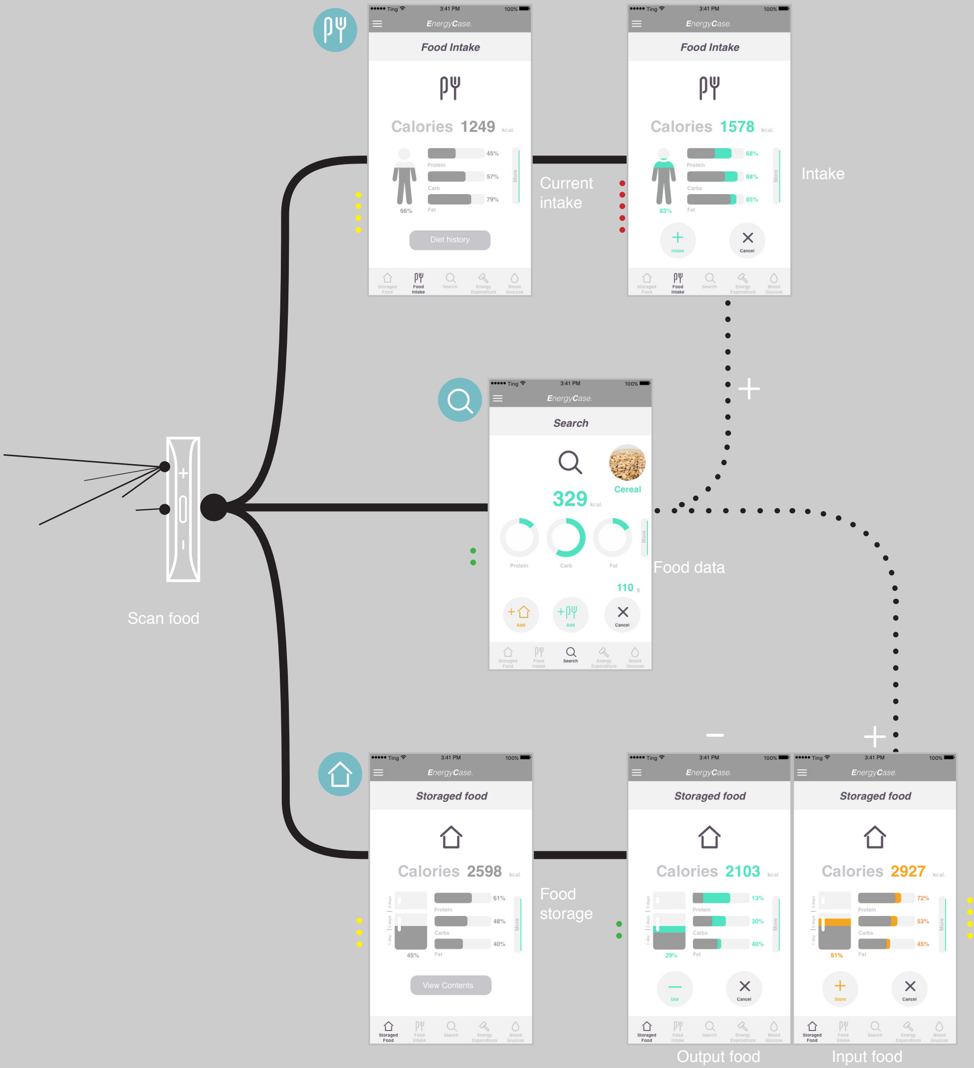
4.3.9 App

Smart device is now more and more powerful, App on smart device will provide user more detail on its screen. And the the data will be also possible for accumulation and deep learning.



Body activity monitoring

Blood glucose monitoring


Food Intake
Calories 1249 kcal.
Diet history
Food Intake
Calories 1578 kcal.
Intake
Cancel
Current intake
Intake
Search
329 kcal.
Cereal
Protein
Carb
Fat
110 g
Add
Add
Cancel
Food data
Scan food
Storaged food
Calories 2598 kcal
View Contents
Food storage
Storaged food
Calories 2103 kcal
Cancel
Storaged food
Calories 2927 kcal
Store
Cancel
Output food
Input food

4.3.10 Logo& name

Future

Transfer

Health

Nutrition

Life

Energy

I:for

Safe

Effect

I:for

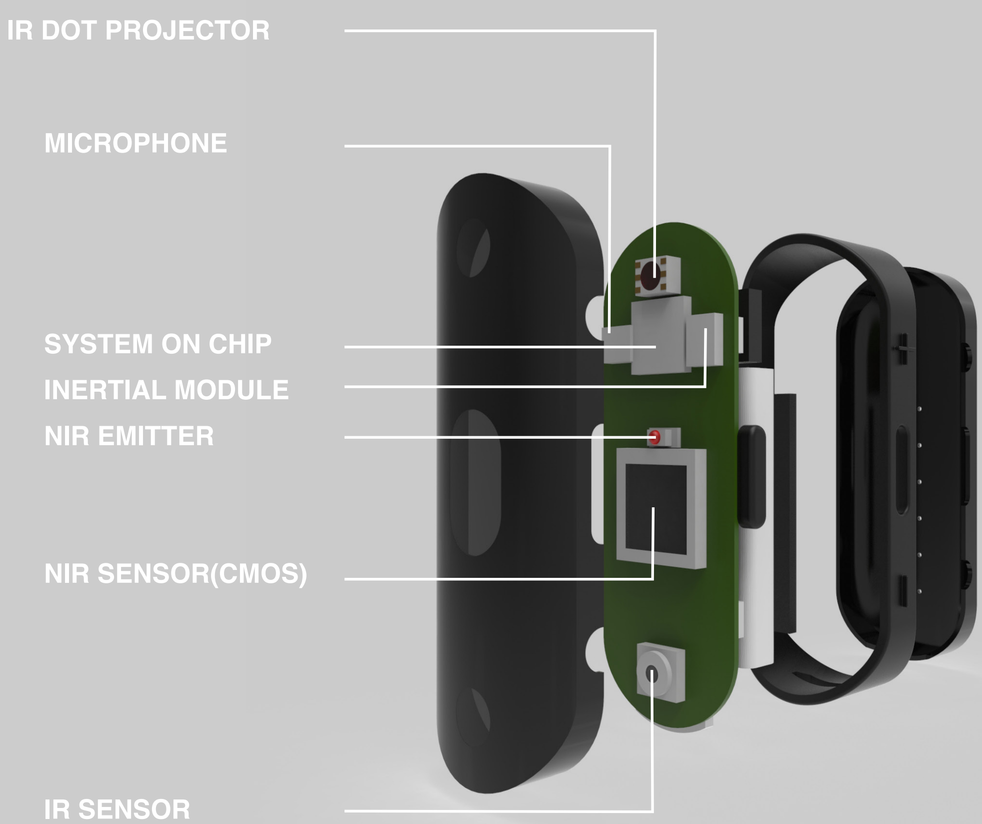
Analyzer

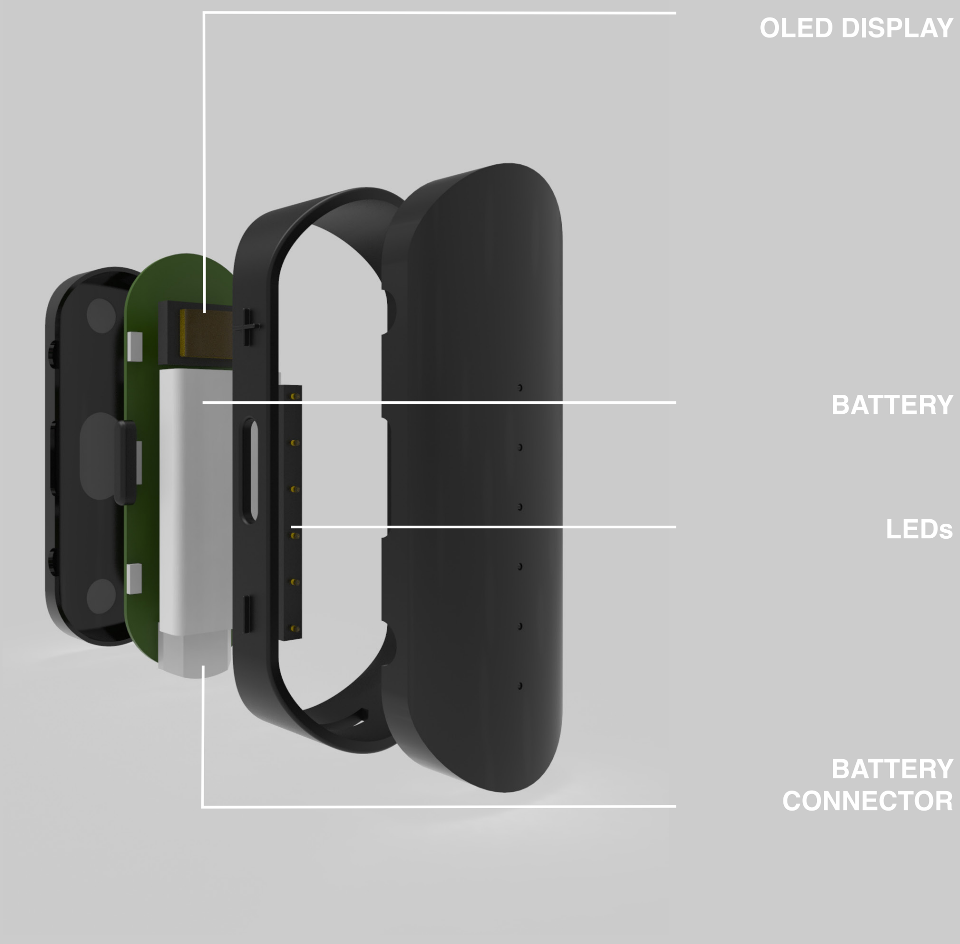
Food

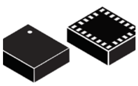
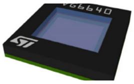
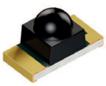
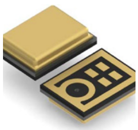
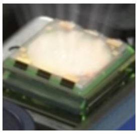
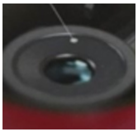
Eat

Efficiency

4.3.11 Components




OLED DISPLAY
BATTERY
LEDs
BATTERY
CONNECTOR

	NAME	PRODUCT
	SYSTEM ON CHIP	DA14681(DIALOG)
	INERTIAL MODULE	LSM9DS1(ST)
	NIR SENSOR(CMOS)	VG6640(ST)
	NIR EMITTER	SFH 4059SR CHIPLED LENS(OSRAM)
	MICROPHONE	MP34DB02(ST)
	IR DOT PROJECTOR	VASEL (LUMENTUM)
	OLED DISPLAY	Flexible OLED
	BATTERY CONNECTOR	Micro-B USB
	IR SENSOR	image sensor(ST)

DESCRIPTION	SIZE
Bluetooth 4.2 standard. An ARM® Cortex™ M0 processor, various embedded memory options, enabling the management of multi-sensor arrays and always-on sensing.	WL-CSP53 (3.4 x 3.0 x 0.5mm)and AQFN60 (6 x 6 x 0.9mm)
3D accelerometer, 3D gyroscope, 3D magnetometer	TFLGA 3.5X3X1 24L
high performance, high dynamic range 1.3 megapixel image sensor	M2BGA 9X9.3X1.375 100 F10X10 PI
High Power Infrared Emitter (850 nm) Version 1.3	(LxWxH) 3.2 mm x 1.6 mm x 1.85 mm
MEMS audio sensor omnidirectional digital microphone	RHLGA 3X4X1 METAL CAP
The dot projector sprays object with more than 30,000 invisible dots.	4 x 3 x 2 mm
OLED screen can achieve a higher contrast ratio, works also in low anbient light condition	0.42 inch
Various	6.85 x 1.8 mm
detect and receive reflected IR light from object.	4.5 x 4 mm

4.4 User journey

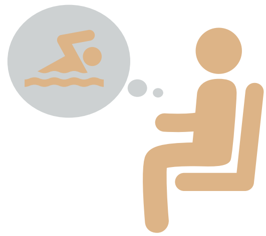
4.4.1 Function &use

Mode	Place	Situation	Interaction
1 Energy expenditure	anywhere	anytime	press **O** button and read
2 Search	restaurant/shop/ home	choosing food type/quantity to eat/buy	press **+** button, scan food and read
3 Food intake	restaurant/home	before eating	press **O** button and read
			press **+/-**-button, scan food and read
4 Storaged food	shop	before buying	press **O** button and read
			press **+/-**-button, scan food and read
5 Blood glucose	anywhere	anytime	press **O** button and read

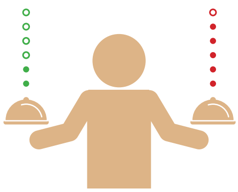
Direct Feedback (User)	Indirect Feedback	User behavior
current activity level	calculate body energy expenditure and will be as base for mode 2,3,4.	know activity level objectively
food advice	calculate food energy, compare with results of mode 1&5	decide and switch to mode 3 to eat/mode 4 to buy
current daily energy intake add/reduce daily energy intake	calculate food energy, compare with results of mode 1&5,multiply storage period	see energy intake visually
current food storage situation add/reduce food storage	calculate food energy, compare with results of mode 1&5,multiply storage period	remind and know storaged food
current blood glucose level	predict BGL trend/ alarm when in danger (for diabetic). keep monitoring, analyzing, adjusting and will contribute to personalized ratio of protein, carbs, fat for mode 2,3,4.	corresponding behaviors to regulate BGL

4.4.2 Senario

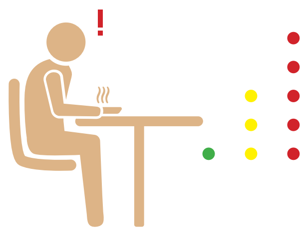
BILL



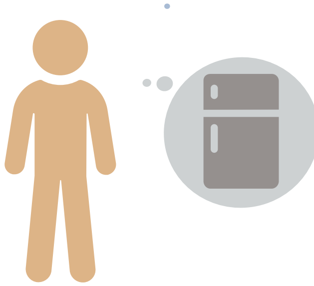
Bill considers having some sport, cause his current body activity level is low.



Bill will consider foods which benefit for him.

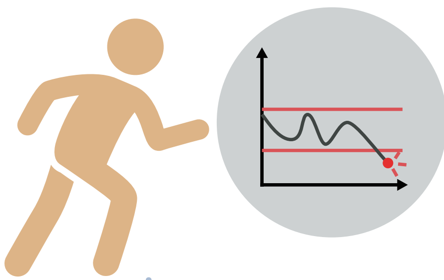


Bill will not keep eating anymore, cause the energy intake can be seen.



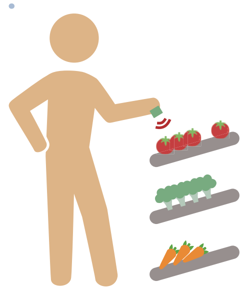
Bill will never have the trouble of forgetting existing food at home.

ANNA

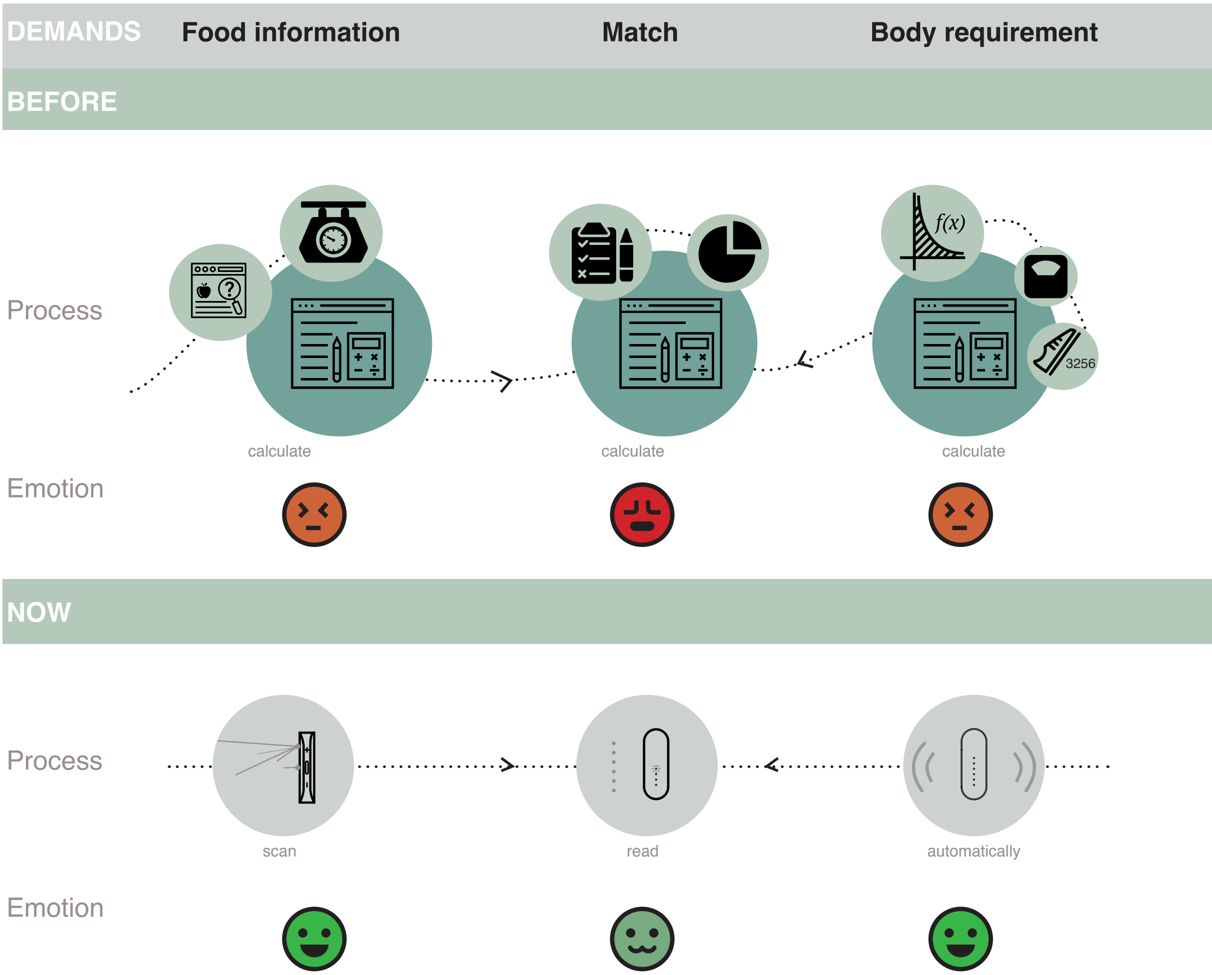


Anna can know the changes of her BGL during sport without worry.

Anna will choose food contributing higher stability for her BGL.



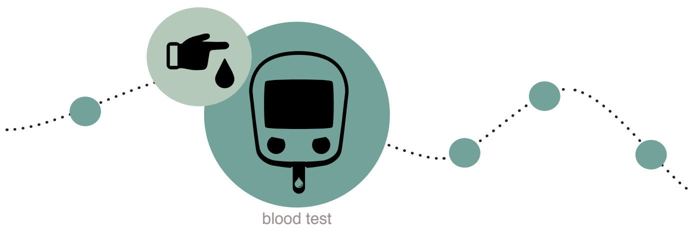
4.4.3 Actual process



Blood glucose monitoring

BEFORE

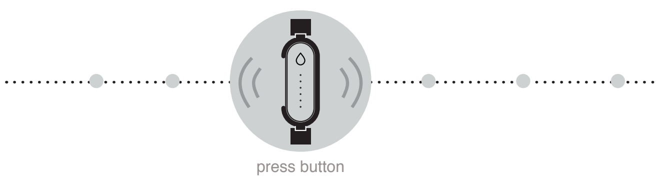
Process



Emotion

NOW

Process



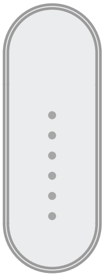
Emotion

4.5 Vision

NOWADAYS

Currently, with **limitations** of:

- battery capacity or charging technology (for 24h monitoring),
- verification and correction of clinical technology
- accumulation of food database

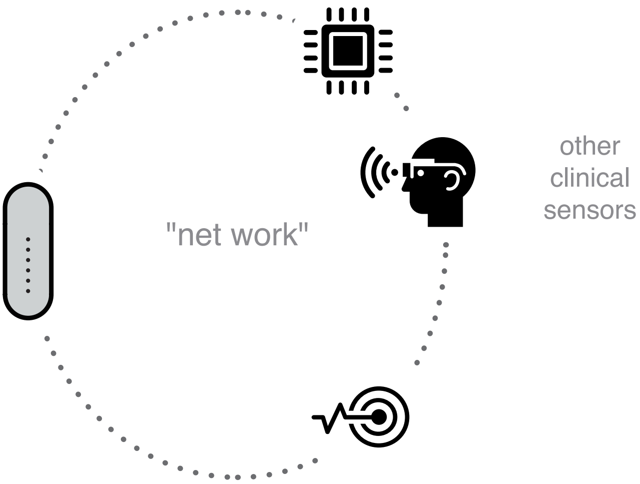


EAT SMART project, now is more like a food adviser, giving relative reference about food choice.

NEAR-FUTURE(5Y)

With the development of portability or creation of different accurate clinical device/sensor.

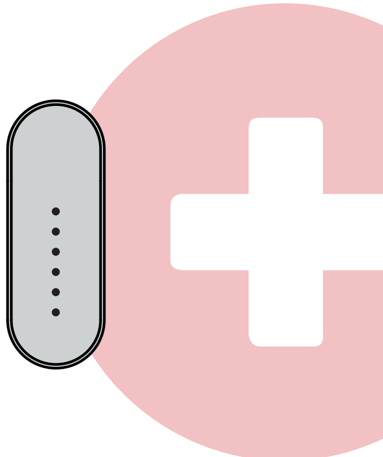
EAT SMART project will be possible working with those devices/sensors which provide accurate data for Efor, creating a network collaboration.



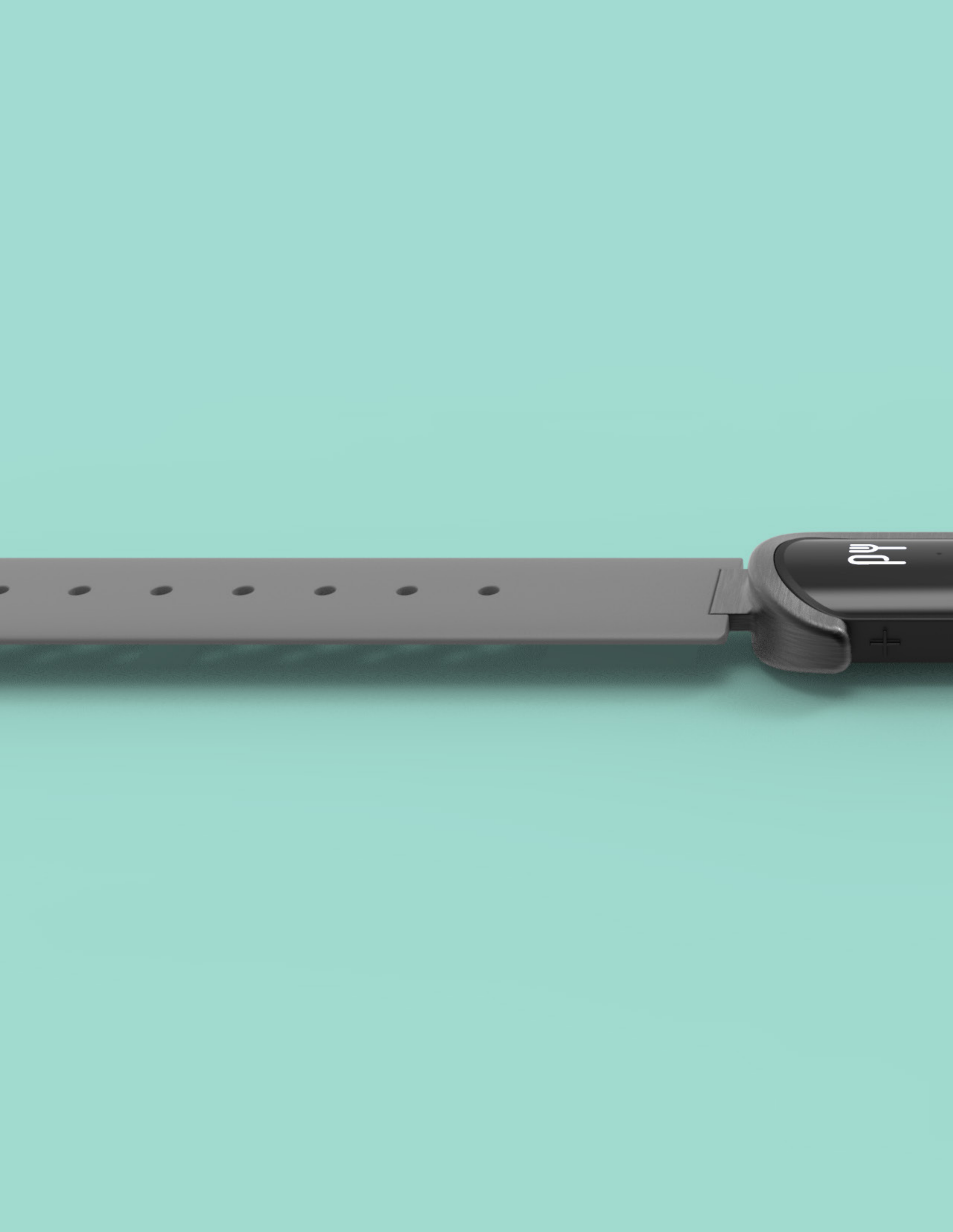
FUTURE

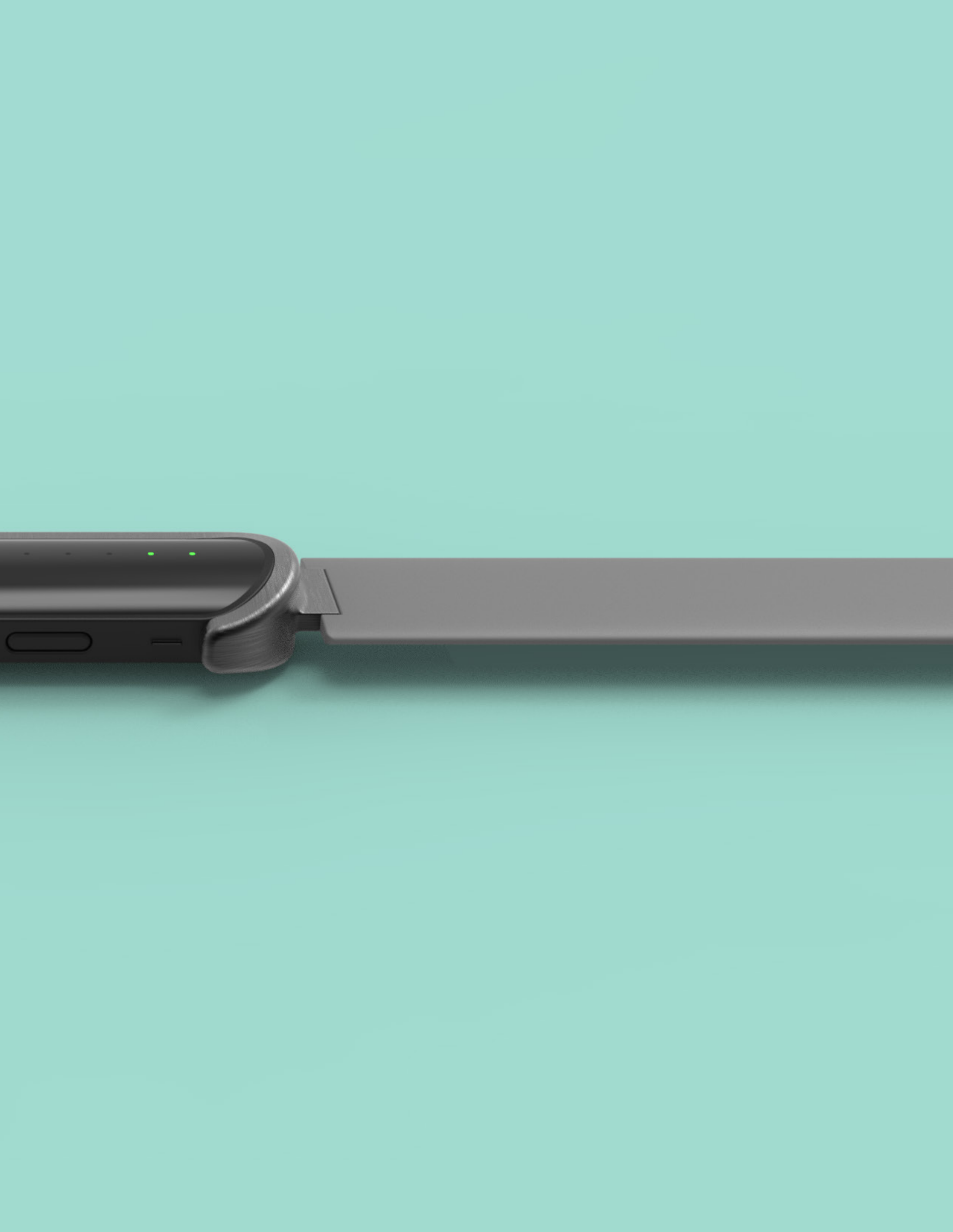
After years clinical correction and development, Eat Smart project will finally be a **reliable system** on **clinical level** for both multiple body value monitoring and accurate food energy detector.

A real **energy manager**!



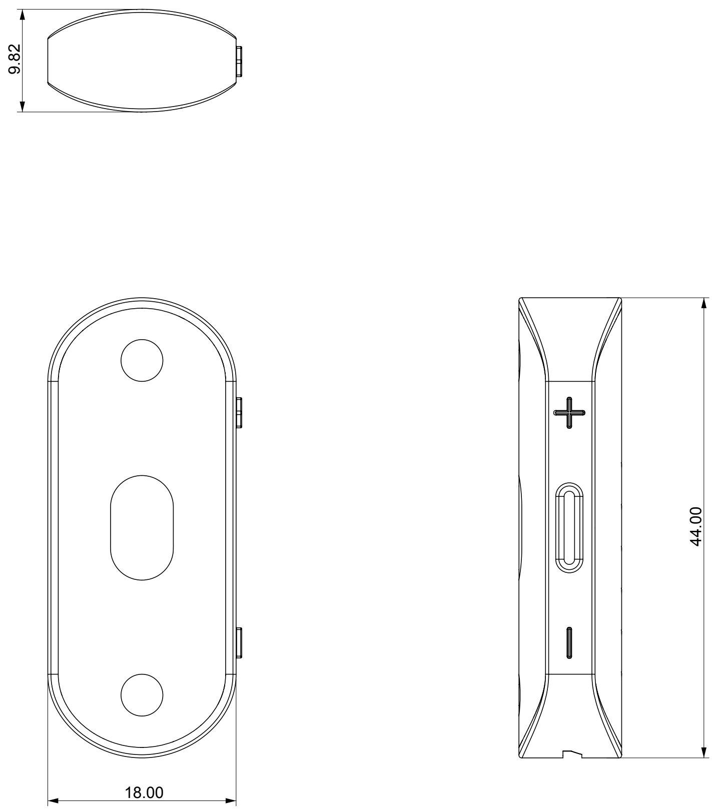
4.6 Rendering

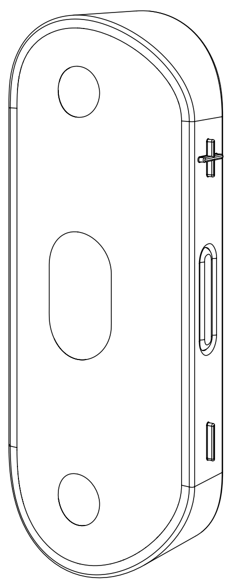




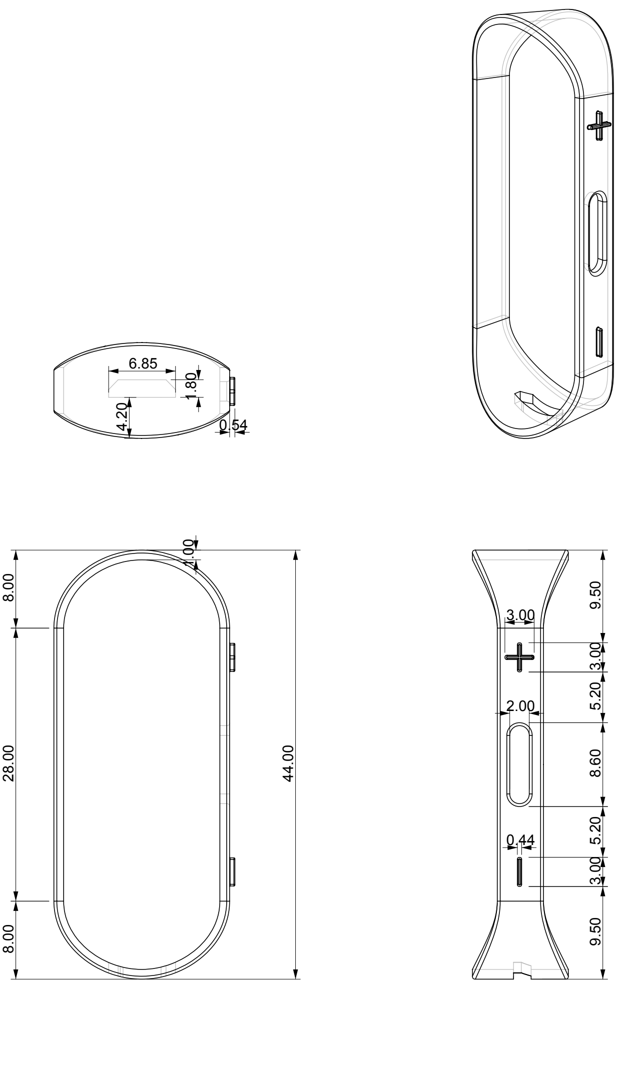

fn
control
alt
option
command

4.6 Technical drawing





POLITECNICO MILANO 1863	NOME PROGETTO	EFOR	
	TITOLO TAVOLA	DISEGNO DI PRODUZIONE	
	AZIENDA COMMITTENTE	Scala di riferimento	Unità di misura: mm
A.A. 2017-2018	TING JIN 840482		N° TAV.
TESI DI LAUREA MAGISTRALE RELATORE: VENANZIO ARQUILLA			1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4.20
0.54
1.00
8.00
28.00
8.00
44.00
3.00
9.50
3.00
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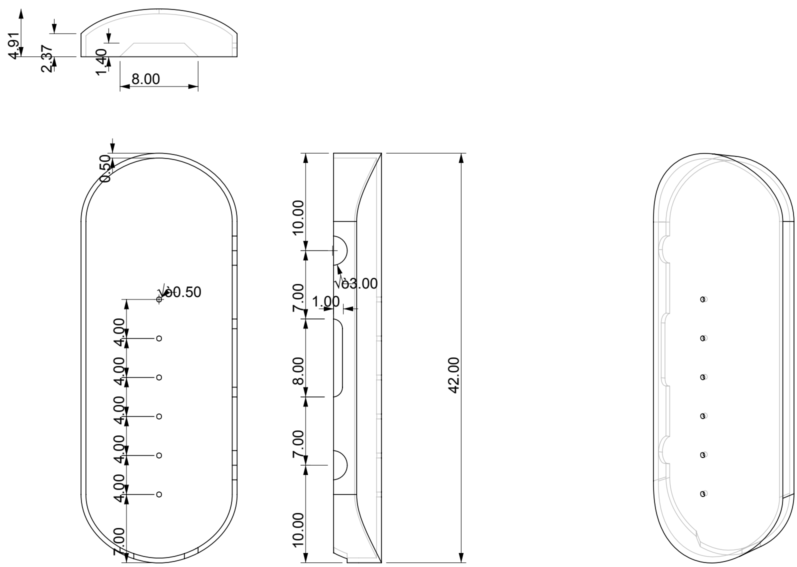
0.44
3.00
9.50



POLITECNICO MILANO 1863	NOME PROGETTO	EFOR	
	TITOLO TAVOLA	DISEGNO DI PRODUZIONE	
	AZIENDA COMMITTENTE	Scala di riferimento	Unità di misura: mm
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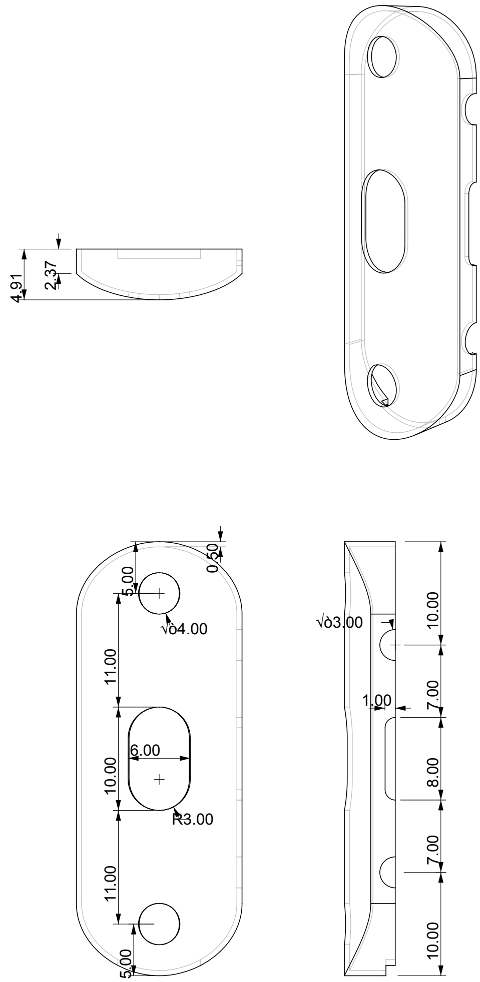
TESI DI LAUREA MAGISTRALE RELATORE: VENANZIO ARQUILLA			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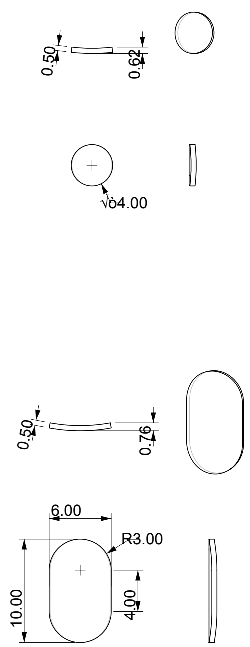
0.50
5.00
√ò4.00
11.00
6.00
10.00
R3.00
11.00
5.00
√ò3.00
10.00
7.00
1.00
8.00
7.00
10.00



POLITECNICO MILANO 1863	NOME PROGETTO	EFOR	
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	AZIENDA COMMITTENTE	Scala di riferimento	Unità di misura: mm
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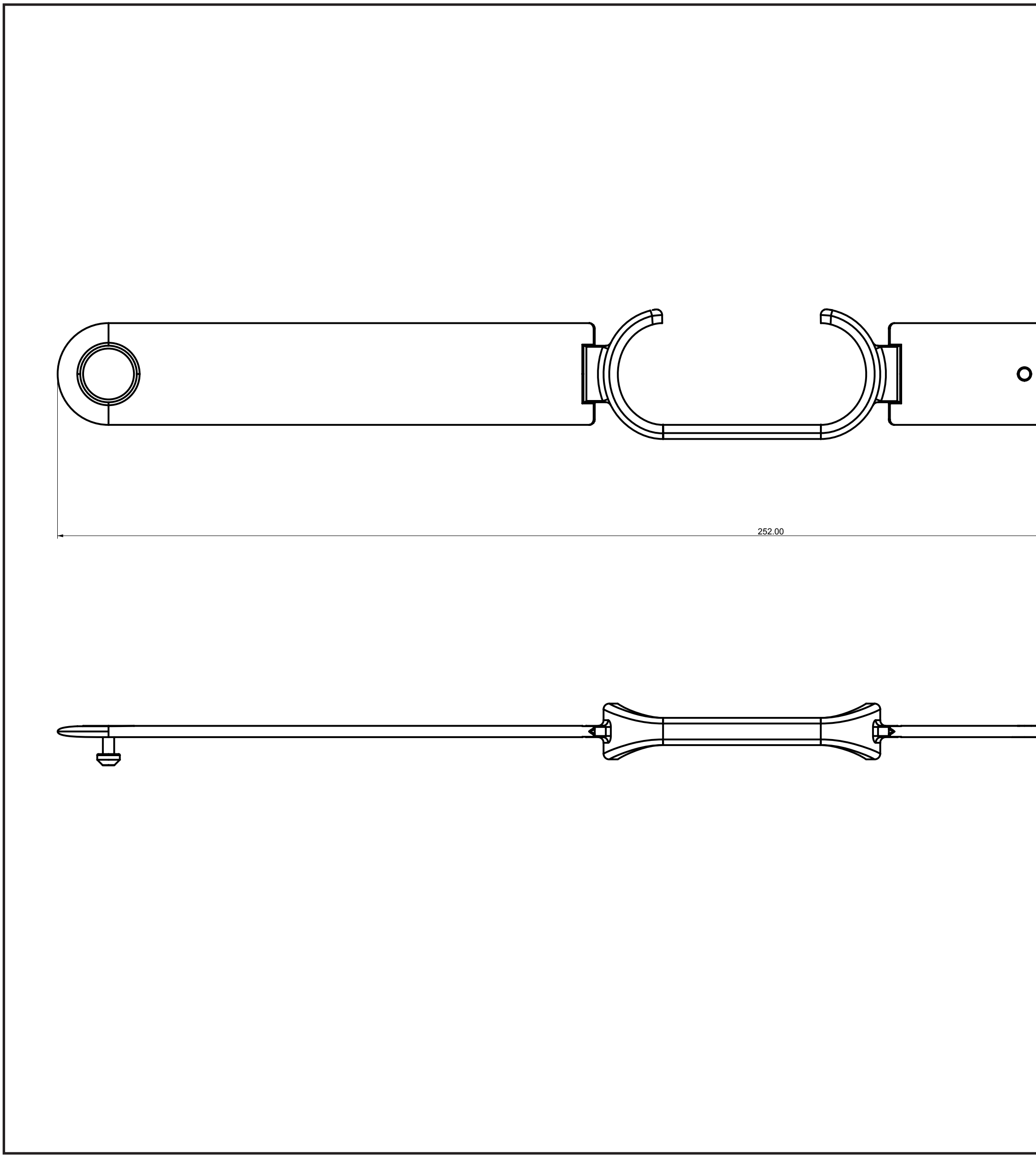
TESI DI LAUREA MAGISTRALE RELATORE: VENANZIO ARQUILLA			3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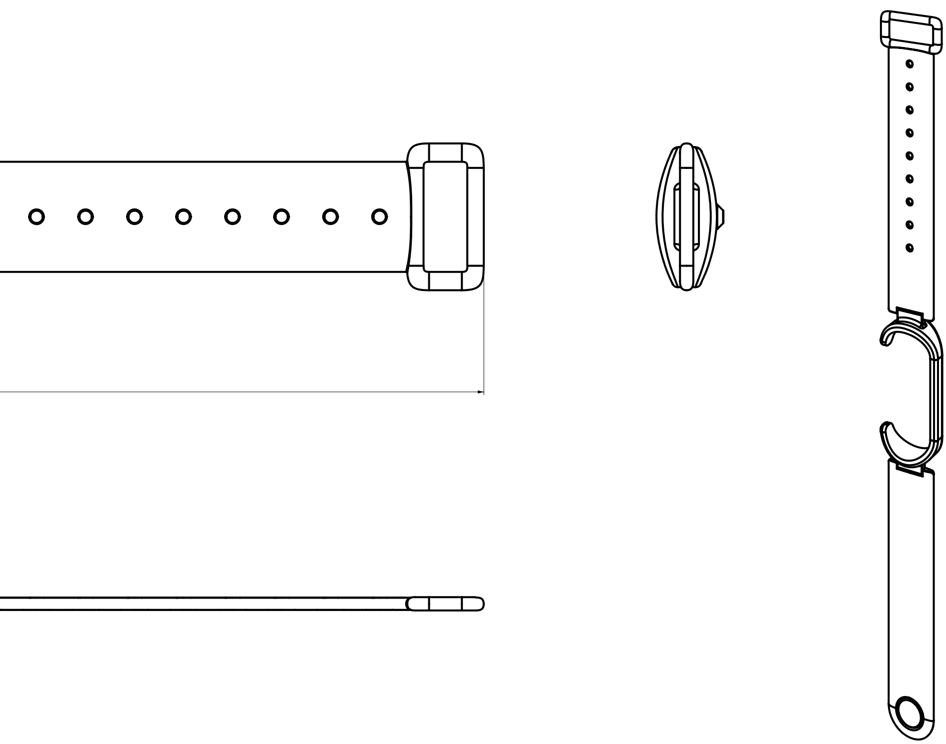
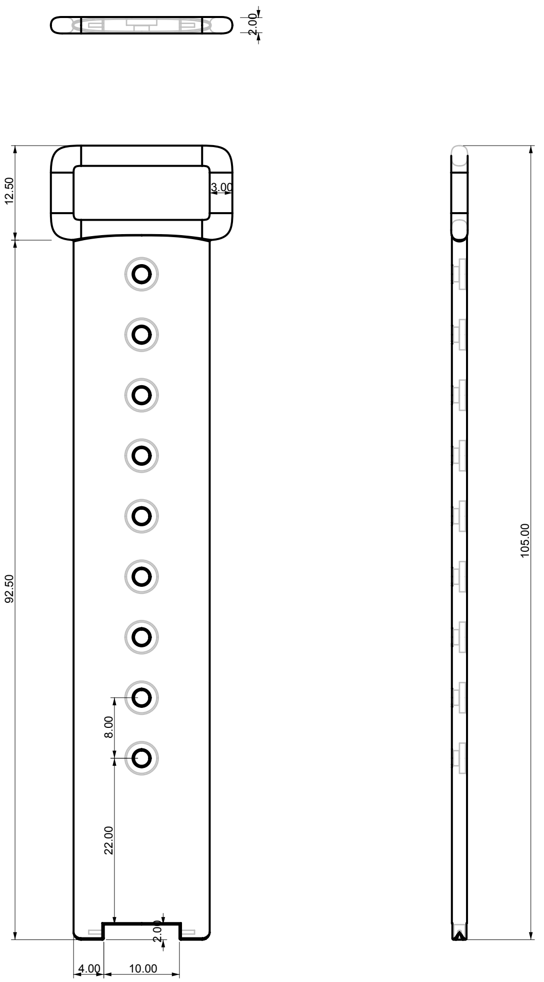


POLITECNICO MILANO 1863	NOME PROGETTO	EFOR		
	TITOLO TAVOLA	DISEGNO DI PRODUZIONE		
	AZIENDA COMMITTENTE		Scala di riferimento	Unità di misura: mm
A.A. 2017-2018	TING JIN 840482			N° TAV.
TESI DI LAUREA MAGISTRALE RELATORE: VENANZIO ARQUILLA				4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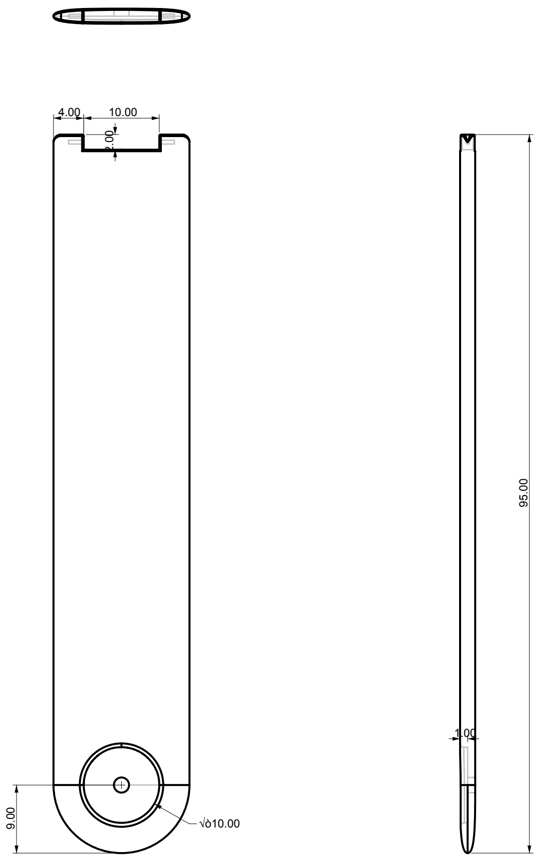
12.50
3.00
92.50
105.00
8.00
22.00
2.00
4.00
10.00



POLITECNICO MILANO 1863	NOME PROGETTO EFOR		
	TITOLO TAVOLA DISEGNO DI PRODUZIONE		
	AZIENDA COMMITTENTE	Scala di riferimento	Unità di misura: mm
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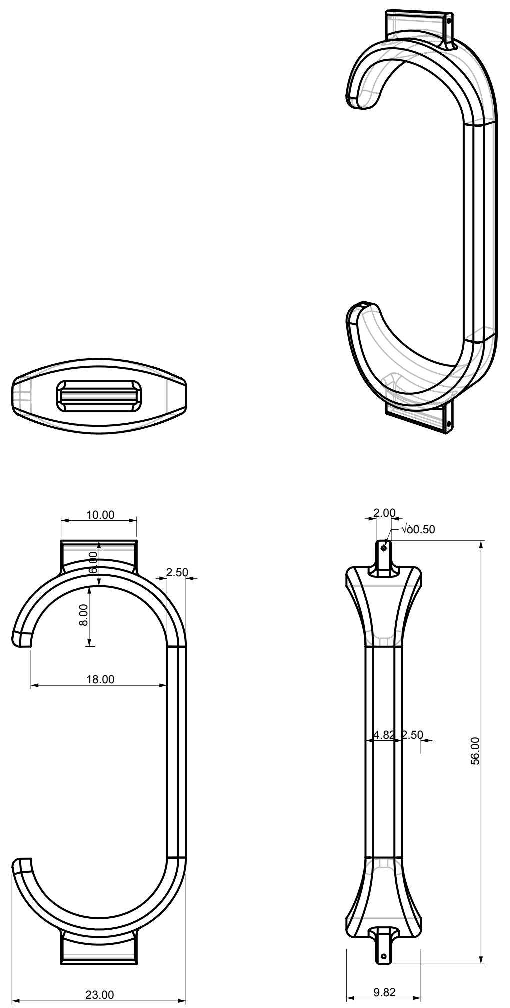
TESI DI LAUREA MAGISTRALE RELATORE: VENANZIO ARQUILLA			5


10.00
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8.00
18.00
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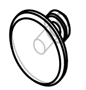
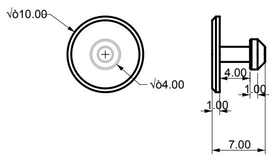
√ò0.50
4.82
2.50
56.00
9.82





POLITECNICO MILANO 1863	NOME PROGETTO EFOR		
	TITOLO TAVOLA DISEGNO DI PRODUZIONE		
	AZIENDA COMMITTENTE	Scala di riferimento	Unità di misura: mm
A.A. 2017-2018	TING JIN 840482		N° TAV. 6
TESI DI LAUREA MAGISTRALE RELATORE: VENANZIO ARQUILLA			

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Figures&Tables