24 – 36
PARTICIPANTS

15 MIN – 3H

EN
LANGUAGE

my IoT

A DISCOVERY GAME

FACILITATION GUIDE

NEED for IoT
Université Grenoble Alpes

UGA
Université
Grenoble Alpes

NANOELEC.

SUMMARY

INTRODUCTION

GAME ORIGIN

This game evolved as part of the NEED for IoT research project. This project, which lays the foundations for sustainable nanoelectronics, develops methodologies integrating economic analyses, geopolitical issues, acceptability and the durability of new technological solutions to apply to the design of the elements supporting the Internet of Things (IoT).

Developed by Laetitia Thomas, as part of her mission as a pedagogical engineer for the NEED for IoT project, the game anticipates and supports a sustainable transition in the field of nanoelectronics. The game itself has been adapted from the one developed by her former colleagues from Slow Fashion Forward, Maureen Dickson, Carlotta Cataldi, Crystal Hodges: "My Garment: a discovery game".

CONTEXT

Microelectronics are the invisible part of products we use every day: cars and keys, to giant factories, kitchen and office machines, to smartphones and toothbrushes...
The microelectronics industry raises a number of critical sustainability issues. Some issues have been addressed, whereas others remain to be treated, or improved on all phases of the life-cycle of connected objects.
Digital technologies benefit from a clean industrial image. They are even touted as necessary to solving environmental problems. However, far from their dematerialized image, they have many impacts on the environment.

OBJECTIVES OF THE GAME

Players are invited to see the bigger picture and to understand how the microelectronics industry is interconnected with ecological and social systems.

This interactive game aims to raise awareness and initiate a change in mindsets and behaviors regarding the impacts of the globalized micro and nano technology industry in an accessible, creative and engaging way.

Currently, the microelectronics value chain presents certain vulnerabilities. Namely, stakeholders are aware of the impacts on their immediate suppliers or customers, but have no visibility of those of the entire production chain. The 2017 Greenpeace report noted this lack of transparency.
This game therefore seeks to make information on the impacts of the IoT production chain accessible in order to encourage dialogue among different stakeholders: students, designers, and IoT users.

Using knowledge-sharing, serious games and circular economy tools, the group's collective intelligence is engaged to reflect on the implementation behavioral changes for digital sobriety.

This game is modular and combines different phases that may be used separately or in combinations, depending on the facilitator's objectives:

- **EXPLORE IMPACTS** → My IoT a discovery game
- **PRIORITIZE IMPACTS** → Value chain canvas, to think about a future mission
- **IDENTIFY STAKEHOLDERS** → Partner Map
- **BUILD SOLUTIONS** → Circular Canvas

LEARNING OBJECTIVES

- Share knowledge: Learn from the unique experience of each participant and from classroom collective intelligence.
- Discover the ecological and social impacts of the micro and nanoelectronics supply chain at each stage of its life-cycle.
- Acquire a systemic understanding of the microelectronics industry and connected objects (IoT).
- Stimulate transversal competences to understand the complexity of the world in its scientific, ethical and civic dimensions.
- Practice co-constructing future scenarios aligned with Sustainable Development Goals (SDG - developed by the UN) and reflect on how to build peace and participate in the sustainable evolution of our society.
- Trigger behavioural changes. As we are all IoT consumers we can have a positive impact by adopting conscious and sustainable consumption patterns.

TARGET GROUPS AND PREREQUISITES

High school students, undergraduate and graduate students, doctoral students, designers and industry managers in the context of continuing education.
Number of players: at least 24 participants. Divide participants into 6 groups.

Level 1: general public discovering stakes and facts of connected objects (high school, general public);

Level 2: industrial public (masters, continuing-education);

Level 3: engaged public (Ph.D. students, experts, academics).

A facilitator is required for exchanges at each stage as well as for respecting allotted time. Prerequisites for levels 2, 3: academic and industrial experts are invited to participate in the exchanges; ideally, one expert per life-cycle phase: raw materials, design, manufacturing, distribution, use and end of life.

TIME

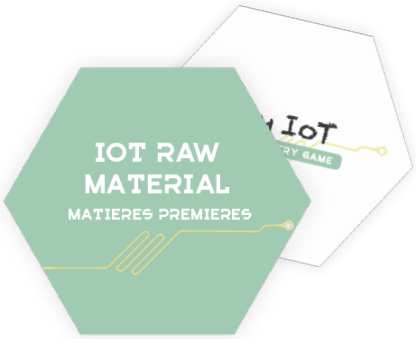
From 15 minutes to 6 hours, depending on the number of phases played, excluding restitution phases. Count 30 minutes to 1 hour for each step, excluding icebreaker questions.

GAME COMPOSITION

▶ 1 Smartphone card

▶ 18 "Context" Cards
divided into 3 levels

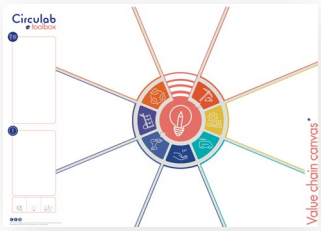
▶ 1 facilitator booklet



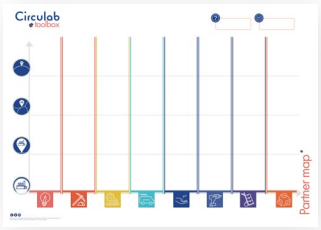
▶ 6 kits of 6 hexagonal "Phase" cards

▶ 6 kits of 33 hexagonal "Impact" cards

▶ 36 wooden pawns



▶ 1 "Value chain canvas"



▶ 1 "Partner Map"

▶ 6 "Circular canvas"

ACCESS TO RESOURCES

- Printable version: Downloading the cards in square format is recommended as they will be easier to cut and print.

  https://need.univ-grenoble-alpes.fr

  Sets may be printed and sent to each player, or each may download and cut out his/her own set before the session.

- Digital version: Downloading the cards in the individual, square format, is recommended as they may be shared online using digital tools such as Mural, Miro or Google Jamboard, for example.
  Download the individual unit pdfs of the maps here: *https://need.univ-grenoble-alpes.fr/*

Example of a shared desktop under Mural, when starting the game, with unordered cards.

GAMES MODES

- **EXPLORE IMPACTS** → My IoT a discovery game
- **PRIORITIZE IMPACTS** → Value chain canvas, to think about a future mission
- **IDENTIFY STAKEHOLDERS** → Partner Map
- **BUILD SOLUTIONS** → Circular Canvas

FACILITATION: RESOURCE PEOPLE

- Posture: We suggest a benevolent posture. That is to say a non-judgmental posture, where participants are not put in rivalry. They are not obliged to do something "good". The idea is to explore impacts together, as well as possible solutions.

- Facilitators are responsible for ensuring that the allotted time is respected and that each step is validated before moving on to the next.

- Experts by area of expertise, will act as "knowledge facilitators"; each participant's own experience is also to be valued.

For remote animation, it is recommended to have technical support to facilitate the animation on the respective digital tools (i.e. assign participants to group rooms, ...).

PREPARATION BEFORE THE SESSION

- Prepare as many game-tables as groups: 6 tables for 6 groups.
  On each table, place the 6 "Phase" cards, a set of "Impact" cards and the "Circular Canvas".
  Place post-it® notes and a pen for each participant.

- Prepare a 7th table which will be your "shared" table from which you will start the session.
  Place the "Smartphone" card face down in the center of this table.
  Take out, without putting them on the table, the 6 "Context" cards adapted to the level of the participants (level 1, 2 or 3).

STARTING THE SESSION

- Introduce the context, the game, its objectives and how it is played.
- Introduce the resource persons and their roles: facilitators, experts and technical leader if applicable.
- Form the groups, each group will be assigned to one the 6 phases on the life-cycle phases: raw materials, design, fabrication, distribution, use, end of life.

You are ready to launch the game !

STEPS OF THE GAME

STEP 1 - THE 6 ICE BREAKER QUESTIONS

Time: 15 minutes

Objective: get to know each other starting from a shared-knowledge base. Exchange reciprocal perceptions concerning the microelectronics sector.

Animation:

Three icebreakers types are available corresponding to the level and the objective of the session:

Level 1 - cards from 1 to 6:

general public discovering connected objects stakes and facts (high school, general public).

> answers: next page

Level 2 - cards from 7 to 12:

industrial public looking for more open, perhaps more philosophical questions - answers are to be built together (master, continuing education).

Level 3 - cards from 13 to 18:

an engaged public wishing to address non-binary questions - answers are to be built together. (Ph. D. students, experts, academics).

- Gather all participants around the "shared table".
- The facilitator selects the 6 appropriate "Context" Cards, one after the other, and allows 2 minutes for participants to exchange on their answers.

Tip for the remote version: send questions to participants a week before the session to allow for preparation.
Furthermore, you may suggest participants watch the documentary on Arte by Guillaume Pitron: "The hidden face of green energies": https://www.youtube.com/watch?v=rpUmfZb4XBI&t=2s as it complements the session.

Debriefing tips:

- In your opinion, what other issues would make relevant discussion regarding sustainability of the microelectronics industry?

Conclusion: The microelectronics industry is useful everywhere and for everyone: it contributes to improving people's lives... but not at any price.
In the next step, we will inventory the impacts currently known.
The facilitator assigns one life-cycle phase per group.

Answers for Level 1 questions:

QUESTION 1	QUESTION 2	QUESTION 3
What is a connected object?	**At what age do you think a human is first exposed to an object with imbedded electronics?**	**Which trades/industries do not use electronics?**
Everyday objects (smartphone, television, toothbrush...) connected among each other via Wi-Fi, or Bluetooth, permitting them to exchange information.	Exposure today is about two years of age, but earlier in developed countries (see: https://www.youtube.com/watch?v=ovbeMGfSO2M)	Depending on the context, the 4. 0 revolution impacts very traditional industries from connected tractors to blue-tooth enabled teddy bears.

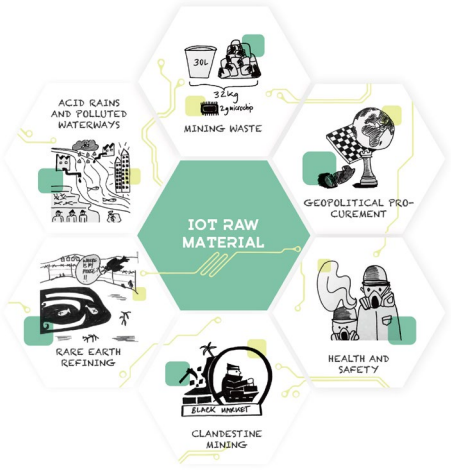
QUESTION 4	QUESTION 5	QUESTION 6
What was the first connected object?	**How many connected objects per household in 2020?**	**How many kilos of raw materials are needed to produce a 2-gram microchip?**
Sunbeam Deluxe Automatic Radiant Control Toaster. Between 1989 and 1990.	According to projections by the GFK research institute, more than 30 connected objects will be installed in homes by 2020.	32 kg. That is a ratio of 1:16000, most of which is water (30 L).

For Level 2 and Level 3 questions, request participants to answer the questions with a partner.

STEP 2 - EXPLORATORY PHASE

Time: 30 to 60 minutes

Animation:



Objective:

- Learn from each other and discuss different ecological and social impacts while matching them with the right life-cycle phase.
- Make a diagnosis from key information gathered on the smartphone market from a resource, an end-user, a stakeholder, a technology or policy and legal perspective across the entire value chain(s).

Part 1:

The participants organize the different IoT life-cycle phases.

Part 2:

According to their own vision, participants discuss and match ecological and social impacts with the corresponding life-cycle phase. All answers and choices are justifiable.

Part 3:

Ask each group to choose ONE impact at this point that stood out as being surprising, important, or a new discovery. Ask the group to share this knowledge with the other groups. Facilitators may complement with details.

While the teams are working on the game, the experts walk around the room asking each group if there are any questions about any of the cards. If a group is not sure what a specific card represents, facilitators provide information and assistance if necessary. See impact cards in the appendix.

Debriefing tips:

- What information surprised you the most?
- What did you learn?

Conclusion: This industry is a system engaging numerous and diverse players in a complex, multi-level supply chain. No single company and no single person is capable of having a complete vision of this system.

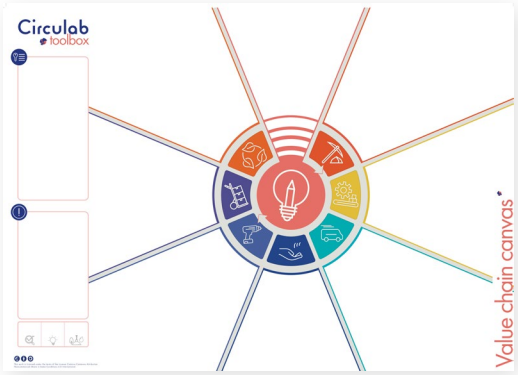
STEP 3 - VALUE CHAIN CANVAS

Time: 30 to 60 minutes

Facilitation:

Objective:

▶ Based on the previous exercise, prioritize the challenges identified in the previous step and develop a vision of how they may be addressed.



Participants consult with the expert associated with the life-cycle stage on which they are working.
The groups discuss their respective findings with the experts who question their proposals.
Then they present their findings to the other groups.

Part 1:

Gather your collaborators around the "shared" table where you will have laid out the "Value chain canvas".
Invite each group to place its priority impacts on the canvas, in the areas corresponding to the respective life-cycle phase: raw material selection, design, manufacturing, distribution, use and end of life.

Part 2:

Invite each group to associate a green post-it® note with the opportunities related to these challenges, and a red post-it® note with the risks related to them.

Part 3:

Then have each group brainstorm questions such as "how can we radically improve this industry within three years?".
Remember, we tend to overestimate what we can do in one year, and to underestimate what we can do in three years (*Lakhiani*, 2019).

Going farther:
Give a wooden pawn to each participant.
Ask each to position him/herself on the action, the impact, or the phase where he/she could contribute: acting tomorrow as the agent in his/her field, discipline, or as a citizen of a given country.

Debriefing tips:

▶ Discuss the opportunities and challenges the groups consider are most important.

Conclusion: Once having composed these questions, we will think back to which stakeholders in the value chain have an interest or influence on these issues.

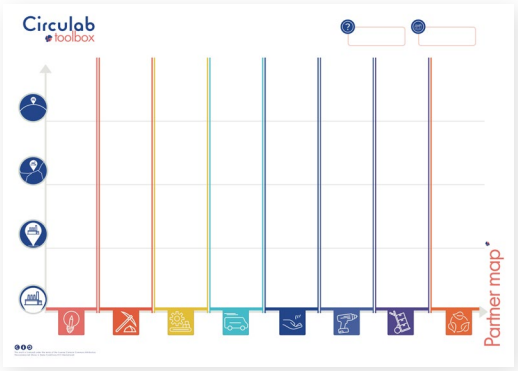
STEP 4 - PARTNER MAP

Time: 30 to 60 minutes

Facilitation:

Objective:

- Identify and map your stakeholders, then create virtuous synergies for all of the value chain phases.



Still around the "shared table" where you will have placed the "Partner Map", invite the participants to fill in the column corresponding to their phase.

Part 1:

Using post-it®, place your stakeholder suggestions on the canvas according to the 4 level scale: origin of the headquarters, regional, national and international stakeholders. Stakeholders are the natural or legal persons actively or passively involved or impacted.

Part 2:

Once completed, there are many ways to go farther with the partner map. Here are a few tips:
Using post-it®, or different colored markers, rank each stakeholder's interest and power from 0 to 3 by asking yourself the following questions:
- Is this project important to the actor (interest)?
- How much influence or power does the stakeholder have in this issue?

Part 3:

Once the different stakeholders are identified, share them with the entire group and discuss to avoid duplication: each should appear only once.

Debriefing tips:

- Which stakeholders do you consider critical and/or strategic?
- What difficulties or obstacles do you imagine their involvement will impose on your approach?

STEP 5 - CIRCULAR CANVAS

Time: 60 minutes

Facilitation:

Objective:

- To arrange the steps of a business model integrating the negative and positive impacts of an industrial activity on a given ecosystem.

Each group gathers around its table.
Explain to the groups that they are to imagine they are employees of a fictitious local "GreenPhone" company. They must design the new generation of "GreenPhone" (microprocessors, memories, imagers,...) in a sustainable and ethical manner.

Each group works on the business model related to the life-cycle phase it has been assigned to from the beginning.

Each team fills the Circular Canvas from left to right:

- Fill the "Mission" box, bottom left, with the question formulated in the "Value Chain Canvas" step (i.e. "How might we?")
- Place the most important actors of your "Partner Map" in the "Partners" box.

The questions at the bottom of each box help guide participants.

Once the 10 white boxes are completed, fill in the yellow lines and then the green lines according to what corresponds to the column indicated.

Going farther:

Once completed, there are many ways to use the "Circular Canvas".
Here are a few ideas to facilitate your team's cooperation and creativity:

- *Hide all items in the same box to find alternatives and anticipate likely changes.*
- *Consider transforming the negative impact into opportunities or cost reduction.*
- *Using different choices in the white boxes, try to make all your negative impacts disappear.*

STEP 6 - RESTITUTION OF FUTURE SCENARIOS

Time: 30 minutes

Objective:

- Exchange perceptions and ideas of each group.

Facilitation:

Using the most appropriate support, each team presents its future scenarios in 5 minutes.

Conclusions and feedbacks:

Have the participants vote on the basis of the established pedagogical objectives.

DETAILED DESCRIPTION OF THE "IMPACT" CARDS

RAW MATERIALS PHASE

Mining for essential and finite raw materials often endangers workers and leaves the Earth irreversibly scarred (*Greenpeace*, 2017a). Extracting minerals from the soil is intrinsically dirty. This has been conducted by the most dynamic mining states in such an irresponsible and unethical fashion that this severely undermines the righteous purpose of energetic and digital transition. According to the Blacksmith Institute Report in 2016, it is the third largest polluting industry after lead battery recycling and dyeing.

Mining waste

Sentence on card: *32 kg of raw materials produce a 2 g microchip. A 1 to 16,000 ratio compared to a 1 to 70 ratio for a car, most of which is water 30 L.*

32 kg of raw materials needed to produce a 2 g microchip. A 1 to 16. 000 ratio beyond what most objects we use (a car is 1. 70). Most of this is water (about 30 L).

Geopolitical procurement

Sentence on card: *Diminishing resources and monopolies in rare earths create an availability risk.*

The dwindling supply of rare earths (copper, cadmium), which will lead to economic and geopolitical procurement issues. China produces 95% of rare earths, even if the country China in its subsoil that 36% of the world's reserves. This monopoly results in a high supply risk. These factors, lead to concerns regarding **critical metal availability** (*Grandell et al.*, 2016).

Health and safety

Sentence on card: *Aside from dangers associated with conflict zones, miners exposed to silicon, aluminum and copper particles are subject to respiratory and cancerous disorders.*

On top of the necessity to source from Conflict free zones, the health of minors and their exposure to silicon, aluminum and copper particles which lead to respiratory disorders (silicon is linked to lung cancer[1])

[1] *http://www. electronicstakeback.com/2014/05/27/samsung-apologizes-to semiconductor-workers-who-contracted-cancer-promises-compensation/*

Clandestine mining

Sentence on card: *Illegal mining supplies a global black market.*

There are more than 10 000 mines in China and many more clandestine ones, where health and safety measures are even less followed. Albeit Chinese government sanctions trying to stop them, these operations feed a colossal black market, where the rare metals are exported globally (*Pitron*, 2018, p. 41)

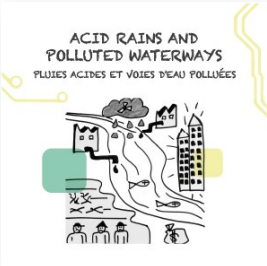
Rare earths refinement

Sentence on card: *Ecotoxicity on mining sites leads to a rural exodus.*

In some of the most dynamic mining states: China, Kazakhstan and the Congo, the waste waters of the refining process are discharged into rivers and lakes. In Baotou, China (which represents 75% of global production), the local population of 2000 dropped to 300 because the lake was poisoned, they could no longer grow their vegetables and all their cattle got sick. At this time mining area rehabilitation is uncommon (*Bontron*, 2012, *Pitron*, 2018, p. 45).

Acid rains and polluted waterways

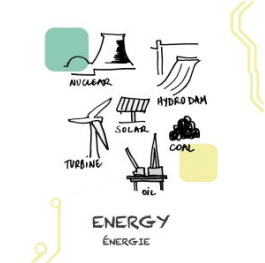
Sentence on card: *Instances have been reported of releases of industrial chemical waste into fresh water sources.*



In 2006, 60 companies producing indium for solar panels were found dumping tons of chemicals into the Xiang River, compromising fresh water for local citizens. In 2011, the same happened in Fujian where a mine was producing gallium for low emission light bulbs (*Bontron*, 2012, *Pitron*, 2018, p. 45).

Energy

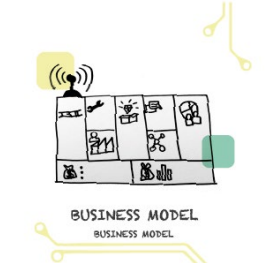
Sentence on card: *Over 70 % of the carbon footprint of electronic devices occurs during manufacturing.*



Upwards of 70 to 80% of the carbon footprint during the lifespan of personal computing devices occurs during manufacturing (*Greenpeace*, 2017; *Schneider*, 2016).

Programmed Obsolescence

Sentence on card: *Scheduled obsolescence and low-repairability designs imply a projected smartphone lifespan of two years.*



Planned obsolescence is a product feature in existing business models to avoid market saturation. Companies increasingly change design to accelerate the replacement cycle making the product difficult to service or upgrade, shortening the user-life of otherwise functional devices. This drives consumption and waste (*Greenpeace*, 2017b).

Resource consumption

Sentence on card: *The linear production model requires massive amounts of virgin materials, the supply of which generates numerous negative impacts.*

The linear production model requires massive amounts of virgin inputs. Sourcing these damages the environment, depleting finite resources at risk to workers and communities. Ideally, a closed loop production model would reduce the hazardous e-waste stream to dangerous, rudimentary recyclers in the Global South, and lessen demand for virgin materials. A Fairphone study, indicates devices dismantled at end of life, prior to smelting, provide higher recovery rates of more materials, than shredding or smelting alone. Modular design can improve essential metal recovery for electronics, (including gold, copper, silver, cobalt, nickel, palladium, platinum, gallium, indium, zinc, tungsten and tantalum), as well as functional component recovery and reuse for spare parts (*Greenpeace*, 2017b).

Toxicity of chemicals

Sentence on card: *Identification and elimination of toxic products.*

Companies need to identify and eliminate hazardous chemicals used in the production of their products, improve worker health and safety due diligence, and develop safe substitutions (*Greenpeace*, 2017b).

MANUFACTURING

Assembly line off-gassing

Sentence on card: *Toxic chemicals off-gasing is harmful to the health of assembly line employees.*

The combination of toxic raw materials such as brominated and chlorinated substances, plastics and plastic additives constitute a heavy burden on the environment and the health of employees working on assembly lines.

Polution delocalization

Sentence on card: *The West transfered the production and pollution of rare metals to poor countries.*

Rather than assume leadership of rare metals, the West has preferred to transfer their production - and the associated pollution - to poor countries willing to sacrifice their environment to get rich (*Pitron*, 2018, p. 87).

Violation of labor laws

Sentence on card: *The rights of Chinese workers are often neglected (working hours, wages, proper equipement, ...).*

Excessive overtime hours are pervasive. With low wages and cut costs on welfare and insurance. Example are Foxconn with 160 hours of overtime per month (lilmit is 36 hours) and Pegatron (which manufactures the Iphone 7) lack proper protection equipment (*China Labor Watch*, 2019).

Manufacturing waste

Sentence on card: *An estimation of 20 to 80% of platinum is lost during the deposition process in the spray chambers.*

The Platinum lost during the deposition phase in the sputtering unit can be at least partially recovered. However, the Platinum etched away from the wafer during the memory cell nano-patterning process will always be difficult to recover. A fully closed loop of Pt seems difficult to achieve. (*Palomino Lopez et al.* , 2020).

Strategy

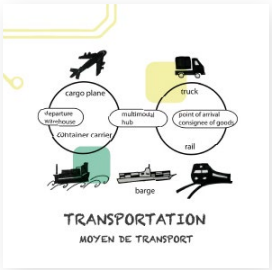
Sentence on card: *Microelectronics are crucial to promising markets such as the automotive, logistics, healthcare and energy sectors. A strong local industry is necessary to ensure competitivity.*

Microelectronics and the software industry represent 90% of the innovations made in promising automotive, medicine, logistics and energy sectors. Without a strong, independent French and European microelectronics industry, the competitiveness of entire economic sectors would be jeopardized, and durably weakened, to the benefit of Asian and American competitors (*Saunier*, 2002).

DISTRIBUTION

Means of transportation

Sentence on card: *98% of the transportation market is based on oil, which has many environmental impacts.*



Transporting finished industrial electronic products requires producers to make decisions on factors such as speed, cost and associated pollution of shipment by land, sea and/or air, plus existing infrastructures. 98 % of the transportation market relies on petrol. Other environmental impacts include greenhouse gases: for an iPhone 5 - 64 GB model, 3% of GHG comes from transportation in an aquatic environment plus noise pollution (*Notre Planète. info*, 2015; *CNUCED*, 2018).

Concentrated value

Sentence on card: *The concentration of value during the transport of connected objects requires increased means of monitoring.*

Smartphones are extremely coveted consumer goods products. In China, a single long truckload can hold up to 36,000 iPhones. Given the value transported, some vehicles are equipped with cameras or accompanied by armed personnel (*Innocente*, 2016).

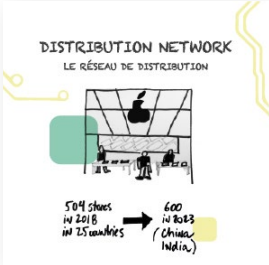
Warehousing and storage

Sentence on card: *The choice of centralized warehousing and the use of logistics service providers increases transport costs and the associated carbon footprint*

Le Organizing storage and warehousing are key to logistics network design. For example, Apple has chosen to have a single warehouse in the USA centralize product stocks that are then distributed to other regions of the world. The company outsources its activities to logistics service providers specialized in managing this type of flow. This type of centralization increases transportation costs and associated carbon footprint (*Black*, 2015).

The distribution network

Sentence on card: *Choices in the distribution network setup have an impact on the environment (multiplication of sales outlets, etc.).*



Distribution networks involve the number of participants in the network, their locations, the size of stakeholder groups, and the nature of relations among the stakeholders.
For instance regarding territory and players, since 2001, Apple's international strategy has been shops to sell only their products (504 in 2018, in 25 countries, plus an online shop in 39 countries, i.e. 65,000 employees). The number of Apple Stores will continue to grow to about 600 in 2023. This increase will be attributed to expansion in two, high potential countries: China and India where Apples Stores will offer easy (end of checkout) pay, a Genius Bar (free technical advice) and a presentation room for making American-style shows (*L. A. Story*. 2019).

Impacts of the distribution network

Sentence on card: *The share of transportation cost in a smartphone product is low but does not factor in indirect costs.*

The share of transport cost in a smartphone product is about 4%. This share is low compared to the share reserved for advertising and profits. This share does not include all the indirect costs of transport (transport externalities including environmental, social, etc. costs), which haven't been factored in (*Fagot*, 2018).

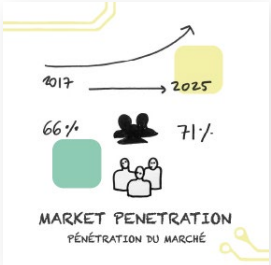
Duties and taxes

Sentence on card: *A grey market exists to circumvent duties and taxes on products.*

Smartphone distribution in a country is an important source of revenue. However, some countries seek to control the import flow of these smartphones by implementing actions to increase duties and taxes on these products (e.g. Algeria and India). To circumvent all these restrictions, a grey market is emerging, particularly in developing countries, which is a promising new market. For information, the price of an iPhone in China is 20% more expensive than in the US because of customs duties and taxes (*Sputniknews*, 2019).

Subsriber penetration

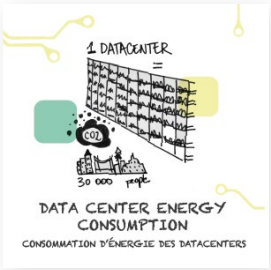
Sentence on card: *Increased mobile subscriptions.*



In 2015, more than 3 billion people owned a smartphone. By 2020, that number is expected to climb to over 6 billion, more than 70 % of global population, and that does not take into account repeat customers (*Palomino Lopez et al.* , 2020).

Energy consumption

Sentence on card: *In 2020, the global environmental impact of the ICT sector is expected to be 11% (energy consumption, data storage, ...).*



Information and communication techniques (ICT) represent 10% of electricity consumed worldwide and 4 to 5% of greenhouse gases (GHG). Even if the 50 to 70 billion IoT (internet of things) devices expected will consume fewer kilowatts, they will generate more data to be used and stored in datacenters.
The projected a smartphone install base is 3. 6 billion units by 2020, moving the global environmental impact of the ICT sector to 11%, an impact of 125MteCO2-e above the last decade. In 2015, more than 3 billion people owned a smartphone. By 2020, that number is expected to exceed 6 billion, more than 70% of the world population, not counting repeat customers (*Belkhir & Elmeligi*, 2018).

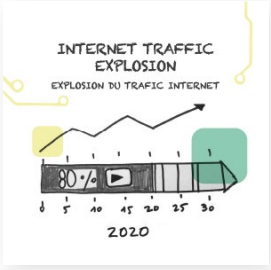
Health Impacts

Sentence on card: *Excessive screen time can lead to psychological disorders.*

Recent finds that excessive screen time in teens (beyond 30 minutes per day), leads to ailments such as depression, Nomophobia (panic of not being connected to the cellphone), interrupted sleep patterns, and a reduced ability to focus (*Twenge & Campbell*, 2018, *Patino*, 2019).

Explosion of internet traffic

Sentence on card: *Unprecedented growth in global mobile data traffic creates varying environmental impact depending on the network technology used.*



With the booming production of smartphones, the industry has experienced a similar increase of subscriptions and an unprecedented volume of global, mobile data traffic. The total, Internet traffic share of video streaming reached 80% in 2020, with a varying environmental impact depending on the network technology: 3G or Wi-Fi (*Cisco*, 2016).

Google queries

Sentence on card: *The estimated environmental burden of queries of French Internet users approximate 287,600 tons of CO^2 equivalent, or more than 1. 5 million km traveled by car.*

Every hour French users generate 180 million queries. If we only consider that each of the 29 million French internet users performs an average of 949 internet searches per year, the environmental load would be approximately 287,600 tons of CO^2 equivalent, which is more than 1. 5 million km traveled by car (*ADEME*, 2011).

Email with attachments to multiple users

Sentence on card: *The impact of sending an email increases according to its weight (attachment) and the number of recipients.*

In France, every employee of a medium enterprise sends approximately 33 emails per day. If each email weighs 1 MB (content + attached files) and is addressed to 2 recipients, annually they will generate 180 kg of CO^2, or the equivalent of more than 1,000 km traveled by car. These impacts could be multiplied by 4 if the number of recipients is multiplied by 10 (*ADEME*, 2011).

END OF LIFE

Electronic waste increase

Sentence on card: *In 2017, small ICT-related e-waste amounted to 3 million tons, representing some $52 billion of potentially reusable resources.*

In 2017 small ICT e-waste amounted to 3 million tons, of potentially reusable resources and a volume sufficient to bury San Francisco annually under 14 feet. Little was collected for recovery, or even treated/disposed of in an environmentally correct manner. Less than one-sixth (5 to 10 %) is thought to have been properly recycled or made available for reuse. This represents both a valuable and a toxic urban mine. The UN report estimates that the 2014 discarded e-waste contained some 16,500 kilotons of iron, 1,900 kilotons of copper, and 300 tons of gold as well as significant amounts of silver, aluminum, palladium, and other potentially reusable resources, with a combined, estimated value of US $52 billion.
It also contained substantial amounts of health-threatening toxins such as mercury, cadmium, chromium, and ozone-depleting chlorofluorocarbons (*Greenpeace*, 2017b).

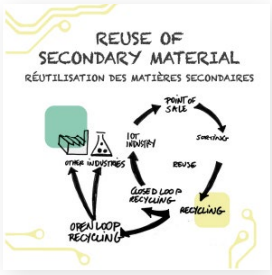
E-waste recycling

Sentence on card: *Working conditions in the informal waste treatment market are harmful to workers.*

Traders send e-waste to developing countries where workers earn extremely low wages and law enforcement is weak. Health, safety and human rights infrastructures are of little concern as is the environment (*Filippi*, 2020). Common (dangerous) practices for recovering metals include:
- Hammer bashing to open cathode ray tubes: inhaling the toxic phosphorus dust within.
- Cooking circuit boards in woks over open fires to melt the lead solder: inhaling toxic lead fumes.
- Burning wires in open piles to melt the plastics and retrieve the copper.
- Burning plastic casings creates dioxins and furans – some of the most poisonous fumes.
- Tossing unwanted (but very hazardous) leaded glass into former irrigation ditches.
- Dumping pure acids and dissolved heavy metals directly into rivers.

Reuse of secondary materials

Sentence on card: *Few materials are used in closed-loop manufacturing of new systems.*



While a few IT companies have incorporated recycled plastics in their products for several years, very little progress has been made in sourcing other secondary materials into new products. Fairphone incorporates recycled tungsten, and Dell has shown success in using closed-loop plastic collected from its take- back channel. Apple recently committed to "closing the loop" for its materials, starting with tin and aluminum (*Greenpeace*, 2017b).

E-waste dumping

Sentence on card: *Electronic recycling in industrialized countries remains expensive.*

Pretexting compliance with the Bâle convention of reuse and repair, electronic waste is sent to Africa. In reality the recycling processes in industrialized countries are too expensive and don't comply with environmental norms (*Pitron*, 2018).

Mafia

Sentence on card: *Do local mafias have a monopoly on waste treatment?*

The informal market for the treatment of electronic waste would be run by local mafias (*Filippi*, 2020).

ACKNOWLEDGEMENTS

The teams of NEED for IoT and IRT Nanoelec teams for their trust and support; Slow Fashion Forward (Maureen Dickson, Crystal Hodges and Carlotta Cataldi) for permitting adaptation of the game "My Garment: a discovery game"; Valérie Schneider for the idea of integrating Circulab tools; Stéphane Pagès from AFB France; Laetitia Vasseur, Lucie Tamet, and Ronan Groussier from Halte à l'Obsolescence Programmée (HOP); the legal support and Doctoral College of Université Grenoble Alpes and Floralis; Elise Monnier of the CEA for accepting to be a co-animator; Olivier Vidal and Guillaume Pitron for the inspiration; and the Kaperli agency and its team of graphic designers for the edition.

Authors: Laetitia Thomas, NEED for IoT & NanoElec Formation
Contribution: Circulab
Funding: IDEX - Université Grenoble Alpes & IRT Nanoelec
Editing: Editions Kaperli

RIGHTS OF USE

REFERENCES

ADEME (2011). Les TIC*, Quels Impacts? ADEME. [online] Available at: <https://communication-responsable.ademe.fr/sites/default/files/guide-ademe-tic-quels-impacts.pdf> [Accessed 9 November 2020].

ARTE. (2020). Génération écran génération malade? (video). Available at: https://www.youtube.com/watch?v=ovbeMGfSO2M. [Accessed 06/11/20].

Belkhir, L. , & Elmeligi, A. (2018). Assessing ICT global emissions footprint: Trends to 2040 & recommendations. Journal of Cleaner Production, 177, 448-463. Bryant

Black, K. , 2020. Apple: A Global Leader In Supply Chain Management. [online] https://smbp. uwaterloo.ca/. Available at: <https://smbp. uwaterloo.ca/2015/06/apple-a-global-leader-in-supply-chain-management/> [Accessed 9 November 2020].

Bontron, C. (2012). En Chine, les terres rares tuent des villages. Le Monde, 53(9), 1689–1699. <https://doi.org/10. 1017/CBO9781107415324.004> [Accessed 06/11/20].

China Labor Watch. (2019). iPhone 11 Illegally Produced In China. [online] Available at: <http://www.chinalaborwatch.org/upfile/2019_09_06/Zhengzhou%20Foxconn%20English%2009.06. pdf> [Accessed 9 November 2020].

Cisco (2016). Network Traffic Forecast [online] Available at: <https://www.cisco.com/c/en/us/solutions/executive-perspectives/annual-internet-report/index.html> [Accessed 9 November 2020].

Conférence des Nations Unies sur le Commerce et le Développement, 2018. Etudes Sur Les Transport Maritimes. [online] United Nations. Available at: <https://unctad.org/fr/system/files/official-document/rmt2018_fr.pdf> [Accessed 9 November 2020].

Electronics takeback coalition. 2014. Facts and Figures on E-waste and Recycling. [online]. Available online at: http://www.electronicstakeback.com/ (Accessed 9/11/20). [Accessed 9 November 2020].

Electronics Takeback Coalition, 2014. Samsung Apologizes To Semiconductor Workers Who Contracted Cancer, Promises Compensation. [online]. Available at: <http://www.electronicstakeback.com/2014/05/27/samsung-apologizes-to-semiconductor-workers-who-contracted-cancer-promises-compensation/> [Accessed 9 November 2020].

Fagot, V. , 2020. Les Apple Stores, Machine À Cash Du Géant Américain. [online] Le Monde. Available at: <https://www.lemonde.fr/economie/article/2018/11/18/les-apple-stores-machine-a-cash-du-geant-americain_5385060_3234.html> [Accessed 9 November 2020].

Filippi, L. , 2020. La Décharge De Déchets Électroniques D' Agbogbloshie, Véritable Défi Économique Et Environnemental Pour Le Ghana. [online] Available at: <https://www.francetvinfo.fr/monde/afrique/societe-africaine/la-decharge-de-dechets-electroniques-dagbogbloshie-veritable-defi-economique-et-environnemental-pour-le-ghana_3863287.html> [Accessed 9 November 2020].

Grandell, L. , Lehtilä, A. , Kivinen, M. , Koljonen, T. , Kihlman, S. , & Lauri, L. S. (2016). Role of critical metals in the future markets of clean energy technologies. Renewable Energy, 95, 53-62. doi:10.1016/j.renene. 2016. 03. 102

Greenpeace. (2017). Greenpeace Report: Guide to Greener Electronics 2017 - Greenpeace USA. In Greenpeace Reports. <https://www.greenpeace.org/usa/reports/greener-electronics-2017/> [Accessed 06/11/20].

Innocente, F. , 2016. Le Périple Des Iphone Depuis Zhengzhou Jusqu'aux Apple Store. [online] MacGeneration. Available at: <https://www.macg.co/aapl/2016/12/le-periple-des-iphone-depuis-zhengzhou-jusquaux-apple-store-96898> [Accessed 9 November 2020].

L. A. Story. 2019. Etude De Cas: L'iphone, Un Produit Mondialisé. [online] Available at: <http://la-story.over-blog.com/2016/11/etude-de-cas-l-iphone-un-produit-mondialise.html> [Accessed 9 November 2020].

Lakhiani, V, 2020. The Buddha and the Badass: the secret spiritual art of succeeding at work. New York: Rodale Books

Notre planete. info, 2020. Commerce Mondial: Le Transport International De Marchandises Va Quadrupler D'ici 2050. [online] Available at: <https://www.notre-planete. info/actualites/4211-augmentation-transport-marchandises-CO2> [Accessed 9 November 2020].

Palomino Lopez, A. , Marty, J. , Auffret, S. , Joumard, R. , Sousa, I. L. , Prejbeanu, B. , Ageron, B. , Dieny, B. (2020). Evaluating critical metals contained in spintronic memory with a particular focus on Pt and its possible substitution. Grenoble: Université Grenoble Alpes.

Patino, B. (2019). La civilization du poisson rouge. Petit traité sur le marché de l'attention. Paris: Éditions Grasset.

Pitron, G. (2018). La Guerre des métaux rares. Paris: Éditions Les liens qui libèrent.

Saunier, C. (2002). Office parlementaire d'évaluation des choix scientifiques et technologiques. L'industrie de la microélectronique: reprendre l'offensive. Paris.

Schneider, V. (2016). Les enjeux sociaux et environmentaux des objets connectés. (23 Juin 2016). Available at: <http://www.valerieschneider.com/2016/06/les-enjeux-sociaux-et-environnementaux-des-objets-connectes/>

Sinaeepourfard, A. , Garcia, J. , Masip-Bruin, X. , Marín-Tordera, E. , Cirera, J. , Grau, G. , & Casaus, F. (2016, June). Estimating Smart City sensors data generation. In 2016 Mediterranean Ad Hoc Networking Workshop (Med-Hoc-Net) (pp. 1-8). IEEE.

Sputniknews.com. 2020. Pourquoi Les Algériens Paieront-Ils Plus Chers Leurs Smartphones À Partir De 2020? [online] Available at: <https://fr.sputniknews.com/maghreb/201911111042406516-pourquoi-les-algeriens-paieront-ils-plus-chers-leurs-smartphones-a-partir-de-/> [Accessed 9 November 2020].

Twenge, J. M. , & Campbell, W. K. (2018). Associations between screen time and lower psychological well-being among children and adolescents: Evidence from a population-based study. Preventive Medicine Reports, 12 (October), 271–283. <https://doi.org/10.1016/j.pmedr.2018.10.003>

US Congressional research service. (2020). The Internet of Things (IoT): An Overview. Available at: <https://crsreports. congress. gov/product/pdf/IF/IF11239> (12 Febuary 2020).