

MAGCD Y1

Unit 1 Methods of Iterating

Brain Storming

We each find the directions we're interested in and then bring them together.

MIKO
Idea A(Hi guys, you can just read the Bold texts which are the core. others are analysis and "fake" plan. Moreover, I think I should think the outcome earlier, preventing we chose an impossible outcome..... However, it is not the final one, i just mentioned anyway)

Research Topic:
Electronic Carbon Emissions

Background:
The estimated total digital carbon emissions of the UK in 2020 are 2,849,000t per year, with a total energy consumption of 8,539,505 kWh per year.

- Computers, printing, and server rack equipment account for 64%, equivalent to 1,824 tCO₂e/year
- Network and telephone account for 37%, 899 tCO₂e/year
- Cloud storage and hosting account for 4%, 127 tCO₂e/year

Within the "Computers/Printing/etc" category, the report lists simple device breakdowns:

- Desktops: 2,709 units (1,428 tCO₂e)
- Laptops: 4,865 units
- Monitors: 3,372 units
- Smartphones: 762 units
- Plus missing robot displays and AI systems

If we convert the actual figure into smaller units like hours or days:

- "Computers/Printing/etc" = 1,824 tCO₂e/year = 4,967 kg CO₂e/day = 208 kg CO₂e/hour (averaged across the year)

Energy consumption and cost for this category are also quantified:

- 3,442,293 kWh/year
- Estimated electricity cost: £856,524/year

Reflection:
All the above data exist on a macro scale of time — it's hard to personally perceive how our daily computer use translates into carbon emissions.

Question:
How can graphic or interaction design translate this macro timescale (year) into micro-scale feedback (hours/days) that individuals can feel — to help build a sense of temporal connection between "behavior — energy use — carbon output"?

Experiment:
Calculation method:
A. Calculate how much electricity we use in one workday:
Energy consumption = Power (W) / 1000 * Hours of use
B. The carbon intensity of electricity grids varies by country/region (EU average = 0.25 kgCO₂e/kWh)
C. Daily electricity consumption * 0.25 kgCO₂e/kWh = Daily carbon emissions.

Output Proposal:
Create a desktop pet (small widget) — like a digital companion that moves around on the screen and occasionally pops up a notification showing today's computer-related carbon emissions.

Visual References:
• Desktop Gnome: YouTube Link: <https://www.youtube.com/watch?v=UdUdUdUdUd>
— The gnome occasionally wanders around the desktop saying things like "good work." This kind of playful interaction could be a reference.
• Desktop Cat: Bongo Cat

Frame 7: A central hub of information with various charts, graphs, and text blocks related to digital carbon emissions.

Frame 8: A text block with a yellow highlight: "Some widely cited projections suggest ICT could reach ~14% of global emissions by 2040 under unchecked growth, but outcomes vary a lot depending on efficiency and energy decarbonisation."

Frame 9: A text block with a yellow highlight: "Some widely cited projections suggest ICT could reach ~14% of global emissions by 2040 under unchecked growth, but outcomes vary a lot depending on efficiency and energy decarbonisation."

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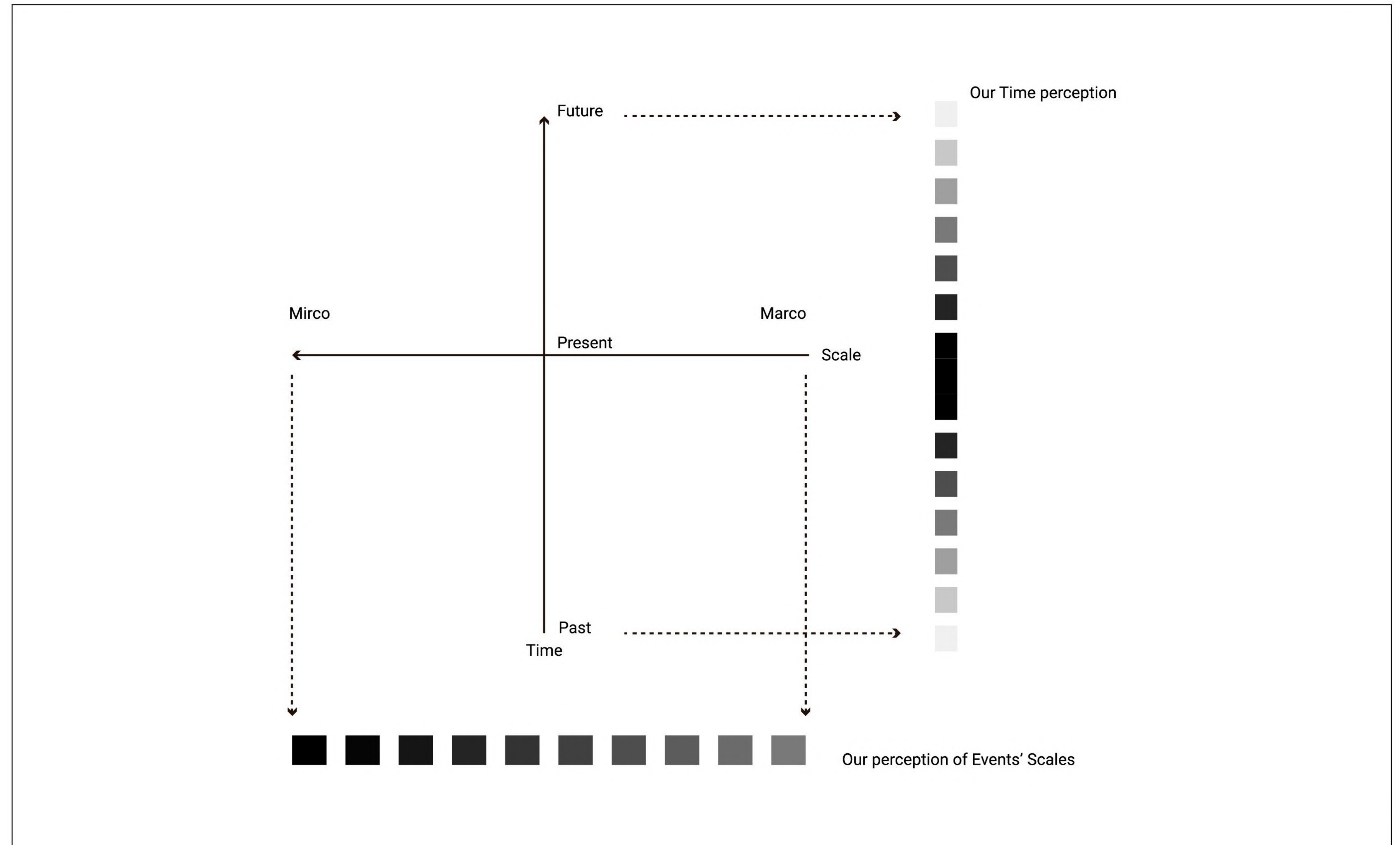
Frame 11: A text block with a yellow highlight: "Some widely cited projections suggest ICT could reach ~14% of global emissions by 2040 under unchecked growth, but outcomes vary a lot depending on efficiency and energy decarbonisation."

Frame 12: A vertical stack of three colored boxes (blue, green, pink) with the text: "Digital Afterlife. The idea of a digital cemetery which explores time in 3 dimensions. Many time dimensions of technology, particularly the aspects of storage and hosting, allow us to store data for years, decades, or even centuries. Carbon emissions, however, are not stored. Carbon already lost: digital that doesn't reset every year // so this can be the mismatch, core issue, starting point"

Assumption

Introducing a temporal axis — present, future — makes the problem more visible. Human perception is sharpest at the present moment.

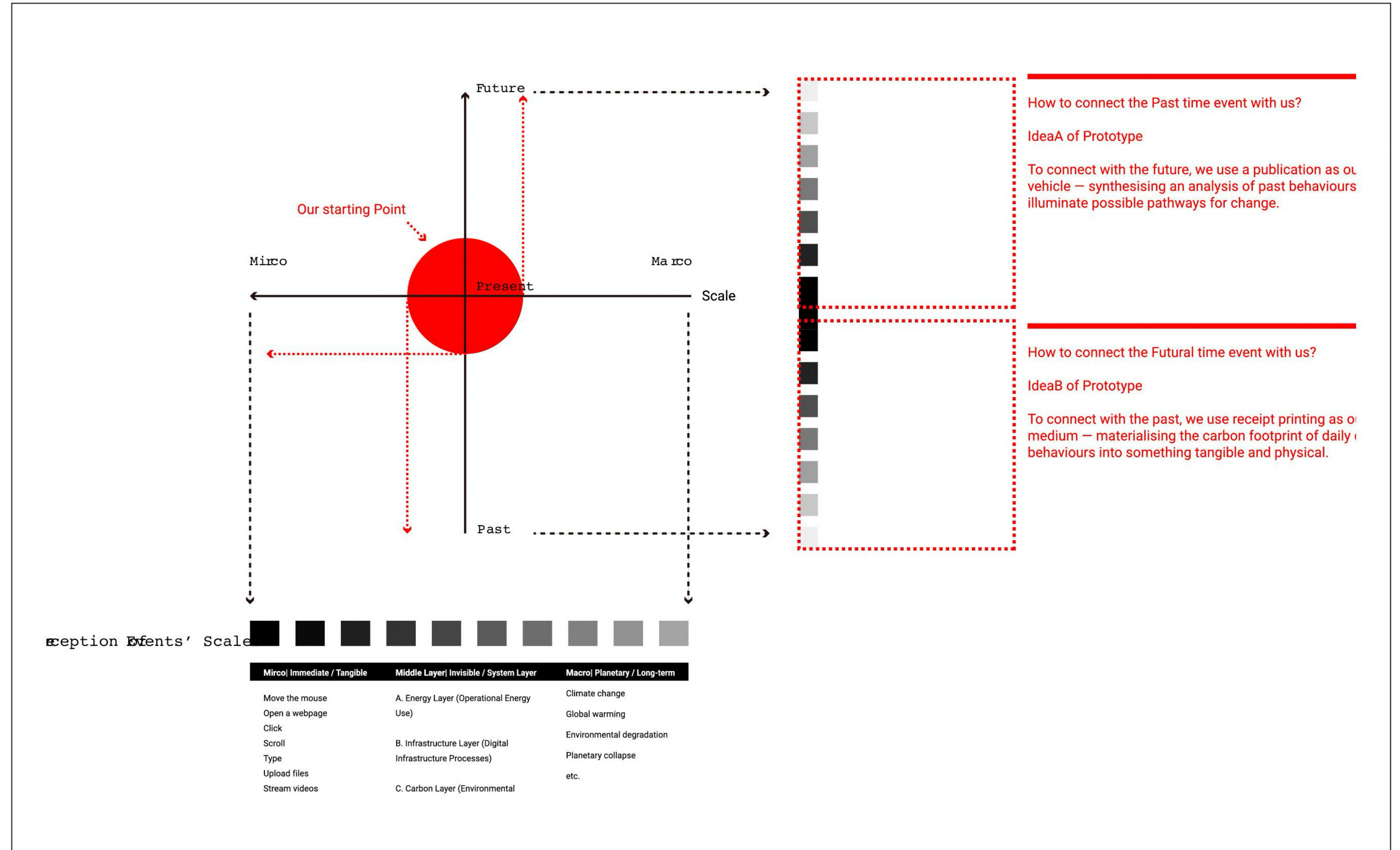
Our sense of the past and the future is comparatively dim, and tends to remain so until anchored by a specific event, a concrete experience, or a tangible point of reference. Without that anchor, distant time remains distant.



Assumption

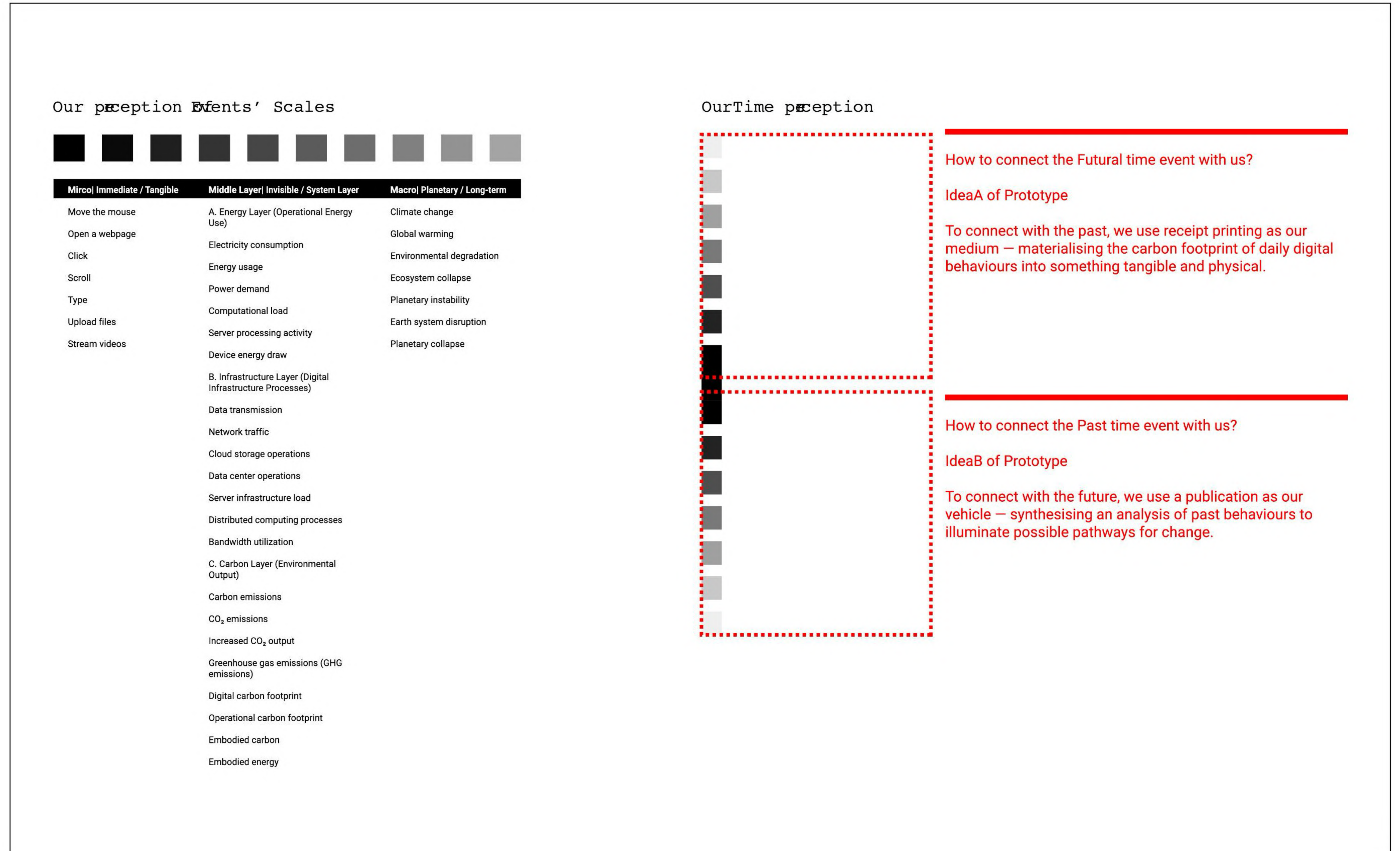
This brings us to a central question:

**How can a design intervention make the hidden carbon cost of everyday digital habits visible and actionable across micro (daily) and macro (future) timescales at UAL?
And furthermore — what role can design play in this context?**



Ideas

To address this question, we decided to explore it from two dimensions:
(1) how we form meaningful connections with the past and the future, and
(2) how stronger connections can be created through a micro scale that we can more directly sense and experience.



Prototype - PartA

-Data Physicalization: Receipt printer

This is a device that tracks every interaction a user has with their computer

— each keystroke, each trackpad gesture, each window opened, switched, or closed, each quiet movement within a browser(to be revised)

Within this system, time spent at the computer serves as the fixed quantity; user behaviour and carbon output become the dynamic variables made visible.

The past is no longer a number on a report.
It becomes something you can hold.

Receipt metaphor



Prototype - PartA

-Data Physicalization: Receipt printer

Our question:

How can we made inner working of the system exposed to the user? In what way we can calculate the power and eventually amount of carbon being used throughout the day of CSM student?

Throughout experimentation we used Python language to pull data from the computer apps to understand how much energy costs daily computer tasks.

- Every few seconds it checks which app is frontmost.

- It translates that app into one of 10 activity categories (Browser, Messaging, Code, etc.).

- When the category changes, it prints one row: time + a bubble code (1–10) + an energy estimate.

- The energy number is calibrated from my real battery drop.

Iterations

1

```
digital_receipt_event_only_mac -- zsh -- 80x24
13:56:09 CATEGORY + Code / Dev
13:56:18 APP_SWITCH + ChatGPT
13:56:18 CATEGORY + Other Apps
13:56:36 BATTERY_N + 38%
13:56:59 BATTERY_N + 39%
13:57:29 BATTERY_N + 48%
13:57:31 CHARGE_STATE + Discharging
13:57:31 POWER_BAND + VERY_HIGH (~214904568458716288.0 W)
14:04:59 POWER_BAND + LOW (-0.0 W)
14:09:17 CPU_SPIKE_START 58%
14:09:20 CPU_SPIKE_END 37%
14:09:22 APP_SWITCH + Terminal
14:09:22 CATEGORY + Code / Dev
14:09:41 APP_SWITCH + Google Chrome
14:09:41 CATEGORY + Browser / Reading
14:09:46 APP_SWITCH + Terminal
14:09:46 CATEGORY + Code / Dev
14:10:17 POWER_BAND + VERY_HIGH (~288521995889212736.0 W)
14:10:21 APP_SWITCH + ChatGPT
14:10:21 CATEGORY + Other Apps
14:10:30 APP_SWITCH + Google Chrome
14:10:30 CATEGORY + Browser / Reading
14:10:34 APP_SWITCH + Terminal
14:10:34 CATEGORY + Code / Dev
```

2

```
GITAL HABITS RECEIPT (terminal prototype)
26-02-17 12:48:04
-----
Controls: s start/stop | p/P print | e export | x CSV | r reset | q quit
-----
Status: STOPPED Poll: 5s

Time by activity (top):
• Other Apps 13m 35s
• Browser / Reading 7m 05s
• Code / Dev 1m 30s

Measured transfer (system):
• Download 96.6 MB
• Upload 9.4 MB
• Total 106.0 MB

Compute proxy:
• High CPU time 25s (CPU>=50%)

Manual actions:
• Printed pages 0
• Exports/versions 0
```

3

```
digital_receipt_bubbles_energy_rightcol_mac -- Python digital_receipt_...
Tot:16.41Wh
143 ○○○○○●○○○○ 14:59:01 CATEGORY → Creative ~+0.000Wh 6.97Wh Tot:16.41Wh
144 ○○○○○○○○○○ 15:01:58 APP_SWITCH → Safari ~+1.339Wh 8.31Wh Tot:17.75Wh
145 ○○○○○○○○○○ 15:01:58 CATEGORY → Browser / Reading ~+0.000Wh 3.13Wh Tot:17.75Wh
146 ○○○○○●○○○○ 15:02:11 APP_SWITCH → Adobe Illustrator ~+0.100Wh 3.24Wh Tot:17.85Wh
147 ○○○○○●○○○○ 15:02:11 CATEGORY → Creative ~+0.000Wh 8.31Wh Tot:17.85Wh
148 ○○○○○○○○○○ 15:02:13 APP_SWITCH → Safari ~+0.017Wh 8.33Wh Tot:17.87Wh
149 ○○○○○○○○○○ 15:02:13 CATEGORY → Browser / Reading ~+0.000Wh 3.24Wh Tot:17.87Wh
150 ○○○○○●○○○○ 15:02:15 APP_SWITCH → Adobe Illustrator ~+0.017Wh 3.25Wh Tot:17.89Wh
151 ○○○○○●○○○○ 15:02:15 CATEGORY → Creative ~+0.000Wh 8.33Wh Tot:17.89Wh
152 ○○○○○○○○○○ 15:03:17 APP_SWITCH → ChatGPT ~+0.468Wh 8.79Wh Tot:18.35Wh
153 ○○○○○○○○○○ 15:03:17 CATEGORY → AI / Chat ~+0.000Wh 3.53Wh Tot:18.35Wh
154 ○○○○○○○○○○ 15:03:50 APP_SWITCH → Finder ~+0.251Wh 3.78Wh Tot:18.60Wh
155 ○○○○○○○○○○ 15:03:50 CATEGORY → System ~+0.000Wh 0.12Wh Tot:18.60Wh
156 ○○○○○○○○○○ 15:04:03 APP_SWITCH → Terminal ~+0.100Wh 0.22Wh Tot:18.70Wh
157 ○○○○○●○○○○ 15:04:03 CATEGORY → Code / Dev ~+0.000Wh 2.17Wh Tot:18.70Wh
```

4

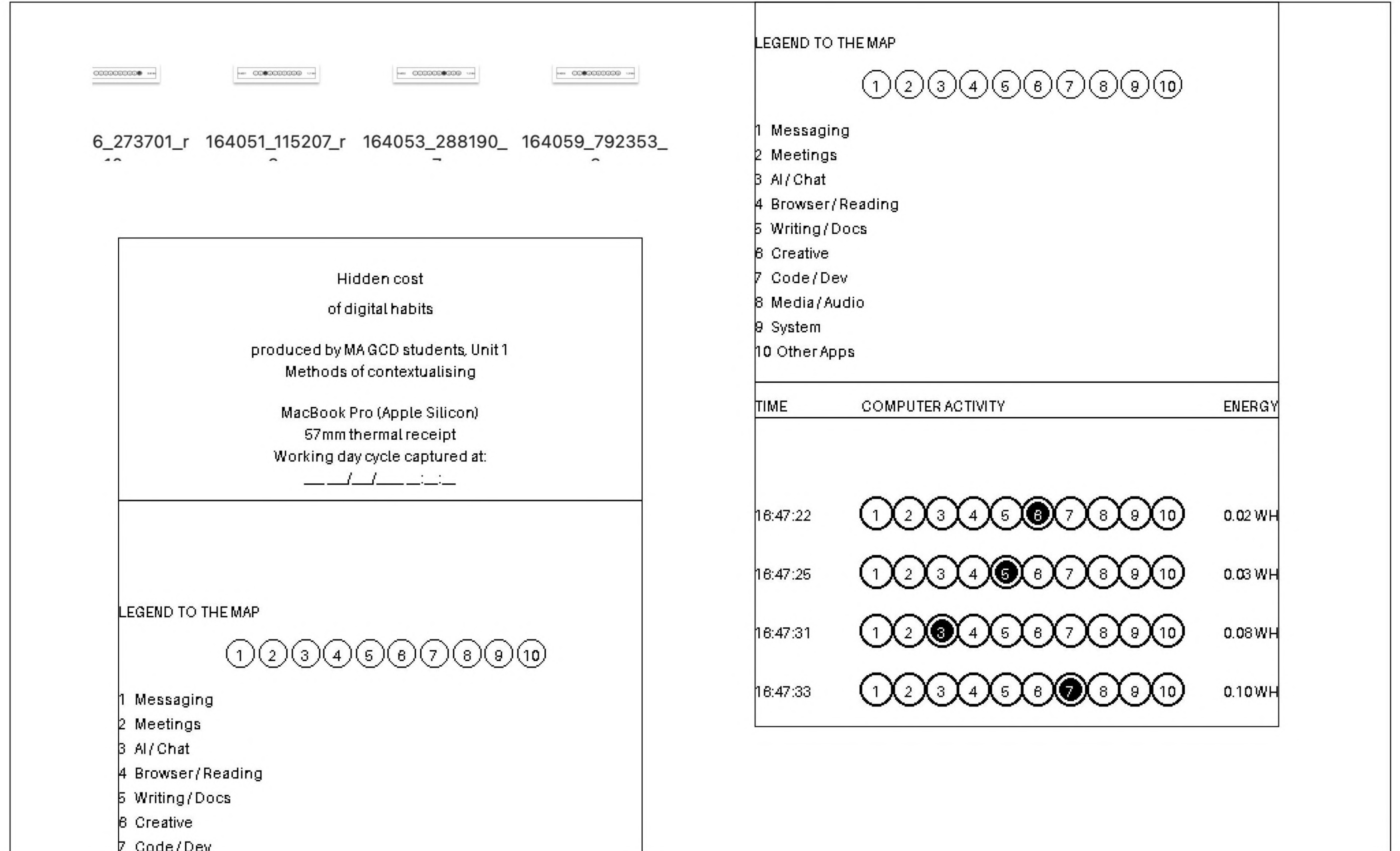
```
digital_receipt_live -- Python digital_receipt_live_header.py --energy 83...
15:06:45 01 02 03 04 05 06 07 08 09 10 8.12 Wh
15:06:47 01 02 03 04 05 06 07 08 09 10 8.13 Wh
15:06:49 01 02 03 04 05 06 07 08 09 10 8.15 Wh
15:09:44 01 02 03 04 05 06 07 08 09 10 1.48 Wh
15:10:39 01 02 03 04 05 06 07 08 09 10 1.98 Wh
15:10:43 01 02 03 04 05 06 07 08 09 10 1.93 Wh
15:10:50 01 02 03 04 05 06 07 08 09 10 1.98 Wh
15:10:52 01 02 03 04 05 06 07 08 09 10 2.00 Wh
15:10:56 01 02 03 04 05 06 07 08 09 10 2.03 Wh
15:11:05 01 02 03 04 05 06 07 08 09 10 2.10 Wh
15:11:11 01 02 03 04 05 06 07 08 09 10 2.15 Wh
15:11:16 01 02 03 04 05 06 07 08 09 10 2.18 Wh
15:12:12 01 02 03 04 05 06 07 08 09 10 2.61 Wh
15:18:19 01 02 03 04 05 06 07 08 09 10 5.41 Wh
15:18:21 01 02 03 04 05 06 07 08 09 10 5.42 Wh
15:22:49 01 02 03 04 05 06 07 08 09 10 7.47 Wh
15:23:11 01 02 03 04 05 06 07 08 09 10 7.64 Wh
15:23:13 01 02 03 04 05 06 07 08 09 10 7.65 Wh
15:23:15 01 02 03 04 05 06 07 08 09 10 7.67 Wh
15:23:24 01 02 03 04 05 06 07 08 09 10 7.73 Wh
15:23:28 01 02 03 04 05 06 07 08 09 10 7.77 Wh
15:23:39 01 02 03 04 05 06 07 08 09 10 7.85 Wh
```

$$8.61 \text{ Wh} / 0.333 \text{ h} = \sim 25.8 \text{ W average}$$

Prototype - PartA

-Data Physicalization: Receipt printer

Current Python iteration
 Currently doesn't use the printer, so it just exists
 digitally



Prototype - PartB

Physical receipt insert

A printed receipt sample that documents everyday digital activity as a “cost” you can hold and review.

Introduction

Context for the project, intentions, and process — explaining why we chose a receipt printer as the format (familiar, immediate, transactional) and how the prototype works.

Infographic 1 — The concertina timeline

A long fold-out strip that visualises the tracked data over time, with a clear legend. It shows accumulated energy use and estimated carbon impact, plus how energy providers/grid intensity influence overall emissions.

Infographic 2 — Futures comparison (best vs worst case)

Two contrasting scenarios shown side-by-side (or printed double-sided): what this footprint could look like if practices improve versus if nothing changes.

Explanatory text

Short, accessible descriptions that decode the infographics: what each element represents, how to read it, and what the key findings are.

Action plan

Practical recommendations at two levels:

- Personal: small habit and settings changes that reduce impact.
- UAL / CSM: institutional suggestions informed by our findings (policies, design standards, procurement/IT choices, publishing practices).

The Miro board displays a prototype design for a receipt printer. It features a handwritten receipt sample on lined paper, a list of publication contents, and a dimension of 57 mm. The receipt sample is titled "C. End user Device" and lists "Creative Tools" etc.) and "TOTAL (Wh) every N seconds (this is your 'continuous'". The handwritten receipt also includes a table with columns for "Something we are using" and "Carbon emission factor".

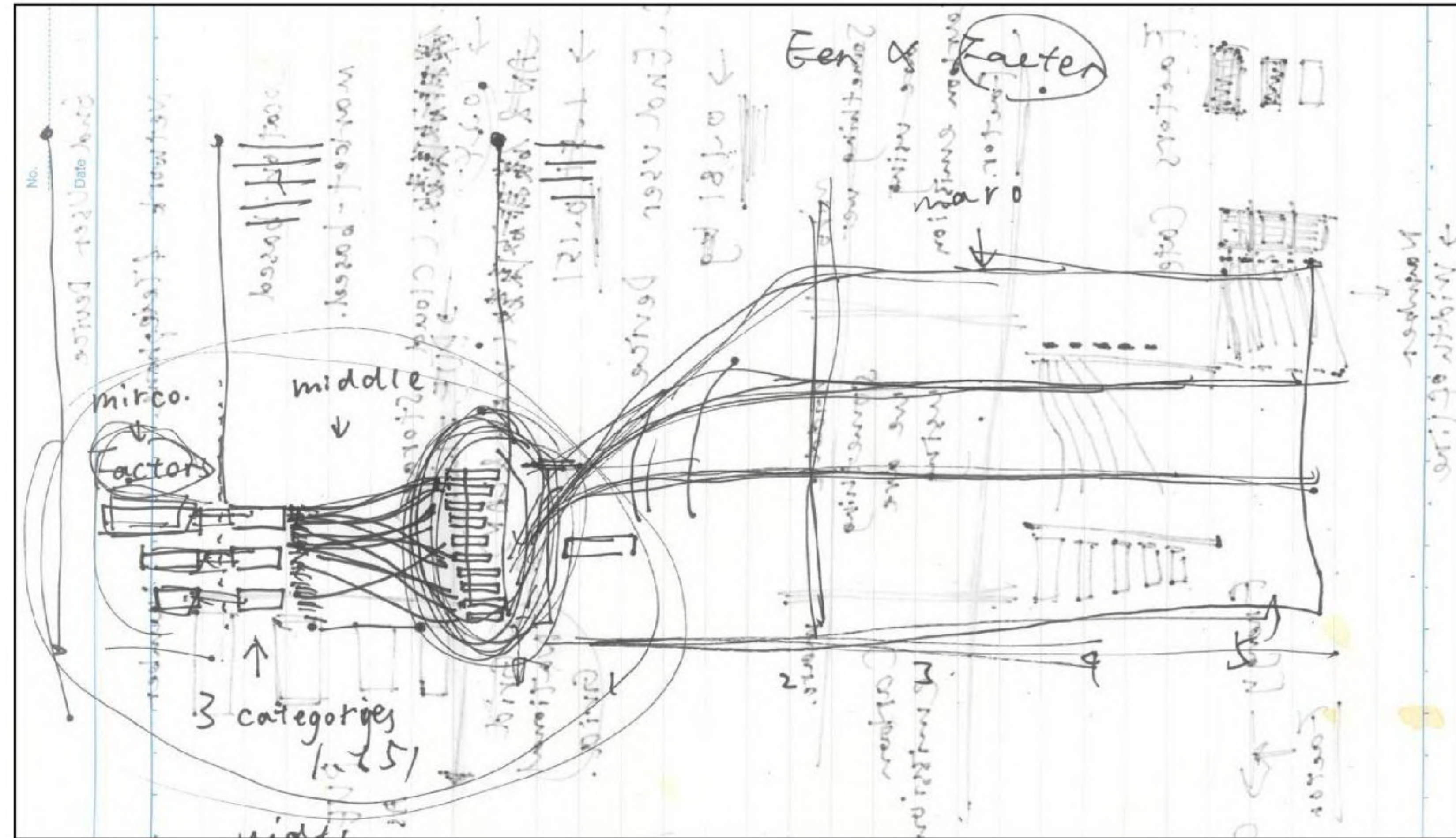
Publication contents:

1. Physical version of the receipt
2. Introduction — explain the context for the work, intentions, the process and why the idea of printer+receipt
3. Infographics 1 — the prolonged concertina with visualized information + legend: it contains accumulated carbon emissions, usage of the energy providers and the way they affect overall usage of the energy and carbon emissions
4. Infographic 2- worst and best case scenario of the future ? Like show the two different scenarios (on the same page but printed double sided)
5. Textualized information/description of the infographics
6. Action plan: can be small suggestions on a personal level, plus suggestions for UAL CSM — based on our findings

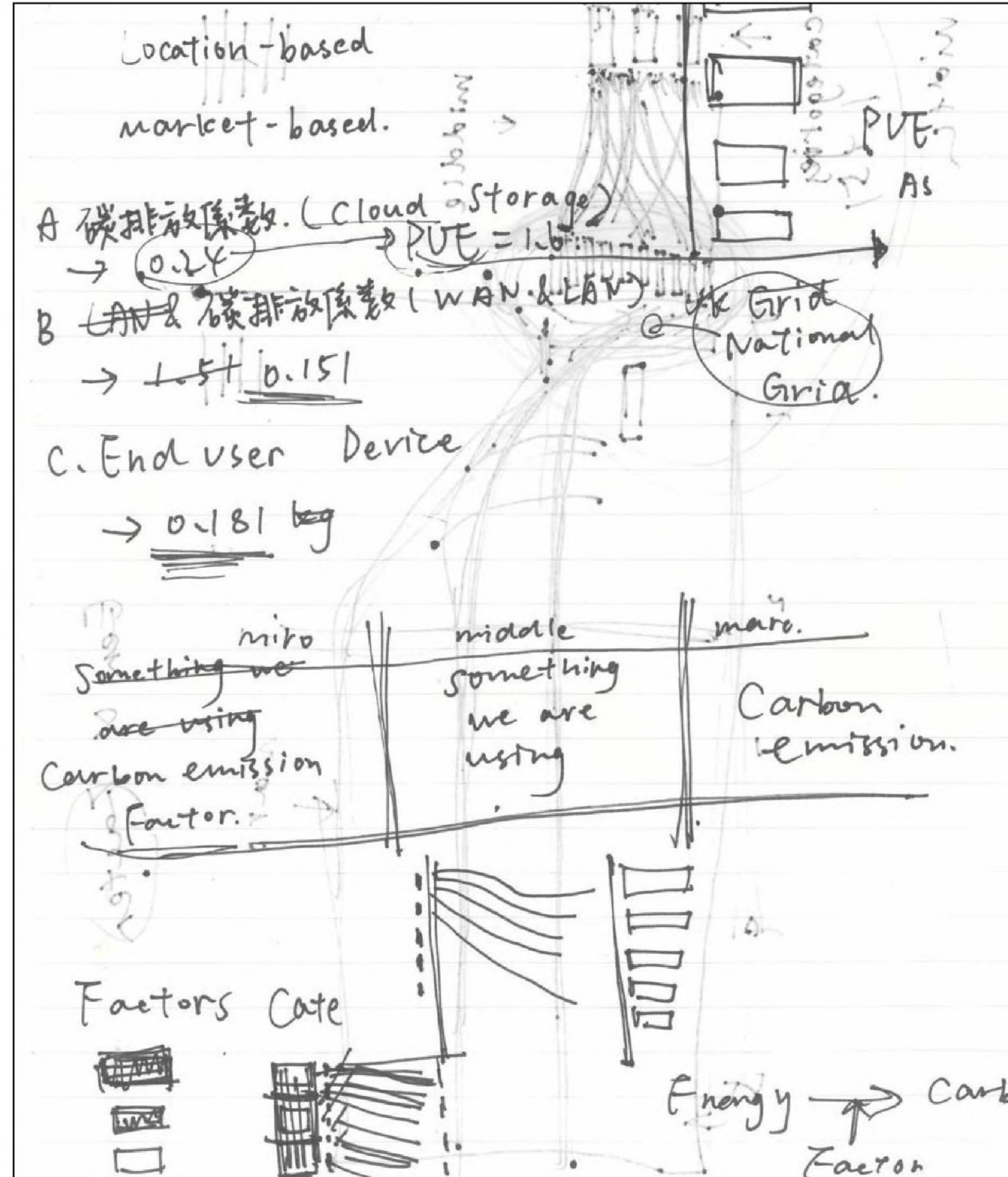
Dimension of the publication: 57 mm

Prototype - PartB

-Publication- the logic of Infographic



Sketch of Infographic



Analysis of Data

	A	B	C	D	E
	Annual Carbon (tCO2e)	Annual Energy (kWh)	Carbon Emission Factor	PUe (Power Usage Effectiveness)	
Devices		92.49	510412	0.181	
Storage		103.58	630509	0.151	1.6
TOTAL	418.49	1202842		0.24	

Section	Item	Annual Energy (kWh)	Annual Carbon (tCO2e)
SERVERS	Desktops	250792	92.49
SERVERS	Wireless Network	9018	0.151
SERVERS	LAN Network	18716.8	0.151
SERVERS	On-prem Storage	11904.4	0.151
SERVERS	Server Rack Energy	1100	0.151
TOTAL	Network Total	630509	103.58
TOTAL	Annual Energy Cost (£)	16099	18.29

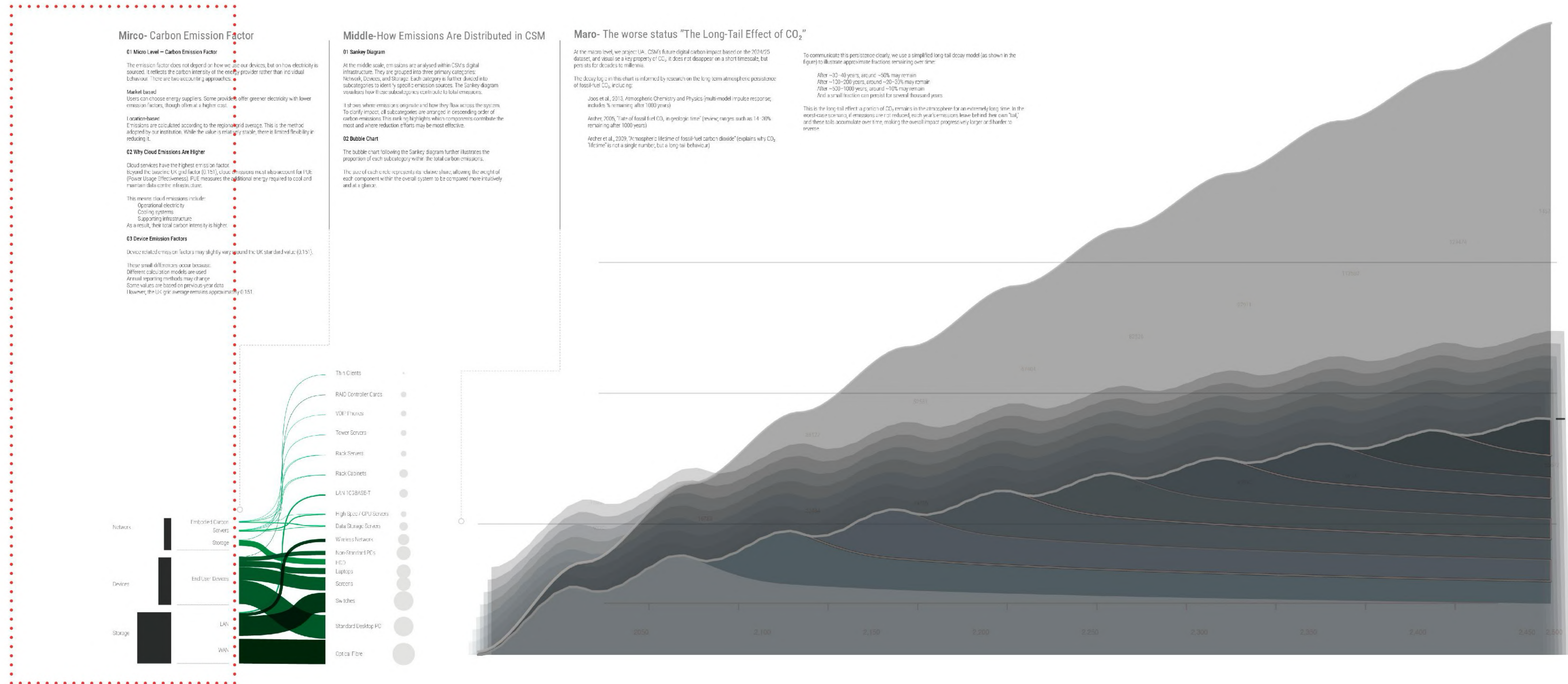
Item	Annual Energy (kWh)
Standard Desktop PC	256431
Thin Clients	0
Non-Standard PCs	44888
Screens	142800
Laptops	65375
VOIP Phones	1918.22
Total Energy	510412
Total Carbon (tCO2e)	92.49

Section	Item	Annual Energy (kWh)	Annual Carbon (tCO2e)
Servers	Rack Cabinets	1068	
Servers	Tower Servers	972	
Servers	Rack Servers	1525	
Servers	High Spec / GPU Servers	8365	
Servers	Data Storage Servers	3328.56	
Servers	Total Server Energy	15258	3.69
Storage	RAID Controller Cards	652	
Storage	HDD	46011	
Storage	Total Storage Energy	46663	11.27
Embodied Carbon	Rack Cabinets		0.72
Embodied Carbon	Tower Servers		0.14
Embodied Carbon	Rack Servers		0.13
Embodied Carbon	High Spec / GPU Servers		0.5
Embodied Carbon	Data Storage Servers		1.84
Embodied Carbon	Total Embodied Carbon		3.33
TOTAL	Cloud Total Energy	61921	18.29
TOTAL	Annual Energy Cost (£)	16099	

Prototype - PartB

Infographic Part 1

Micro Perspective: Carbon Emission Factor



Prototype - PartB

Infographic Part 2

Middle Perspective: Sankey + Bubble Chart

Mirco- Carbon Emission Factor

01 Mirco Level - Carbon Emission Factor

The emission factor does not depend on how we use our devices, but on how electricity is sourced. It reflects the carbon intensity of the energy provider rather than individual behaviour. There are two accounting approaches.

Market based

Users can choose energy suppliers. Some providers offer greener electricity with lower emission factors, though often at a higher cost.

Location-based

Emissions are calculated according to the regional grid average. This is the method adopted by our institution. While the value is relatively stable, there is limited flexibility in reducing it.

02 Why Cloud Emissions Are Higher

Cloud services have the highest emission factor. Beyond the basic UK grid factor (0.151), cloud services must also account for PUE (Power Usage Effectiveness). PUE measures the additional energy required to cool and maintain data centre infrastructure.

This means cloud emissions include:

- Operational electricity
- Cooling systems
- Supporting infrastructure

As a result, their total carbon intensity is higher.

03 Device Emission Factors

Device related emission factors may slightly vary around the UK standard value (0.151).

These small differences occur because:

- Different calculation models are used.
- Annual reporting methods may change.
- Some values are based on previous year data.

However, the UK grid average remains approximately 0.151.

Middle-How Emissions Are Distributed in CSM

01 Sankey Diagram

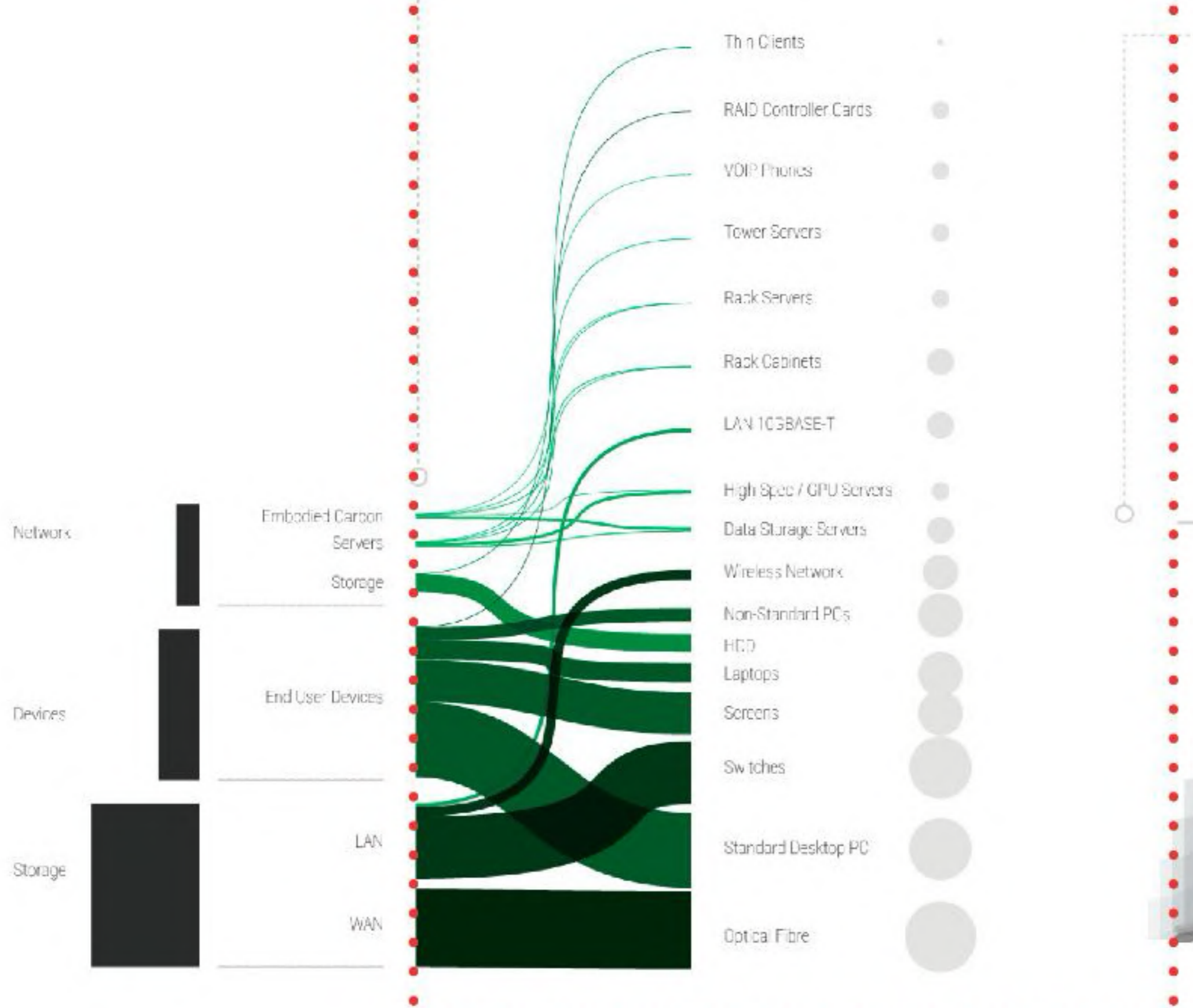
At the middle scale, emissions are analysed within CSM's digital infrastructure. They are grouped into three primary categories: Network, Devices, and Storage. Each category is further divided into subcategories to identify specific emission sources. The Sankey diagram visualises how these subcategories contribute to total emissions.

It shows where emissions originate and how they flow across the system. To clarify impact, all subcategories are arranged in descending order of carbon emissions. This ranking highlights which components contribute the most and where reduction efforts may be most effective.

02 Bubble Chart

The bubble chart following the Sankey diagram further illustrates the proportion of each subcategory within the total carbon emissions.

The size of each bubble represents its relative share, allowing the weight of each component within the overall system to be compared intuitively and at a glance.



Macro- The worse status "The Long-Tail Effect of CO₂"

At the macro level, we project UK's future digital carbon impact based on the 2024/25 dataset, and visualise a key property of CO₂: it does not disappear on a short timescale, but persists for decades to millennia.

The decay log in this chart is informed by research on the long term atmospheric persistence of fossil-fuel CO₂, including:

Joos et al., 2013, Atmospheric Chemistry and Physics (multi-model impulse response, includes % remaining after 1000 years)

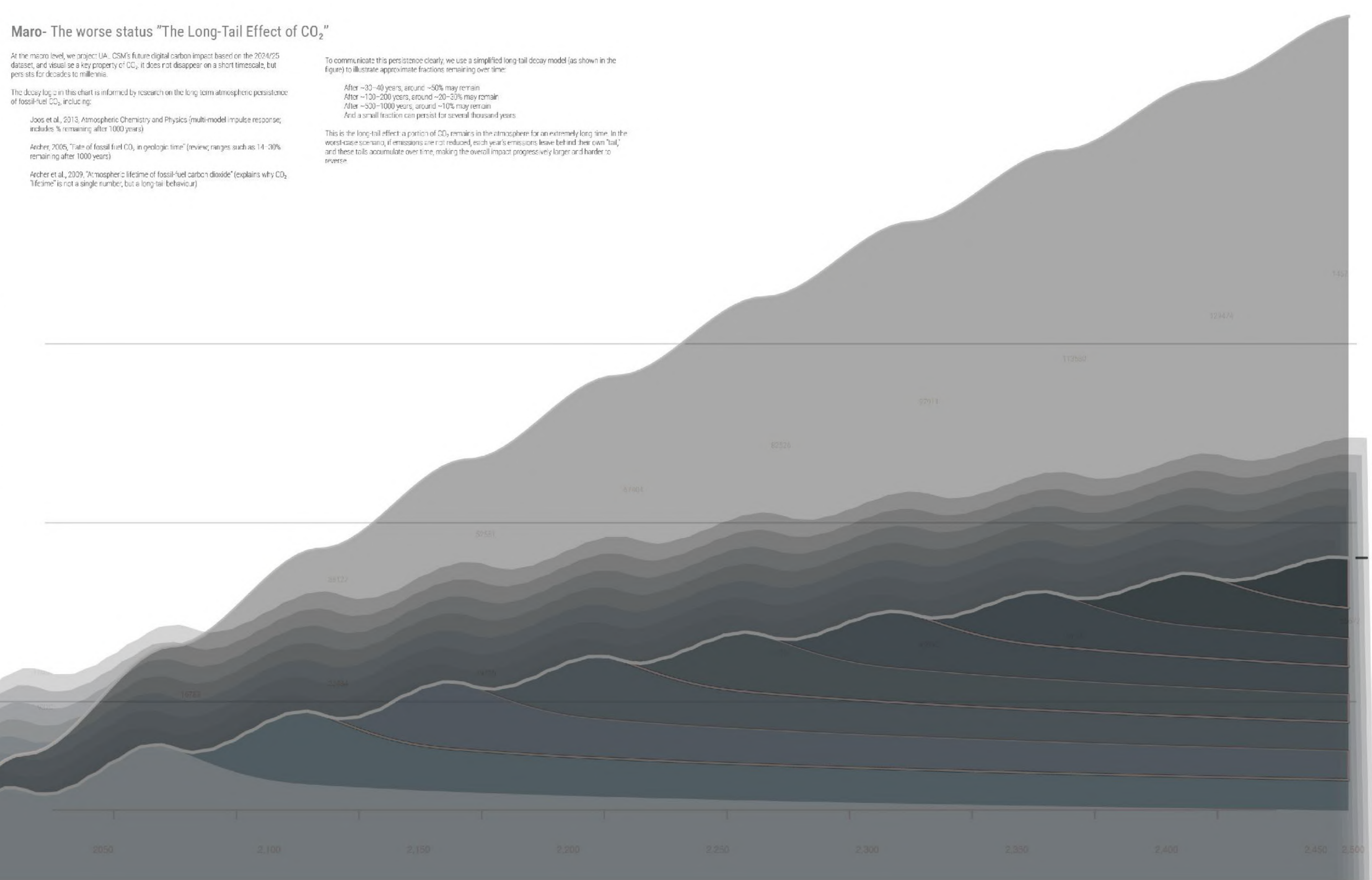
Archer, 2005, 'State of fossil fuel CO₂ in geologic time' (review, ranges such as 14-30% remaining after 1000 years)

Archer et al., 2009, 'Atmospheric lifetime of fossil-fuel carbon dioxide' (explains why CO₂ lifetime is not a single number, but a long tail behaviour)

To communicate this persistence clearly, we use a simplified long tail decay model (as shown in the figure) to illustrate approximate fractions remaining over time.

- After ~30-40 years, around ~90% may remain
- After ~100-200 years, around ~20-30% may remain
- After ~500-1000 years, around ~10% may remain
- And a small fraction can persist for several thousand years.

This is the long-tail effect: a portion of CO₂ remains in the atmosphere for an extremely long time. In the worst-case scenario, if emissions are not reduced, each year's emissions leave behind their own "tail," and these tails accumulate over time, making the overall impact progressively larger and harder to reverse.



Prototype - PartB

Infographic Part 3

Future Projection – Tail Effect

Mirco- Carbon Emission Factor

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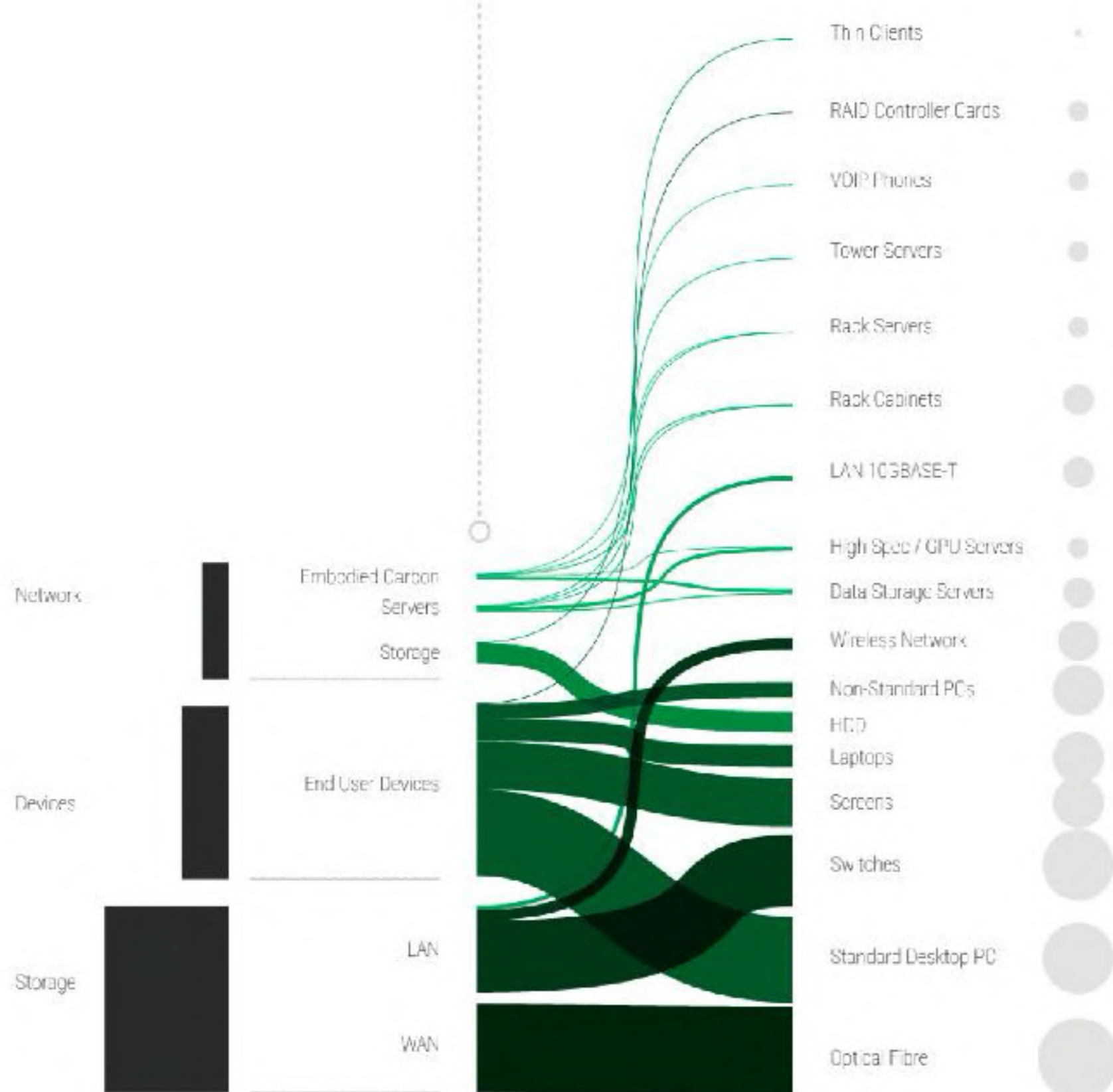
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 - Cooling systems
 - Supporting infrastructure
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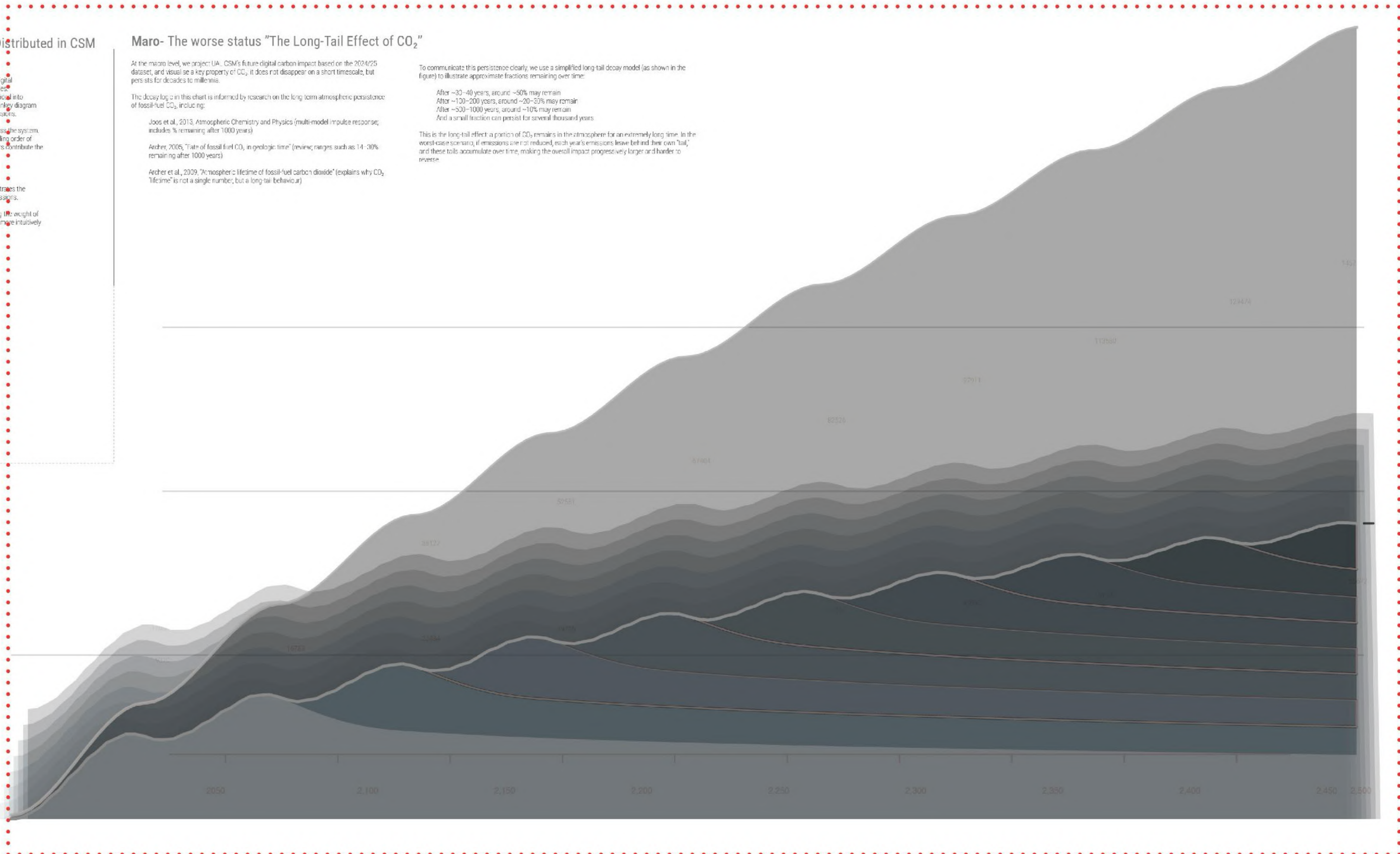
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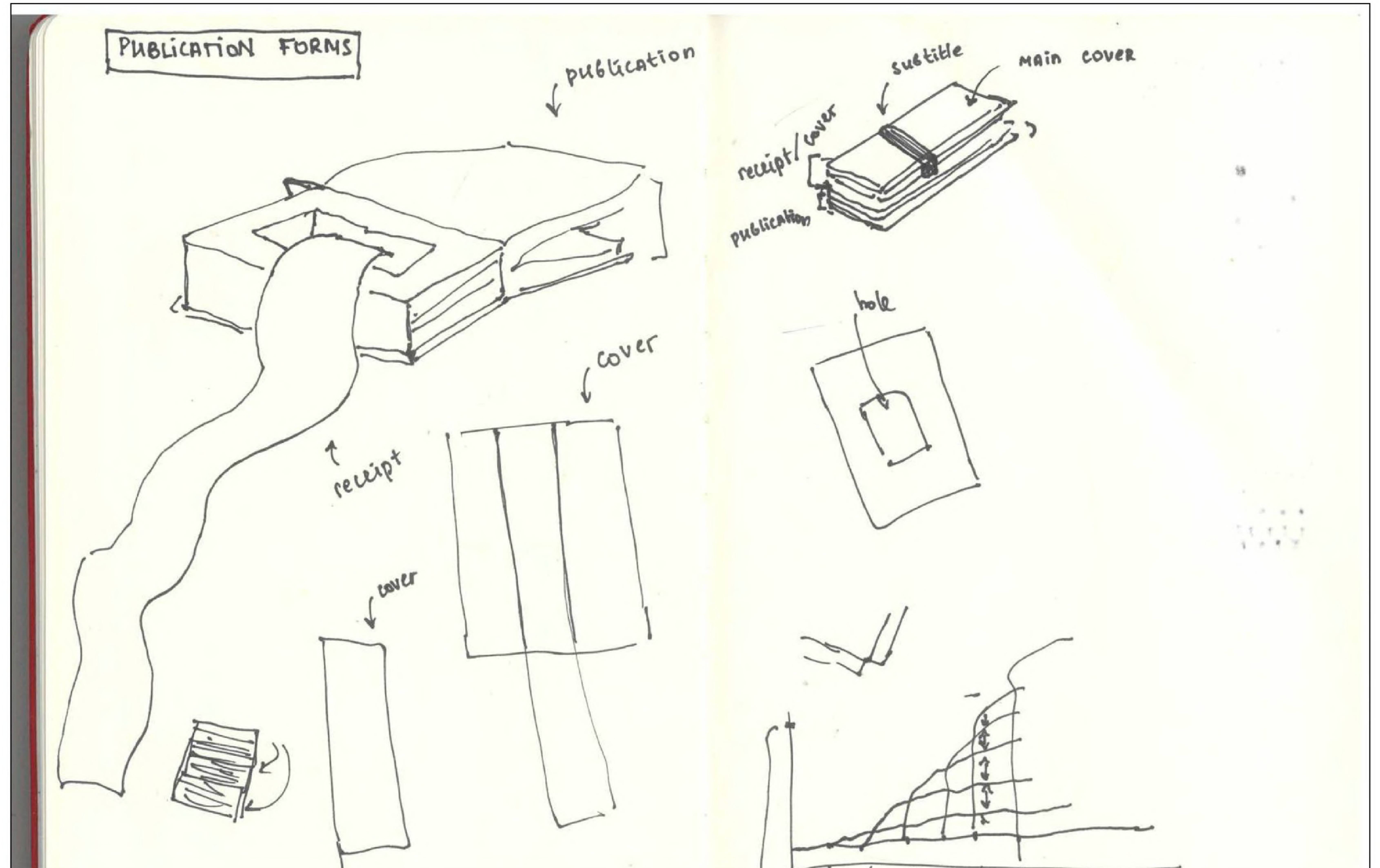
Prototype - PartB

Prototype of the structure of the publication

Pull-down format: Physical receipt insert

Tangible accumulation

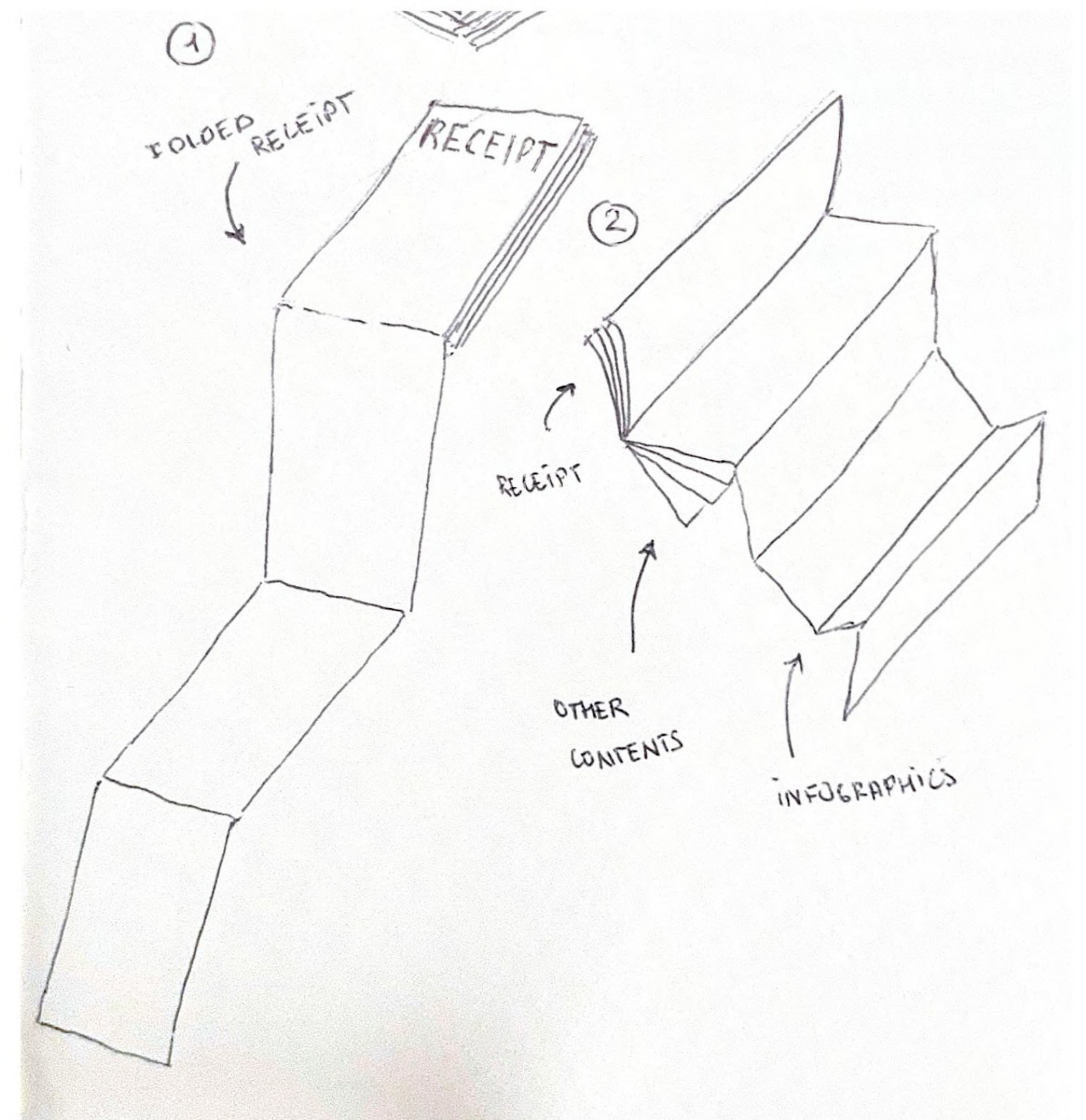
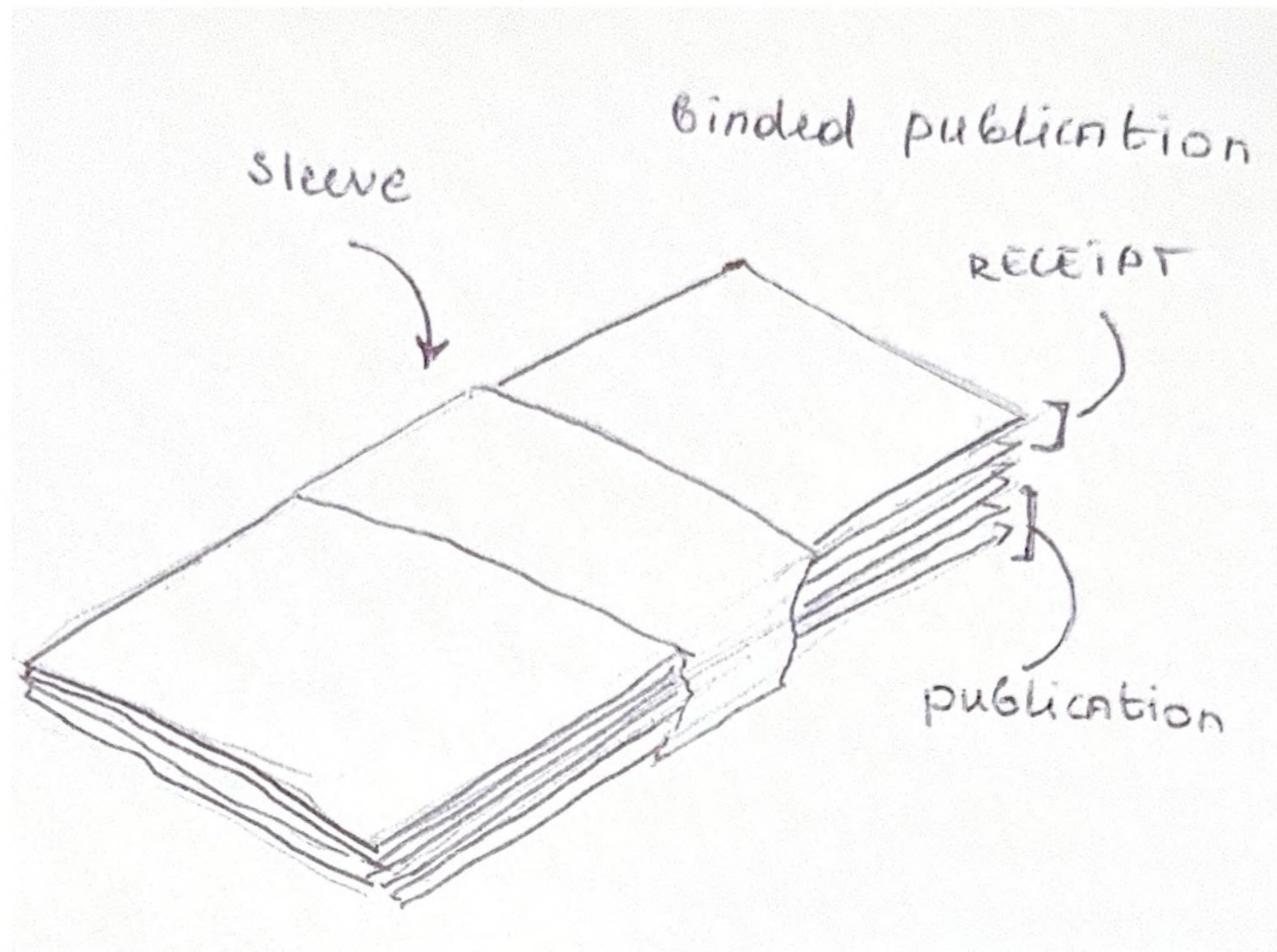
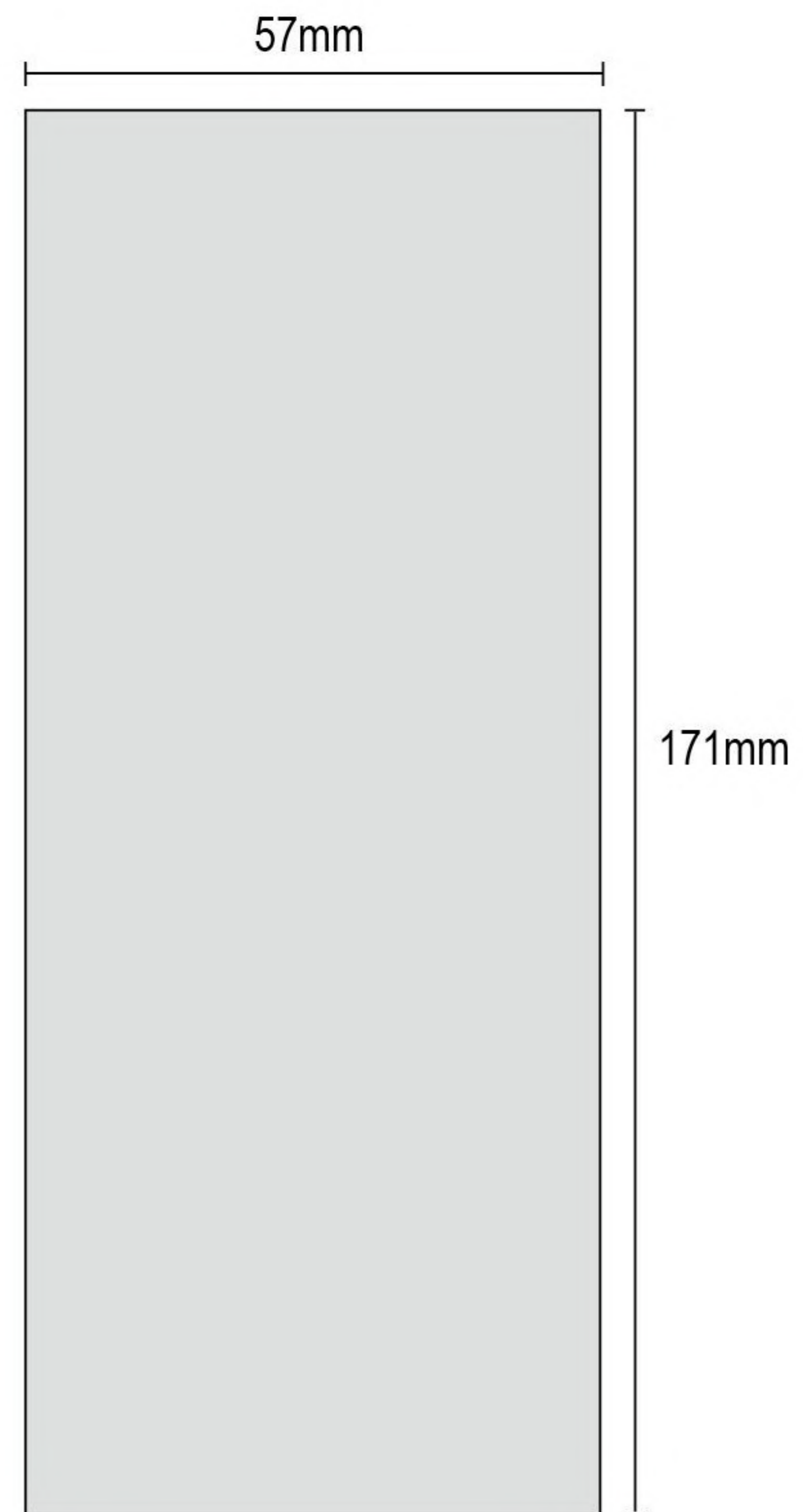
Accordion fold (left-right expansion): Infographics



Prototype - PartB

-Publication-Design

Sketches of the final considerations of the publication's shape.
The publication is designed to match the width of a receipt.



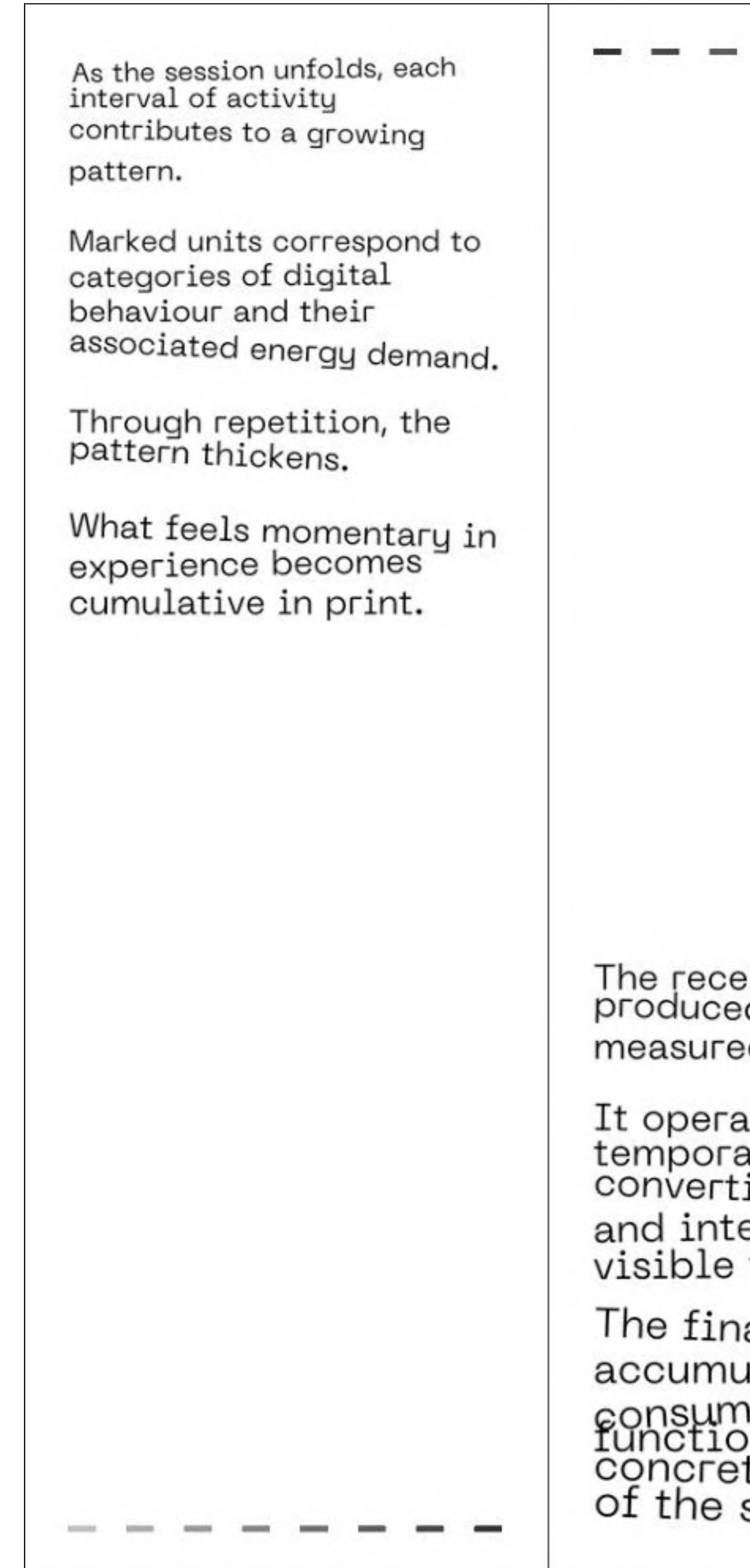
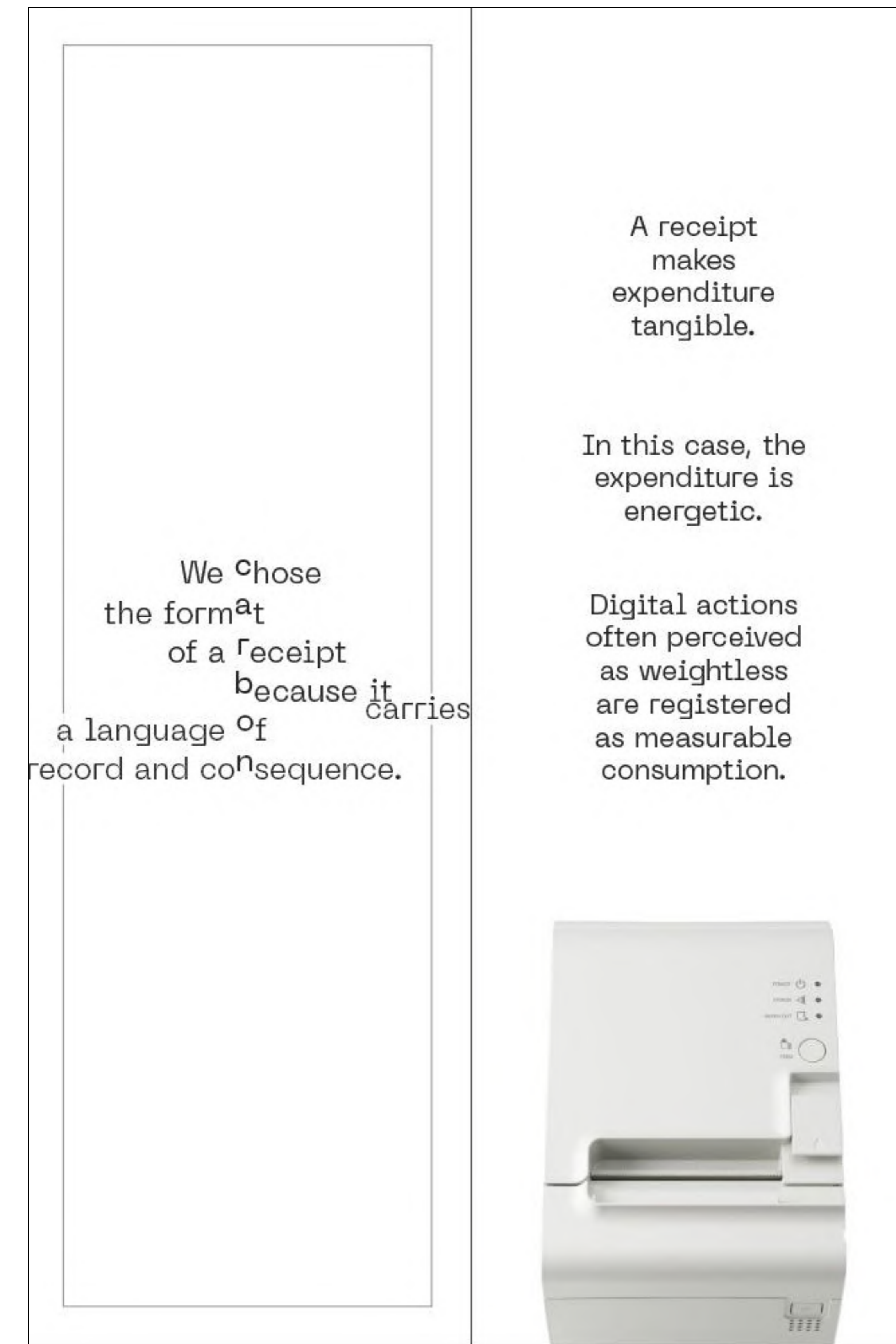
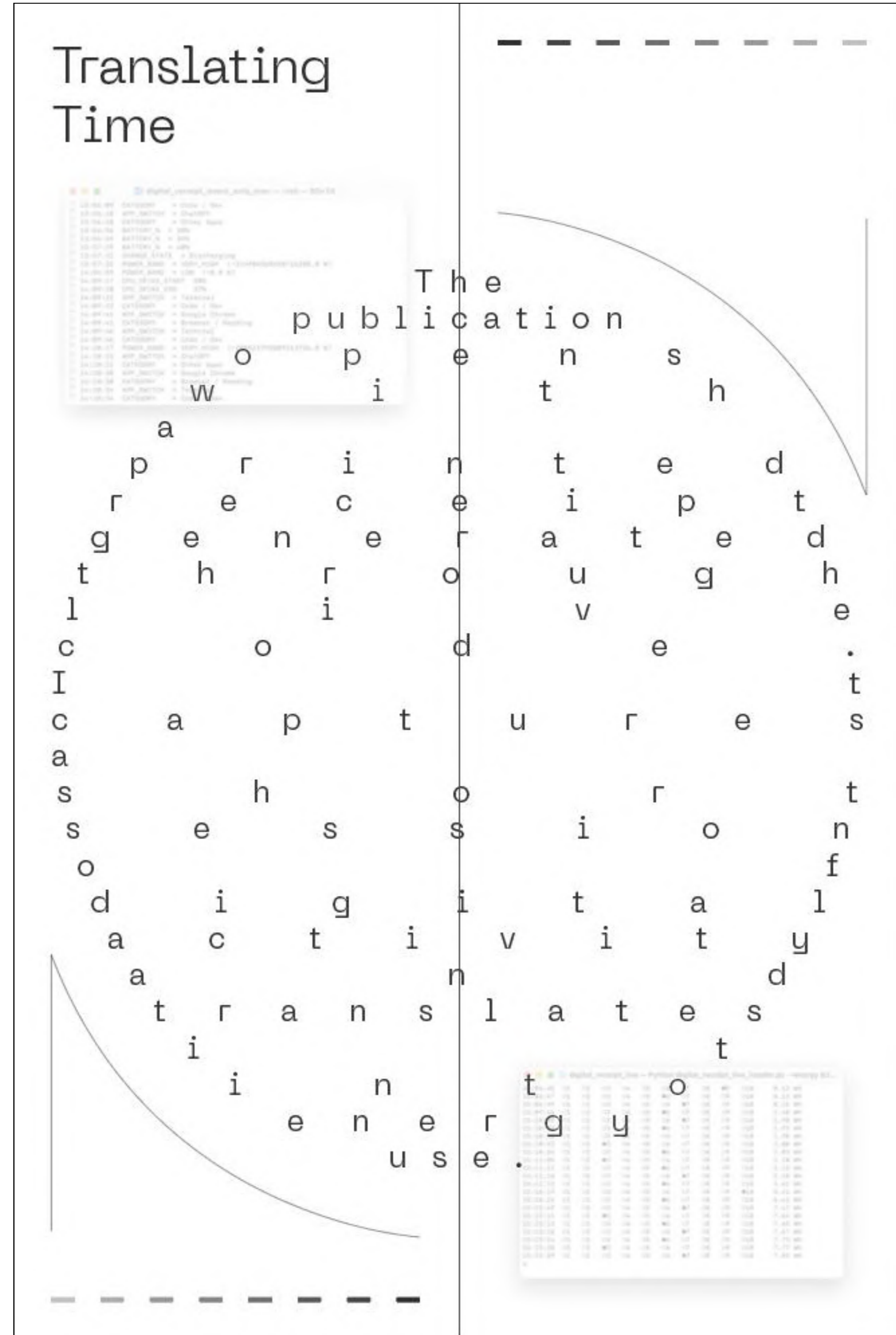
Prototype - PartB

-Publication-Context-Inforgraphic

We chose a monochrome (black and white) layout.

Since digital carbon is difficult to visualise or perceive directly, we adopted a more abstract typographic approach.

At the same time, we limited the ink density to 85% black in order to reduce printing consumption.



The receipt produced measures...
It operates temporal conversion and inter-visible...
The final accumulation of consumption functions concretely of the s...

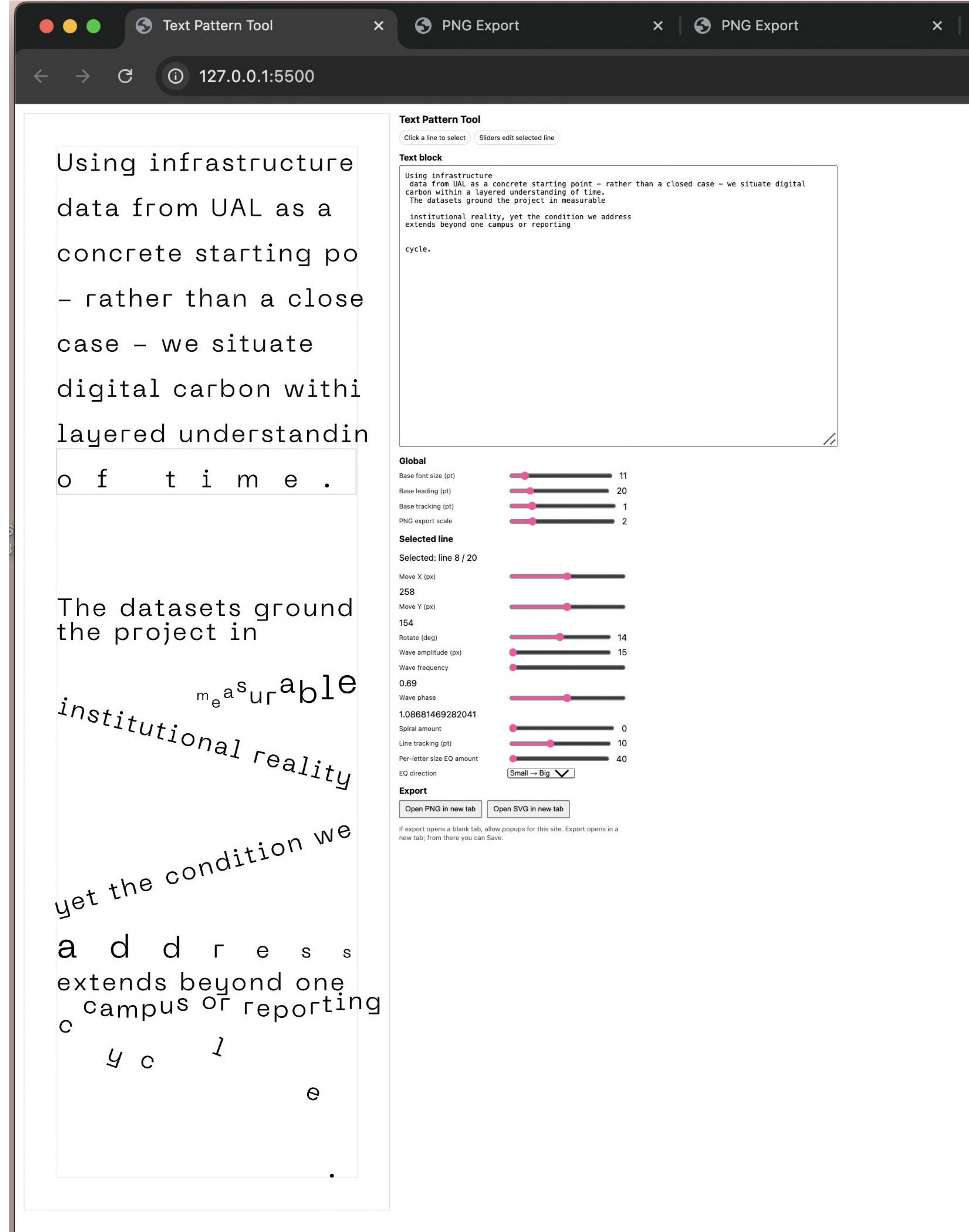
Prototype - PartB

To continue on the publication design we wanted the type itself to become a visual system.

The pattern created by the letters is intentional: it reflects the complexity and instability of digital carbon emissions where something that is invisible, abstract, and constantly shifting over time.

To explore this, we built a small browser-based tool using HTML and p5.js, a lightweight local web tool that allows me to generate and manipulate typographic patterns dynamically.

The idea is not to add digital weight, but to prototype and test how text can embody complexity rather than just describe it.

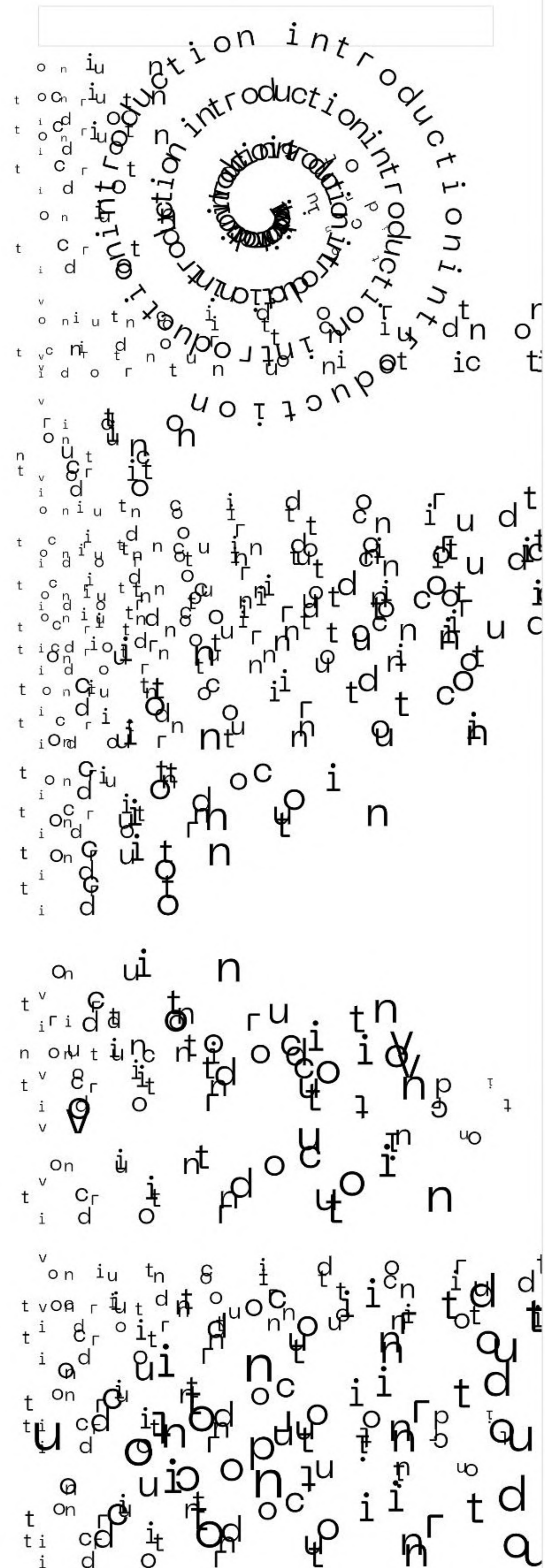


Prototype - PartB

This is still a WIP layout versions.

We're working toward patterns that are more sophisticated, but still readable because legibility remains essential.

The goal is to balance visual complexity with clarity, so the typography communicates both the data and the difficulty of visualising it.



The digital feels immediate. Yet beneath every click lies infrastructure: servers, networks, storage systems, and electricity grids that translate digital habits into energy demand and carbon emissions. Every digital action extends beyond its moment. Files remain stored for years. Servers continue running long after a document is forgotten. Electricity flows whether or not we are looking at the screen. Digital carbon emission does not disappear the session ends.

Digital carbon is often reported in annual summaries, institutional targets, and aggregated datasets. Yet digital infrastructure operates continuously. Single user behaviour unfolds in seconds. Atmospheric accumulation unfolds across decades. These temporalities rarely meet.

Using infrastructure data from UAL as a concrete starting point – rather than a close case – we situate digital carbon within layered understandings of time.

The datasets ground the project in measurable institutional reality yet the condition we address extends beyond one campus or reporting cycle.

Digital carbon unfolds across three temporal dimensions: the immediacy of interaction, the institutional duration of storage and maintenance, and the atmospheric accumulation that exceeds both devices and annual targets. These scales rarely align. The gap between them is not only quantitative, it is perceptual. We feel the present and we rarely feel accumulation.

End

Thank you;-)