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THE MEDICATION FACTORY OF THE FUTURE IS THE HUMAN BODY!

The Green transformation of medication with « **Green Horizon** » is food for thought

ABSTRACT

This report outlines a **transformational approach** of the pharmaceutical sector, **aiming to develop a greener solution for medication.**

In France, **33% of the healthcare sector's greenhouse gas emissions come from the production and purchase of medication**. Environmental impacts of medication were therefore mapped throughout their entire lifecycle to identify the best opportunities to act.

To gain liberation from the take-make-waste paradigm, a mental excursion was conducted with a prospective approach. **The resultant** « GREEN HORIZON » was used **to define a step-by-step transformation roadmap and operating models** for the pharmaceutical sector, while balancing environmental performance, timeline, investment, and costs.

1

INTRODUCTION

What would « Medication » become if we put 100% emphasis on Sustainability?

In an effort to free the sector from the take-make-waste paradigm, we ran a mental excursion with a prospective approach. The resultant « GREEN HORIZON » was used to define a step-by-step transformation roadmap and operating models for the pharmaceutical sector, while balancing environmental performance, timeline, investment, and costs.

This point of view aims to inspire and call for action, providing disruptive food for thought that is still anchored in the reality of pharmaceutical sector, which is highly constrained and regulated.

2

MAPPING THE LIFE CYCLE WITH THE IMPACT JOURNEY

If the healthcare sector were a country, it would be the fifth-largest emitter on the planet, according to a 2019 report by Health Gare Without Harm and ARUP. Ln total, the global footprint is equivalent to 4.4% of global net emissions (2 gigatons of CO2e), or the annual GHG (greenhouse gas) of 514 coal-fired power plants.[1]

Out of the total emissions of the health sector in France, 33% are due to the purchase of medication by the patient (i.e., the pharmaceutical industry). This is a total of 15.6 megatons of CO2 equivalent per year Fig. 1 .[2] Similarly for the UK's NHS in 2019, pharmaceuticals and chemicals clearly represented the largest emissions area Fig. 2 .[3]

Environmental impacts in the pharmaceutical sector reveal the involvement of several stakeholders: pharmaceutical companies, suppliers, hospitals, and water treatment plants, but also patients and HC practitioners.

We built a heatmap of environmental impacts of medications in terms of water, CO2, and waste produced throughout their lifecycle. We examined the entire timeline, from the R&D phase to the end of their first or second life. Costs were also considered Fig. 3 .

1. https://noharm-global.org/sites/default/files/documents-files/5961/HealthCaresClimateFootprint_092319.pdf
2. https://theshiftproject.org/wp-content/uploads/2021/11/TSP_Sante%CC%81_Synthe%CC%80se_DEF.pdf
2. https://theshiftproject.org/wp-content/uploads/2021/06/PTEF_Decarbonons-la-sante-pour-soigner-durablement_RI_Juin-2021.vf_.pdf

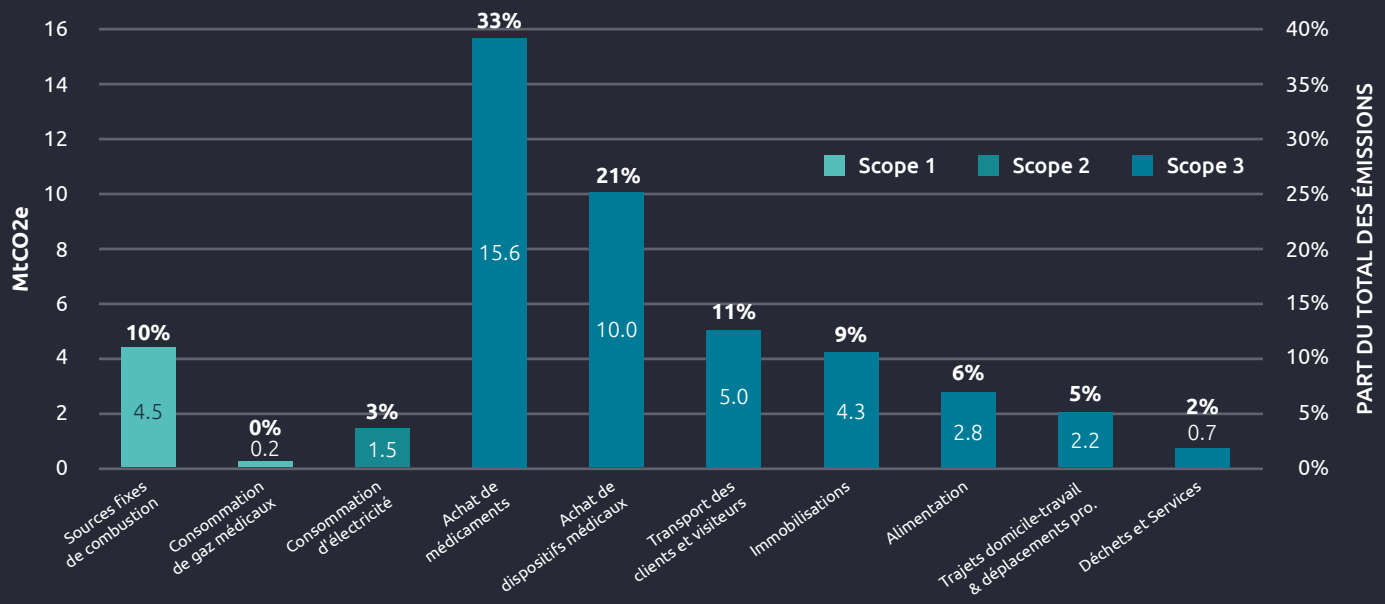


Figure 1 *Emissions distribution of the health sector in France (MtCO2e)*[2]

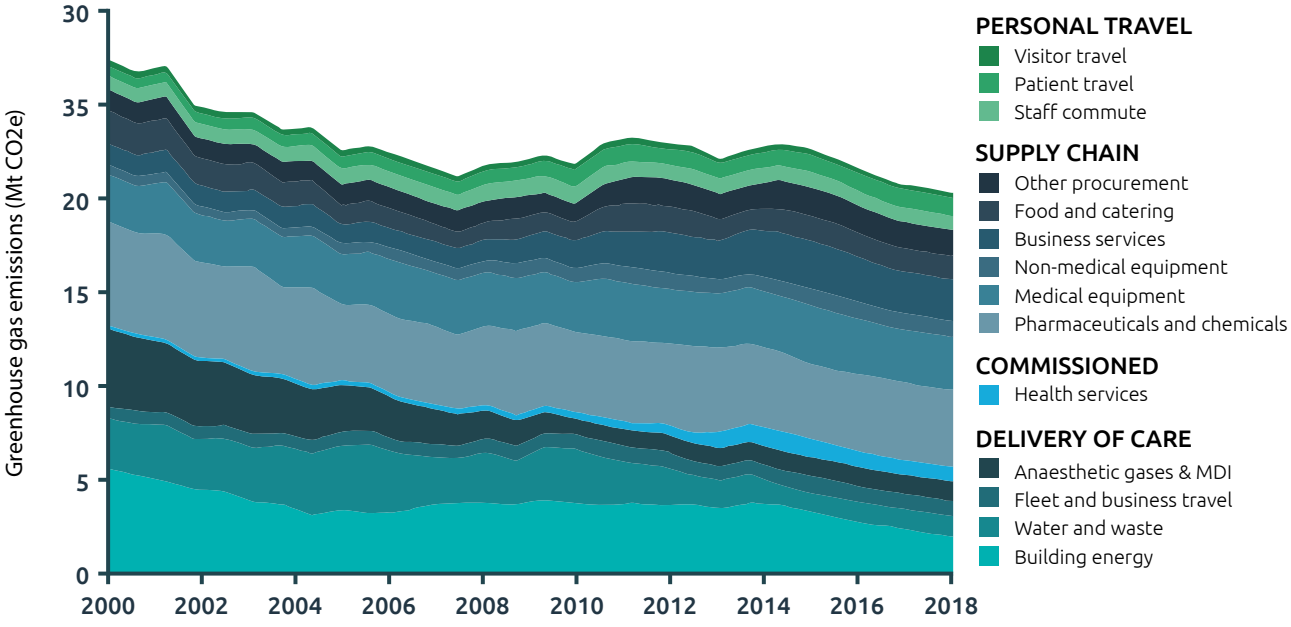


Figure 2 *Evolution of NHS GHG emissions from 1990 to 2019 by source-emission item*[3]

	WATER	WASTE	C02E	COSTS
CLINICAL TRIALS	**Polluting molecules in wastewater** due to lack of adherence	Production and consumption of **placebos to evaluate molecule efficiency** in clinical trials	High **energy consumption** to maintain hygiene conditions - suction, filtration, etc.	Tests on the cell, then on animals, and then humans **3 testing levels** triple cost
RAW MATERIALS EXTRACTION	No reuse of water because of **strict hygiene conditions**	Waste of **buffer solutions and cleaning agents** Unused synthetic raw materials	**Transport** of active ingredients **from emerging countries** (Asia, Central/South America) ta US, Switzerland, Germany for R&D	Extraction of ingredients from abroad and transport to pharmaceutical industries
DISTRIBUTION	Ocean pollution from cargo transport	Large **batch packaging Protections of medication** for transport and distribution Physical marketing	Air/cargo/rail/road **transport** production distribution sites **Cold-chain shipping** (refrigerated vehicles)	Transport costs including taxes to distribution sites
USE	Water pollution from human **excretion of unabsorbed dose** More toxic agents due to bioreactions	30-90% of dose not absorbed by the body - **Adherence lack** 50% of medicines sold (EU) **not used before the expiry date**	Rising emissions due to **increased production and consumption** of medication (tech progress, viruses, etc.)	
END OF LIFE (1ST LIFE)	Toxic agents **not removed by sewage treatment plants** Water pollution by metabolites of drugs disposed of in WC/sink	**Packaging, medicine leaflet** 50-90% of unused medicines **not collected or returned to pharmacies**	**Incineration** of expired medicines in specific plants	Costs of waste disposal (Specific incineration)

Figure 3 *Heat map of the environmental impacts of medication (extract)*

3

HEAT AREAS AND OPPORTUNITIES

Lifecycle analysis highlights impact inducers and elaborates on them with the benchmarking of best practices. It is supported by relevant Biopharma examples and Tech Trends to introduce feasibility questions Fig. 4 .

	HEAT AREA	OPPORTUNITIES «SHOULD IMPACT»	BIOPHARMA EXAMPLES AND TECH TRENDS
CLINICAL TRIALS	Cast and resource-intensive clinical trials, **triple-level of tests** on the cell, animals, and humans Numerous tests for validation use impactful materials, water, energy and are source of waste	**Virtual drug tests** using software simulation for more-efficient drug development and **AI pattern recognition** to assess drugs Partnership with **tech company**	Bayer IT developed 2 **virtual drug tests**, one of which called the PK-Sim'» simulation software, that **predicts pharmacokinetic processes** of an active substance in the body (absorption, transport, metabolism) Wuxi NextCODE uses **AI's pattern recognition to drive clinical trials**, it classifies genes according to their roles and other attributes to look for connections between RNA-sequence variations and more **Regulatory bodies** like the FDA play a key role in the use of technology in the industry - in a 2018 conference, the deputy director of the Division of Applied Mechanics encouraged it to drive change: «Today, realistically, **computer modelling and simulation** does not play a driving role in regulatory decision making, but we want it to. We want to **lessen the burden of evidence in clinical trials** and animal studies. [...]»
RAW MATERIALS EXTRACTION	Active ingredients come from emerging countries and their **manufacturing** largely relies on chemicals derived from **petroleum**	Replace fossil fuel-reliant manufacturing with methods based on **synthetic biology**, inspired by natural chemical processes	Double Rainbow Biosciences, a sustainable biotech dedicated to developing new therapeutics with minimal impact on the environment, is developing a **fermentation-based manufacturing technology** to replace fossil fuel-reliant manufacturing
DISTRIBUTION	High transport emissions due to **complex supply Chain** **Cold-chain shipping** of temperature-sensitive products in refrigerated vehicles requiring additional energy	Use **greener fuels** for vehicles, and **direct-to-consumer** distribution Adopt **«active» packaging** that help to keep medicines' temperatures **Reduce** the amount of **packaging** materials for transport optimisation	**GHG emissions of active packaging** solutions are **more than 90%** lower than passive, even with an extra leg of return transport, according to the CEO of Envirotrainer, a provider of cold chain transport of pharmaceuticals J&J **cut the amount of packaging** used to transport its medicines **by 60%**, allowing more efficient storage of products in transport vehicles
USE	**Lack of adherence & partial absorption** of molecules as major source of waste and of water pollution because of excretion Purchase of medication without choosing the number of doses, waste due to **non-consumption**	Use of **AI to predict adherence** and to develop personalised solutions **Embedded or external electronics** to track and personalise adherence Partnership with **tech company**	Nanomedicine is expected to become commercially available, consisting of **flexible electronic patches** grafted directly to muscles or organs to monitor heart rate, organ functions and more - these devices could also **release medication** (for patients suffering of chronic diseases) The BenevolentBio start-up has its own **AI platform** accelerating the trend towards **personalised treatments** depending on biological profiles
END OF LIFE	**Unused medicines** are thrown away or emptied down the sink, **packaging** is **thrown away** Limited collection of expired medicines **back to the pharmacy**	Facilitate the **collection of expired medicines** to ensure specific waste treatment, often incineration **Eco-design of packaging** for it to be recyclable or biodegradable	French organisation Cyclamed collects **unused medication** brought back to pharmacies by individuals to ensure their **specific treatment** Natupharma has developed a **fully biodegradable plastic** using sugar cane for pharma packaging, tests show it is **comparable to petroleum plastics** in terms of strength and other favourable properties for safety

Figure 4 Heat areas and opportunities (extract)

4

« GREEN HORIZON »

The equation looks complex because there are too many constraints to really shift and transform the sector towards a greener - really greener - medication.

This is where a disruptive approach, such as prospective, can help release the sector from incremental and siloed optimisation schemes. It will not only reveal game changing opportunities but also act as a transformation tool to shape step-by-step, attainable goals, up to the maximum acceptable level of risk and investment possible for the companies in the sector.

What would « Medication » become if we put 100% emphasis on Sustainability in the User-Centric Design Thinking scheme of desirability, feasibility, and viability Fig. 5 ?

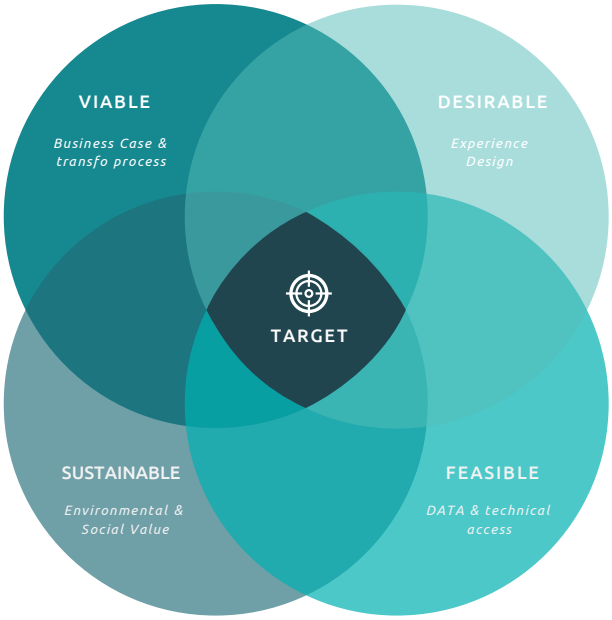


Figure 5
A Holistic approach complete with Sustainability

Based on previous analysis, including the impact journey, the opportunities, and Should Impact, we ran an ideation to « think out of the box » and generate a maximum number of concepts, all based on group facilitation of rebounds and in and out listening.

This ideation led to several directions, including no drugs, low tech, back plant-based medication (Chinese medicine), and more. But we retained a Connected Products and Services approach to secure the ability to demonstrate the actual reduction of impacts. After all, « If you can't measure it, you can't improve it » (Peter Drucker).

Taking a leap into the future enabled us to imagine a greener target, one that constitutes an unattainable asymptote that we name « GREEN HORIZON » for medication.

It consists of functionalizing the human body, thereby constituting a « medication factory ». Practically, a connected patch would deliver a Ribonucleic Acid messenger (RNA) to the patient that would produce its own customised molecule at the right dose and the right time, with full adherence and reduced waste.

The maximum efficient molecule would be customised according to age, gender, and RNA (e.g., with a molecular modular design approach supported by quantum computing).

When the healing is over, the soiled strap would we removed from the connected patch, disposed of, and destroyed. But the electronics would be returned to the healthcare company, who would circularise it and reprogram it to be ready for another patient Fig. 6

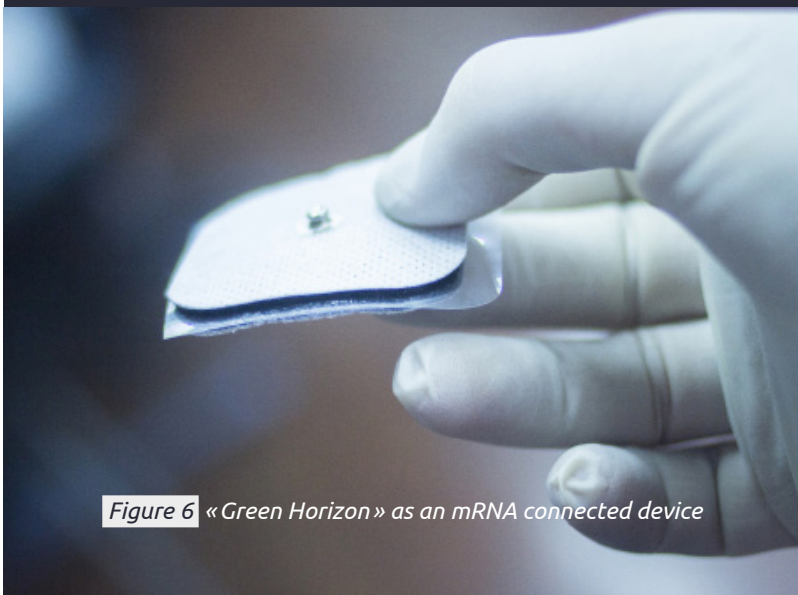


Figure 6 *« Green Horizon » as an mRNA connected device*

5

A ROADMAP TO GREENER MEDICATION

The **GREEN HORIZON** constitutes an asymptote that we cannot reach because it faces strong transformation challenges:

It questions the acceptability of such a solution by patients. For this we would need to involve Behavioural Design to accompany a transformation, for which the healthcare company could play a central role in education.

It questions the sector's value chain as it stands today. This is because it combines pharma and MedTech sectors (i.e., not only the expertise in molecule design, but also in MedTech, electronics, and SaMD). But it can use as a «North Star» to draw a roadmap towards the target, as high as possible, with different echelons of risk and investment (levels 1, 2, 3) starting with the current situation Fig. 7.

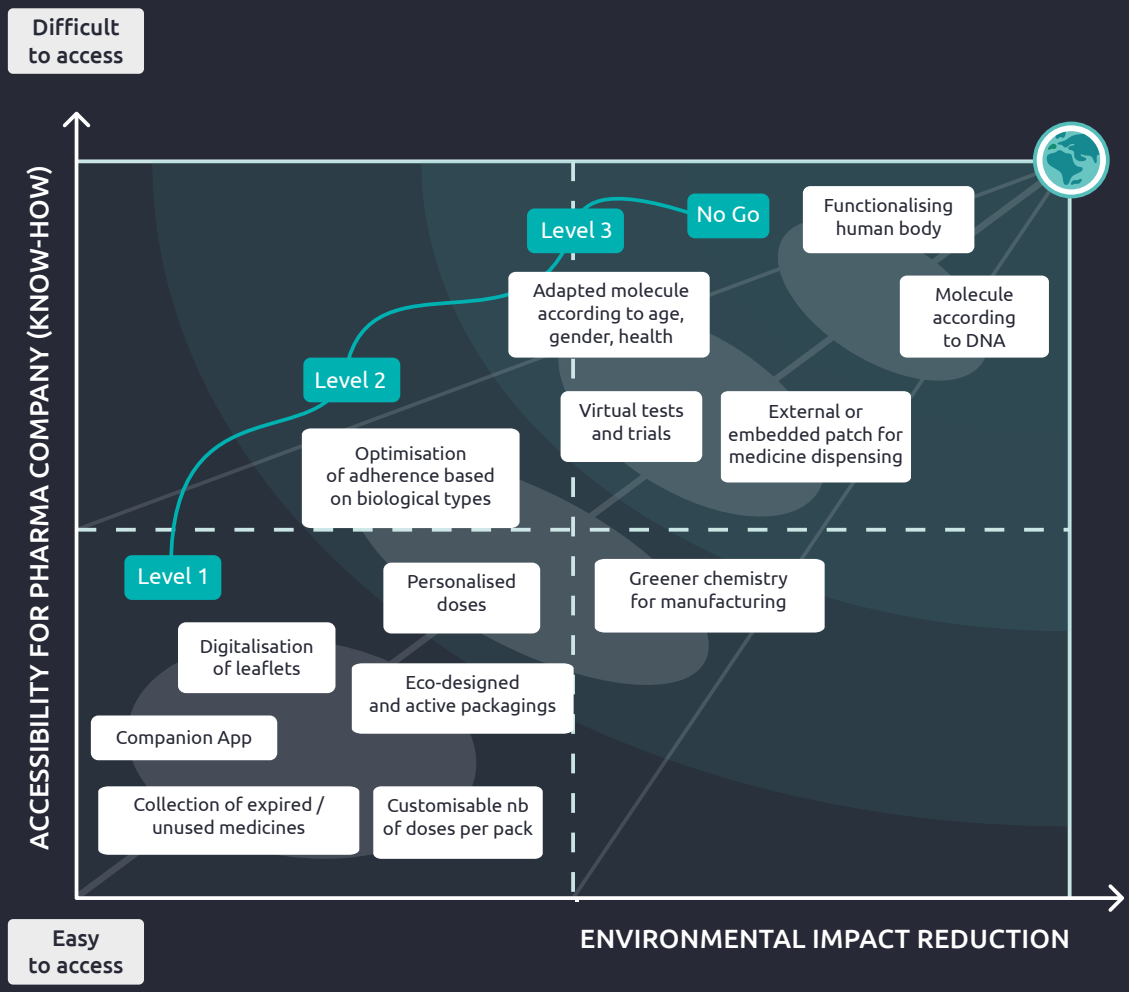


Figure 7 *Transformation scale of medication towards «Green Horizon»*

6

TRANSFORMATION ROADMAP

Finally, following the 3 identified echelons, a transformation roadmap is proposed for the pharmaceutical industry, aiming to develop a greener solution for medication. The main required R&D and Tech innovations to reach the milestones were mapped along the timeline.

The next step would be to formulate the new value proposition of pharmaceutical industry. An organisation activation framework could then be used to identify each facet of the organisation (processes, enablers, partners, data) and map the changes each one of them would have to implement to reach the milestones Fig. 8.

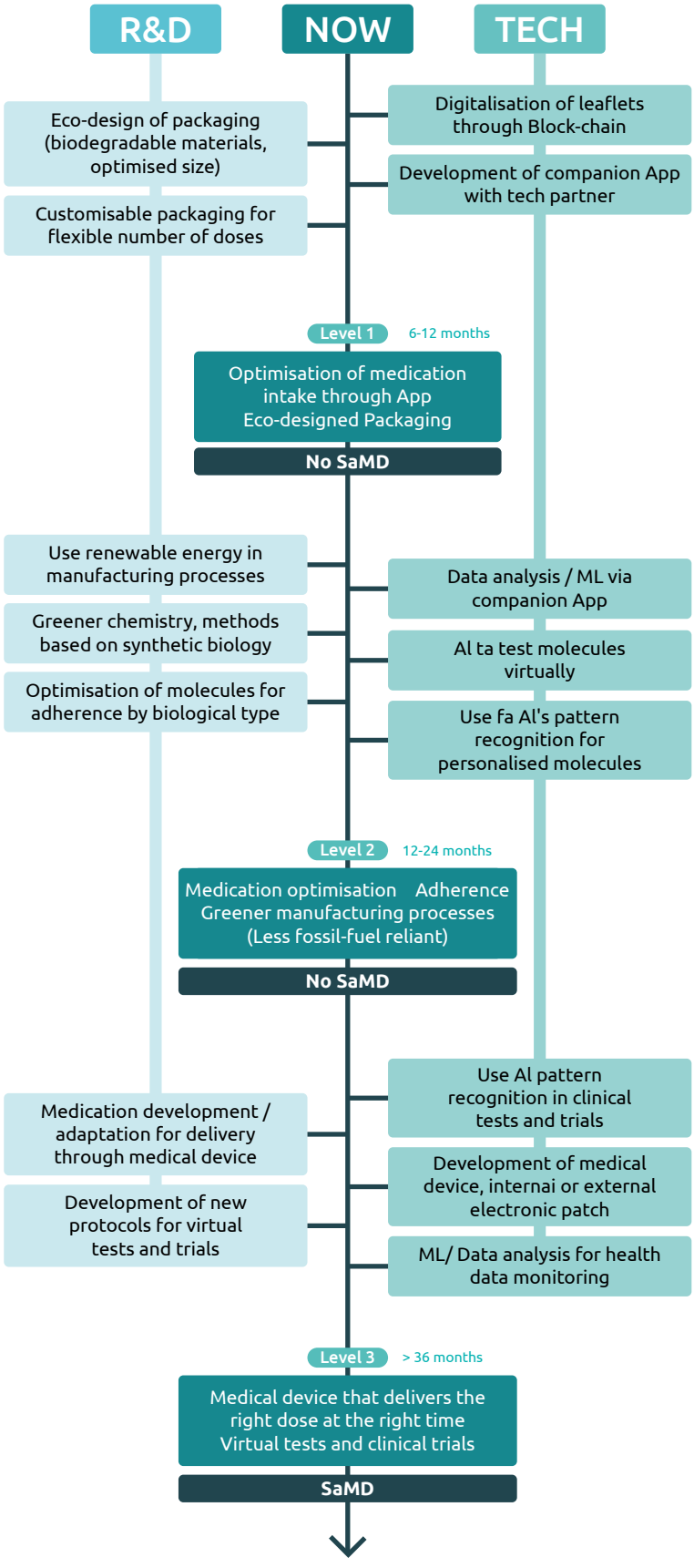
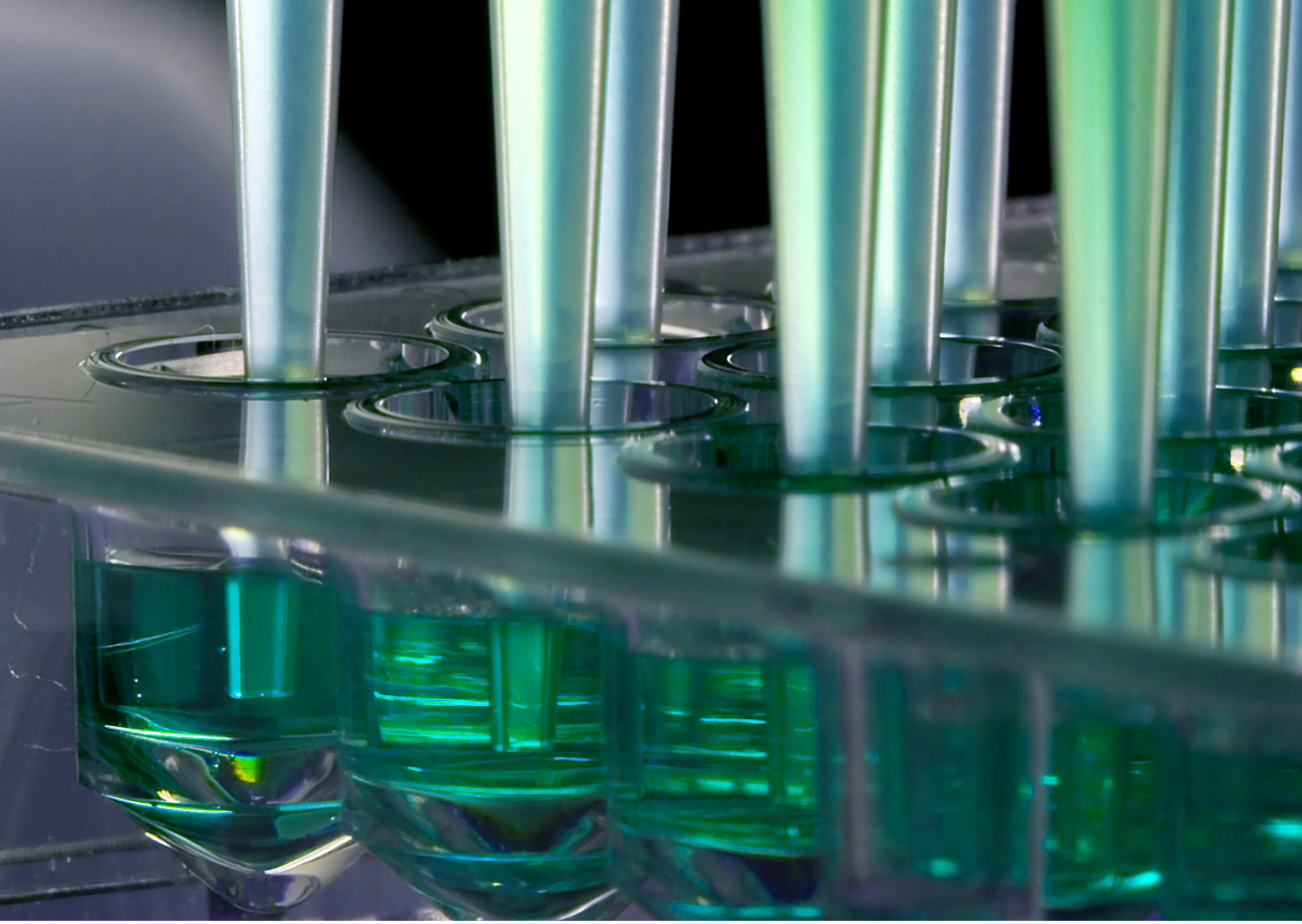


Figure 8 *Transformation roadmap for greener medication*



CONCLUSION

The sustainable transformation of the pharmaceutical industry faces a lot of challenges, both on patient side, due to reluctance to change, and on the sector side, due to strong regulations.

But the sector still needs to find a way to overcome these challenges, as impacts on the environment are significant (e.g., water, waste and GHG).

A prospective approach was run to stimulate outside-of-the-box thinking and to get free from the take-make-waste model. It enabled us to generate a « GREEN HORIZON » of what medication would become if 100% emphasis was put on Sustainability.

Next, this asymptote was used as a tool to shape a step-by-step transformation roadmap of progressive changes while balancing environmental performance, time, investment, and costs. It also highlighted the consequences for pharmaceutical companies, in terms of operational and manufacturing models.

This process of leaping into the future and imagining a « GREEN HORIZON » can be done for every business sector or industry type. Even if not all the changes are feasible or tangible on a large scale, such an approach helps to push the boundaries of innovation and creativity. It is also crucial to keep in mind that even if today, the sustainability focus is very customer-centred. Industries have a crucial role to play - both in the social aspect of raising awareness and in the technical aspect of reducing environmental impacts.

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