



**PIONEERING
DIGITAL
WATERMARKS
FOR SMART
PACKAGING
RECYCLING
IN THE EU**

**Digital Watermarks
Initiative HolyGrail 2.0**



CIRCULAR ECONOMY

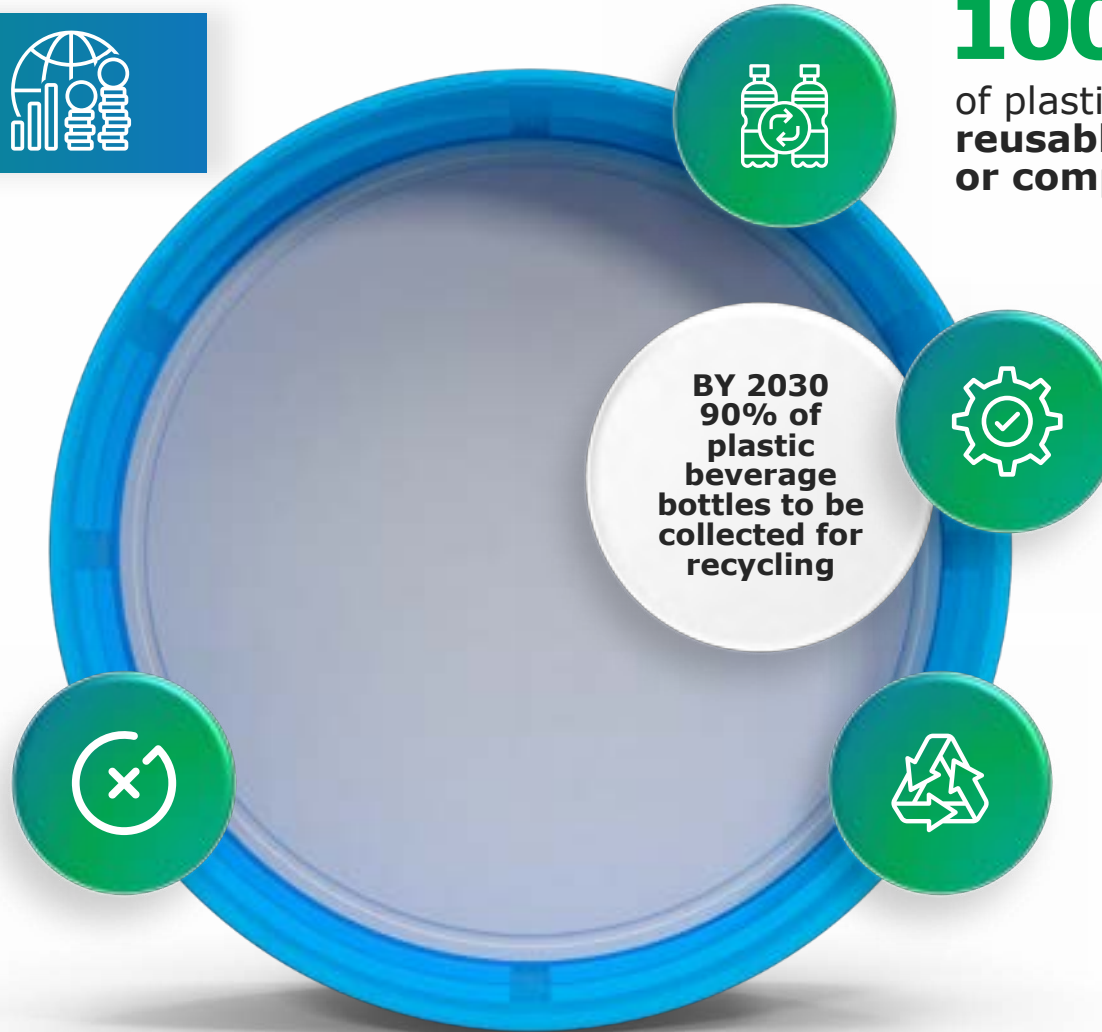
FOR PACKAGING



FACING THE NEW
CIRCULAR REALITY



Eliminate problematic
or unnecessary
**single-use
plastics**



BY 2030

100%

of plastic packaging to be **reusable, easily recyclable, or compostable**

BY 2030

55%

of plastic packaging to be **effectively recycled**

BY 2030

30%

average recycled content across all plastic beverage bottles

CIRCULAR ECONOMY

FOR PACKAGING

How can we achieve a Circular Economy for Packaging in the EU?



One of the biggest challenges is how to **maximize our resources** through optimal sorting and recycling



We need to **better sort our post-consumer waste in the EU waste management systems** by accurately identifying (plastics) packaging, resulting in more efficient and higher-quality recycling

CIRCULAR ECONOMY

FOR PACKAGING

Digital watermarks for smart packaging to **revolutionise the way packaging is sorted**

Opens **new possibilities** currently not feasible with existing technologies



CIRCULAR ECONOMY

FOR PACKAGING

September 2020: Under the auspices of AIM, European Brands Association, companies and organisations from the complete packaging value chain joined forces under the HolyGrail 2.0 project

Objective: Prove the viability of digital watermarking technologies for accurate sorting and the business case at large scale

Website: www.digitalwatermarks.eu



CIRCULAR ECONOMY

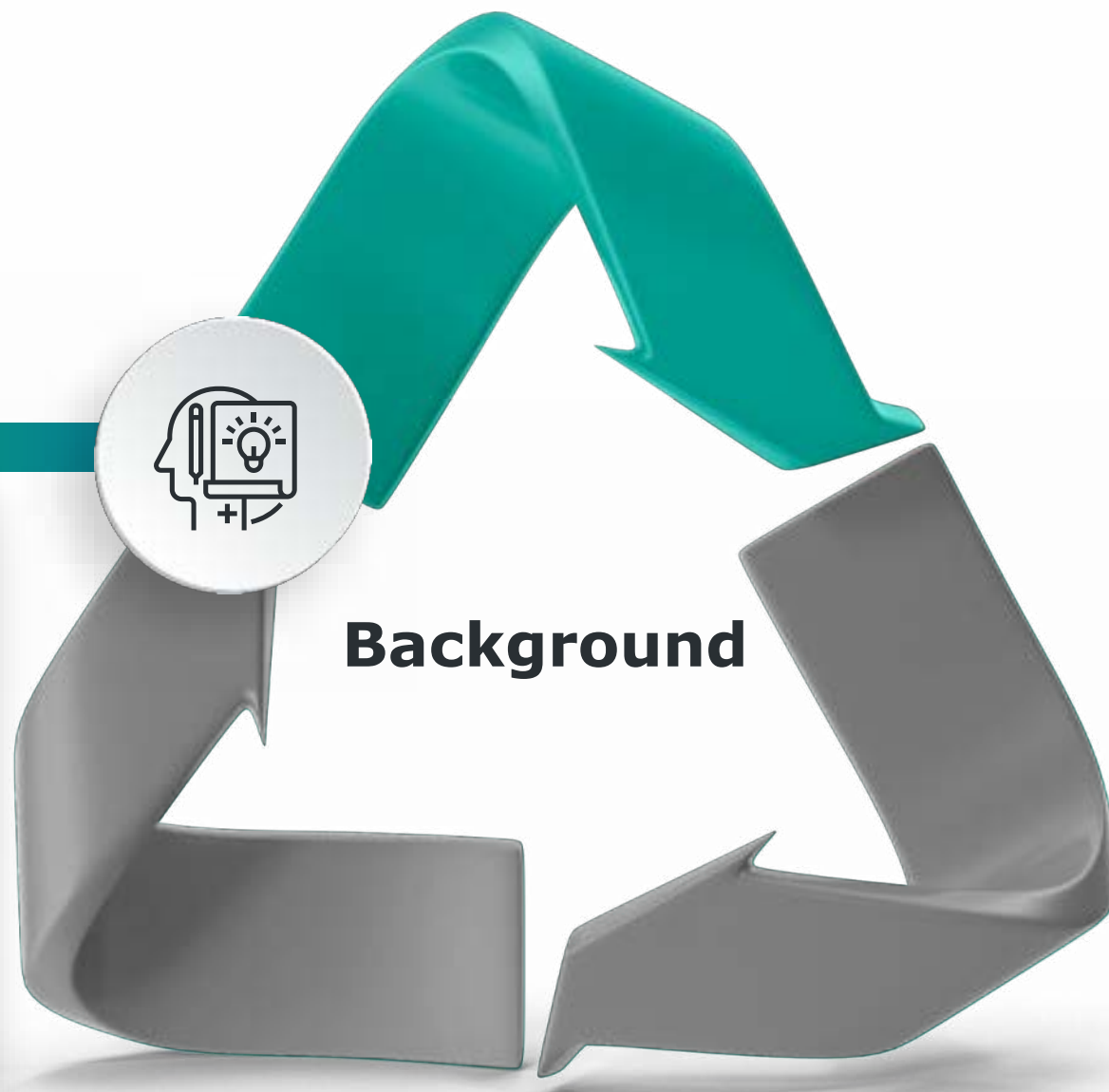
FOR PACKAGING

1st iteration of the **Pioneering Project HolyGrail 1.0** was led by the Ellen MacArthur Foundation 2016-2019

HolyGrail 1.0 investigated **different innovations to improve post-consumer recycling** (digital watermarks & chemical tracers)



Digital watermarks were found to be **the most promising technology**, gathering support among the majority of stakeholders and passing a basic proof of concept on a test sorting line



Revolutionising Sorting and Recycling

by Intelligent Packaging containing Digital Watermarks



Digital Watermarks Initiative HolyGrail 2.0

Driven by AIM – European Brands Association

Powered by AEPW – Alliance to End Plastic Waste





Pioneering
DIGITAL WATERMARKS
for smart packaging
recycling **IN THE EU**

HAPPY COW
Fines Herbes
CREAM CHEESE
500g e



Welcome
to the world
of
**DIGITAL
WATERMARKS**

[Welcome to the world of Digital Watermarks](#)

HOLYGRAIL 2.0 Membership



HolyGrail 2.0 Objective

Prove the viability of digital watermarking technologies for accurate sorting and the business case at large scale.

Proving the **TECHNICAL** viability of digital watermarking technologies (WP1-3), through e.g.:

- ▶ Validating of the prototype in three stages: 1° in an R&D centre (Phase 1 and Phase 2.1), 2° at a test facility on a semi-industrial scale (Phase 2.2), and 3° rolled out on a wider scale during real-time test runs in a commercial sorting and/or recycling facility (Phase 3)
- ▶ Ensuring the readability of the digital watermark embedded in print or in plastic, whilst taking into account esthetical and haptic aspects (e.g. shelf appeal)



Proving the **ECONOMIC** viability of digital watermarking technologies (WP4), through e.g.:

- ▶ Reviewing existing and new business models, in different stages, building on key learnings from each test phase
- ▶ Addressing main market barriers, and assessing similar state-of-the-art technologies
- ▶ Examining cost improvement potential of DW detection systems, as add-on, by retrofitting or new equipment
- ▶ Perform a full techno-economic analysis, incl. cost breakdown structure for the entire packaging value chain

WHAT ARE Digital Watermarks?

- ▶ Imperceptible codes, the size of a postage stamp, covering the surface of a consumer goods packaging
- ▶ Able to carry a wide range of attributes (e.g. manufacturer, SKU, type of plastics used and composition for multilayer objects, food vs. non-food usage)

LOOKS LIKE THIS ◀



WHAT ARE Digital Watermarks?

BEHAVES LIKE THIS ◀

- ▶ Imperceptible codes, the size of a postage stamp, covering the surface of a consumer goods packaging
- ▶ Able to carry a wide range of attributes (e.g. manufacturer, SKU, type of plastics used and composition for multilayer objects, food vs. non-food usage)

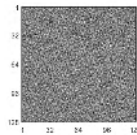


Digital Watermarks @work

FOR PRINT



01 Repeated Tile



02 Pieces of multiple tiles can be combined to recover a Barcode

03 The encoder applies the tiles to graphics in a mosaic manner

04 Uses existing pixels
No special inks
No special printing process



Exaggerated view for illustration purposes

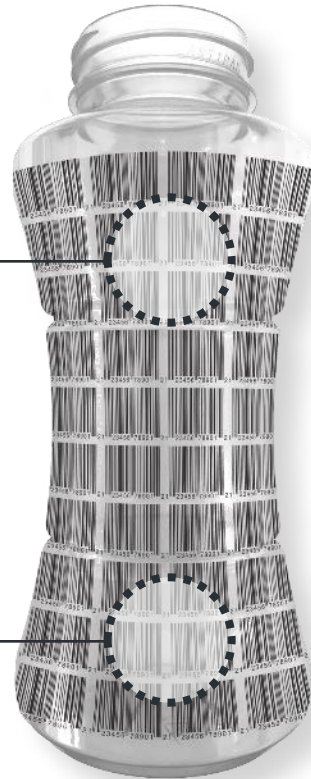
Digital Watermarks @work

FOR MOLDS

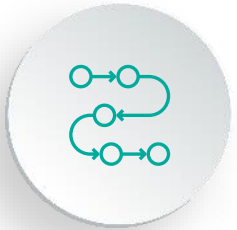


Micro-topological variations in substrate create signal tiles

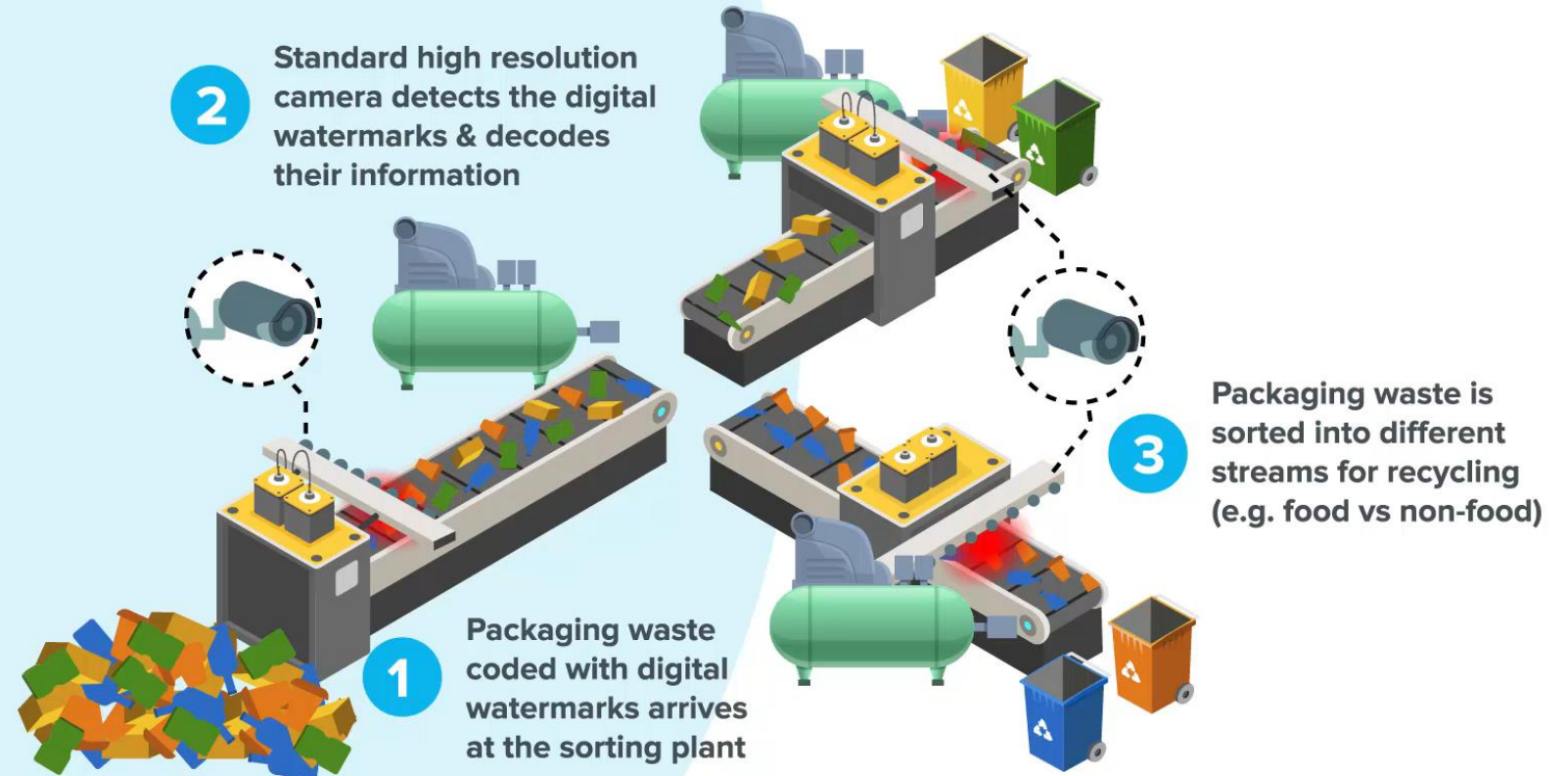
Works in variety of mold types



HOW DO DIGITAL WATERMARKS WORK ON A SORTING LINE?



SMART PACKAGING SORTING FOR A CIRCULAR ECONOMY



HOLY GRAIL 2.0



3 FOCUS AREAS

01

A close-up of a white robotic hand reaching out, with glowing orange nodes and lines representing a network or data flow in the background.

**Intelligent
Sorting**

**Reject
Add
Divide**

02

A background of vertical columns of binary code (0s and 1s) in white and light blue.

**Data
Mining**

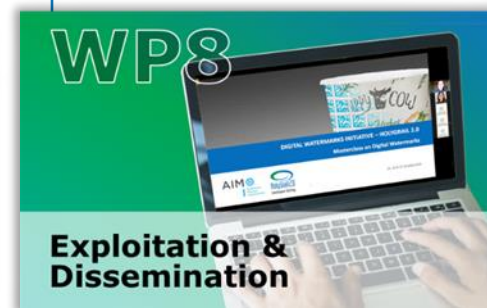
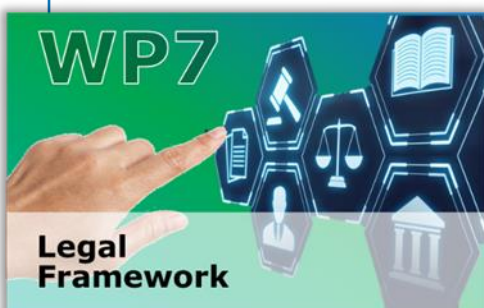
03

Two women, one with dark hair and glasses, the other with blonde hair and glasses, looking at a laptop screen together in an office setting.

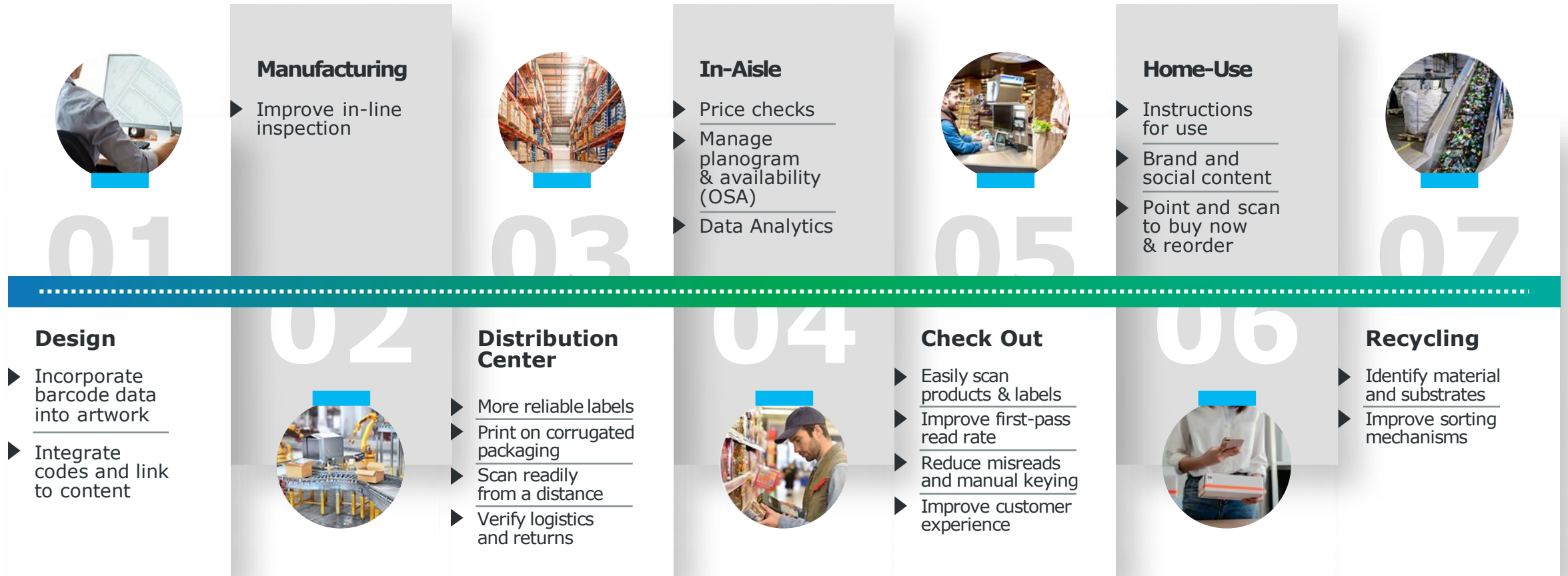
**Consumer
Engagement**

HOLY GRAIL 2.0

WORK PACKAGES

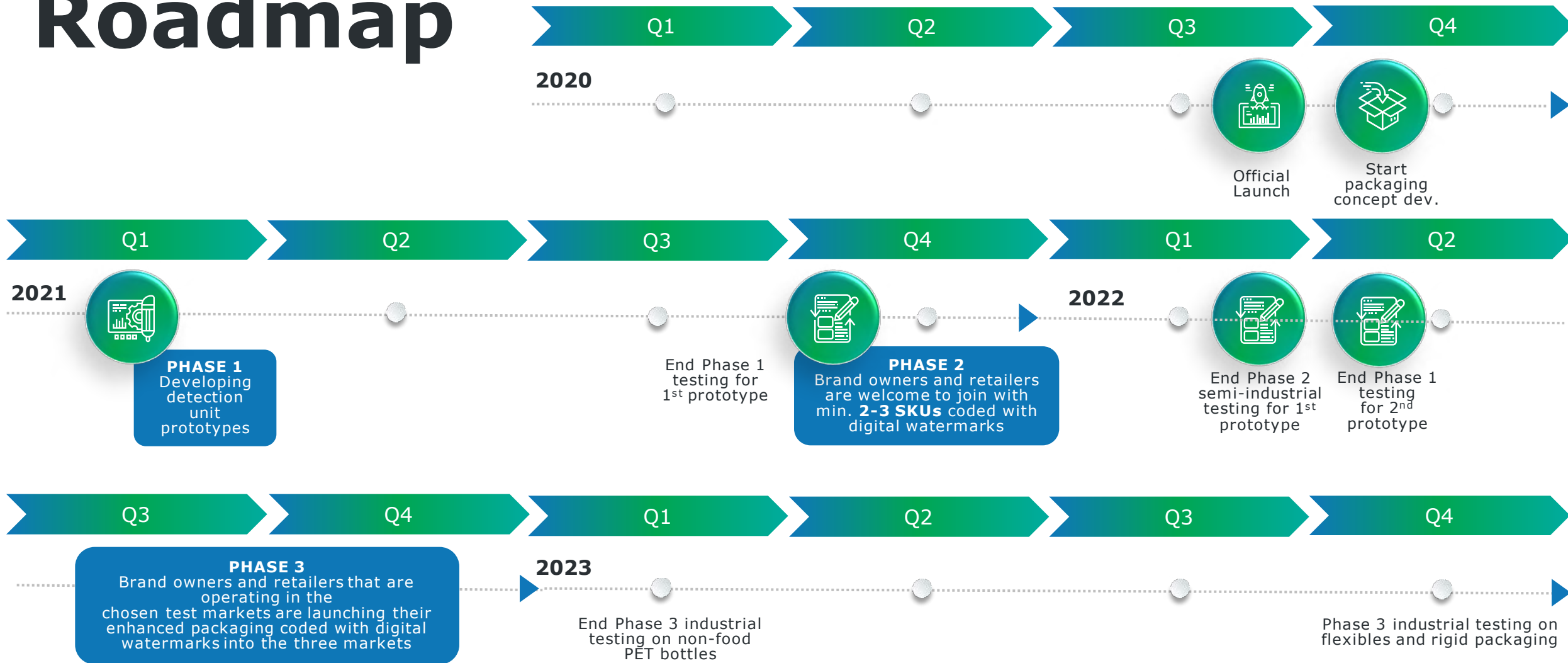


POTENTIAL BENEFITS OF DIGITAL WATERMARKS across the package life



HOLYGRAIL 2.0

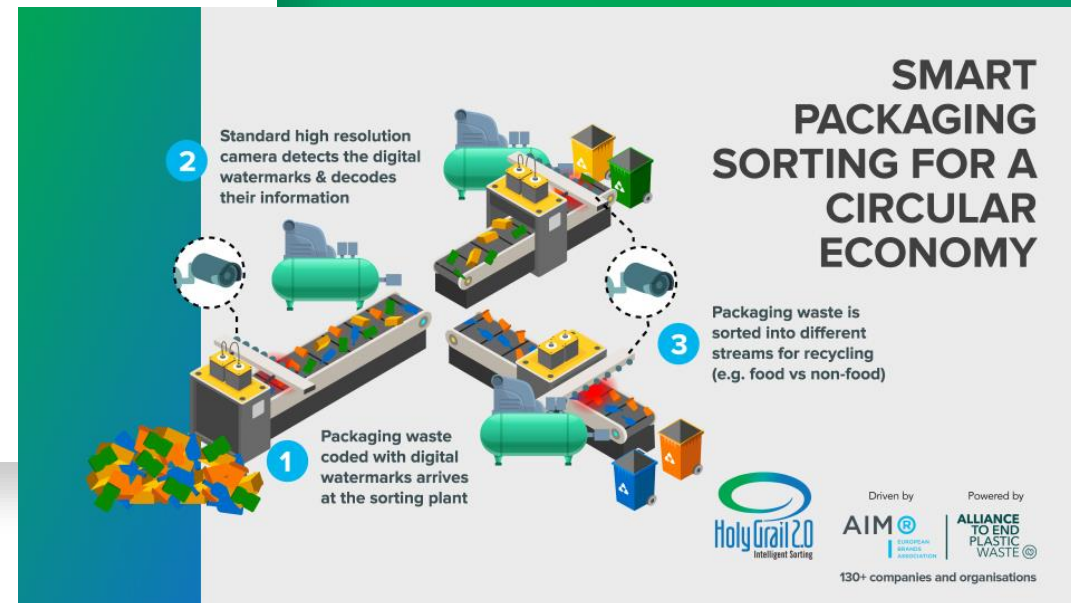
Roadmap



Phase I

Prototype
Development
Q1 2021 – Q1 2022

- ▶ Focus on **functional add-on module for the detection sorting unit** – combined with existing NIR sorters – developed by the machine vendors **Pellenc ST** and **Tomra**, in combination with **Digimarc** (digital watermarks technology provider).
- ▶ Success criteria: unit's ability to detect and sort digitally watermarked packaging of various sizes. The Technical Project Management overlooked and validated the prototypes.
- ▶ The prototypes will be used for the (semi-)industrial testing phase.
- ▶ Successful completion of Phase 1 brings the Technical Readiness Level (TRL) to TRL 6 – *technology demonstrated in relevant environment.*



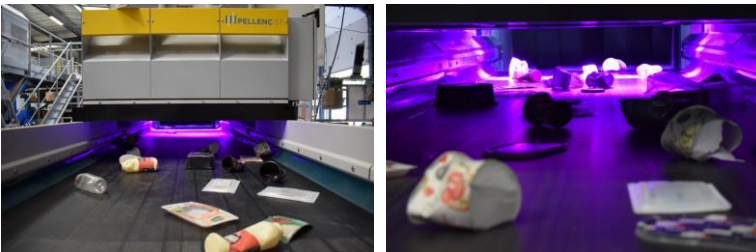


Digital Watermarks Initiative HolyGrail 2.0 reaches milestone with the validation of its first prototype detection sorting unit

Press release for immediate release – Brussels, 13 September 2021 – Following last week's partnership [announcement](#), the Digital Watermarks Initiative HolyGrail 2.0 has reached its first milestone with the successful validation of the project's first prototype detection sorting unit.

Developed by the machine vendor Pellenc ST and the digital watermarks technology provider Digimarc, the prototype, which combines the digital watermarks technology and NIR/VIS infrared for sorting of packaging waste, achieved a >95% ejection rate. This sorter is now ready to be installed in the Amager Resource Centre (ARC) in Copenhagen to start the semi-industrial test phase. Over the next four months, trials and demonstrations with around 125.000 pieces of packaging representing up to 260 different stock-keeping units (SKUs), all prepared by HolyGrail 2.0 members, will be held in Copenhagen. Engineers will test for several parameters including the speed and accuracy of the system, to ensure its ability to withstand the pressures of full-scale industrial operations.

If successful, digitally watermarked products could be introduced to store shelves in Denmark, France and Germany by the first half of 2022 for in-market demonstrations and industrial-scale trials.



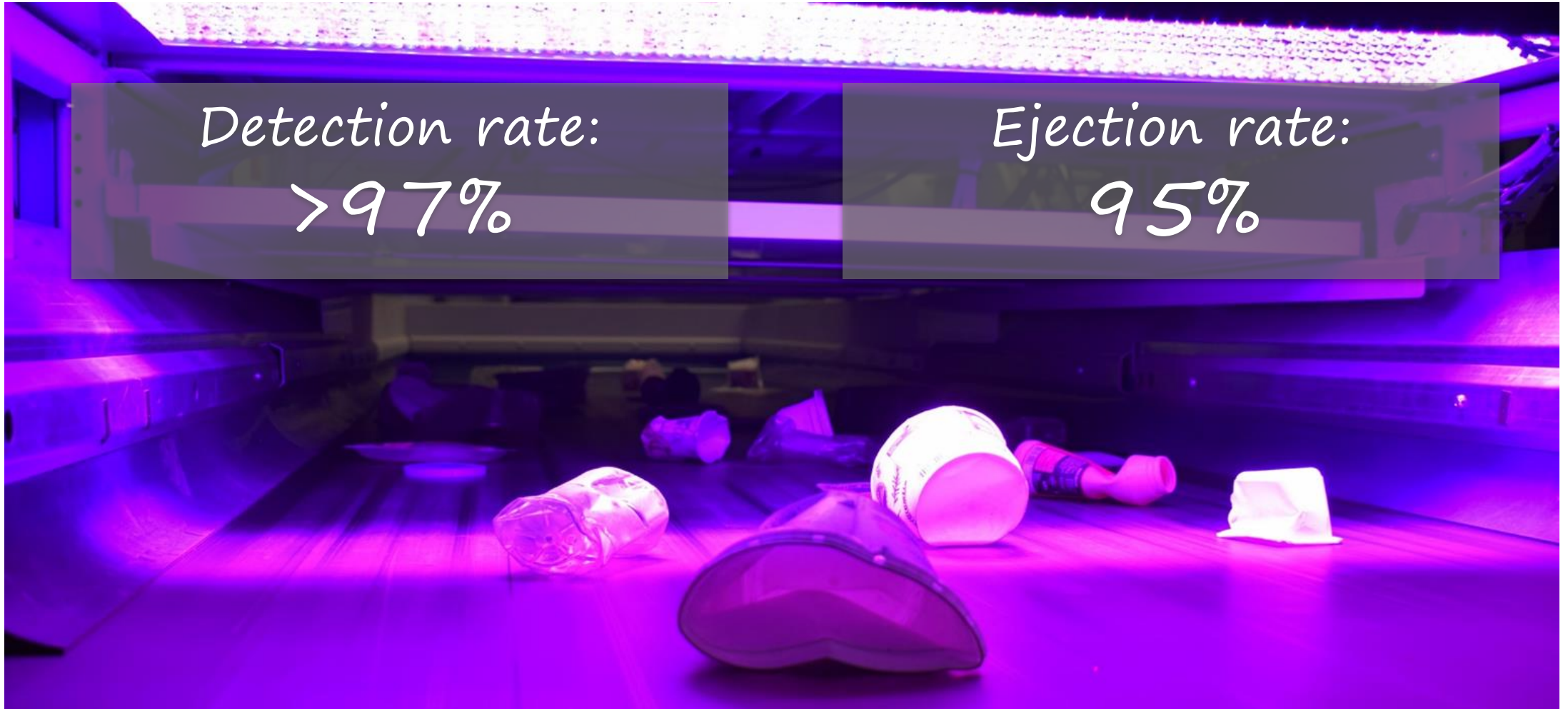
PHASE I

**1st VALIDATED PROTOTYPE
ADD-ON MODULE
BY PELLENC ST,
IN COOPERATION WITH
DIGIMARC**

1ST DETECTION ADD-ON MODULE

Detection rate:
>97%

Ejection rate:
95%





PHASE I

**2nd VALIDATED PROTOTYPE
ADD-ON MODULE
BY TOMRA,
IN COOPERATION WITH
DIGIMARC**

Detection rate:
>96%

Ejection rate:
95%

Phase II

Semi-industrial testing

Q3 2021 - Q2 2022

- ▶ **Software model & identification parameters are developed and tested** for sorting based on digital watermarks detection.
- ▶ System is tested for speed, accuracy, and detection efficiency.
- ▶ **2 test locations for semi-industrial trials** of the detection sorting units:
 - Pellenc ST/Digimarc module:
Sep 2021 - Jan 2022 at the **Amager Resource Centre, Copenhagen** with **125.000 packaging samples coded with DW** (around 260 SKUs)
 - Tomra/Digimarc module:
Q2 2022 in Germany
- ▶ Successful completion of Phase 2 brings the Technical Readiness Level (TRL) to TRL 7 - *system prototype demonstration in operational environment* and TRL 8 - *system complete and qualified*.



AIM - European Brands Association
and City of Copenhagen

INVITE TO

Open Houses

for a semi-industrial test demonstration of the
Digital Watermarks Initiative HolyGrail 2.0

📍 Amager Resource Centre, Copenhagen

📅 19 October and 18 November 2021

Virtual tours for all interested stakeholders
and on-site visits for HolyGrail 2.0 members only



PHASE II

SEMI-INDUSTRIAL
TEST DEMONSTRATION
AT AMAGER RESOURCE CENTRE
IN COPENHAGEN



[HolyGrail 2.0 - Semi-industrial tests @ARC Copenhagen 2021](#)

PHASE II

SEMI-INDUSTRIAL TEST VALIDATION RESULTS OF PELLENC ST/DIGIMARC PROTOTYPE DETECTION SORTING UNIT

- ▶ Consistent high results across all tested categories of plastic packaging material of on average:
 - 99% detection rates
 - 95% ejection rates
 - 95% purity ratesdemonstrated an impressive performance of the prototype.

Results per packaging material

Category	Detection Rate[1] (Estimate)	Ejection Rate[2] (By weight)	Purity[3] (By weight)
Rigid PP	99%	95%	96%
Rigid PE	98%	96%	99%
Rigid PET	99%	98%	95%
Flexibles	99%	91%	90%
Average across packaging materials	99%	95%	95%

Table 1: Average single sort results from mixed packaging waste streams (watermarked samples + contamination (non-watermarked samples + other pack material classes)). Typical industrial process conditions have been used in these trials (belt speed of 3m/s; Loading: Rigids running at ~2.5 tonnes/hr; Flexibles at ~0.5 tonnes/hr). Success criteria (after 1st sort) for detection efficiency/ejection efficiency/purity are 95%/95%/92% for rigid packaging, 95%/87%/90% respectively for film packaging (in line with industrial specifications).

PHASE II

SEMI-INDUSTRIAL TEST VALIDATION RESULTS OF TOMRA/DIGIMARC PROTOTYPE DETECTION SORTING UNIT

▶ High results across all tested categories of plastic packaging material of on average:

- 99% detection rates
- 96% ejection rates
- 93% purity rates

demonstrated an impressive performance of the prototype.

Results per packaging material

Category	Detection rate (by count)	Ejection rate (by weight)	Purity rate (by weight)
Average of rates for PP	99,6%	99,6%	94,2%
Average of rates for PET	99,1%	95,7%	92,6%
Average of rates for Fibre	98,9%	97%	93,1%
Average of rates for PE flexibles	97,6%	92%	90,8%

Phase III

FULL SCALE validation
Industrial tests
2023-2024

- ▶ Functional prototypes now **deployed in commercial sorting and recycling facilities under normal operational conditions on a large-scale.**

Locations in France and Germany, including 1 MRF, 1 PRF, 2 recycling plants

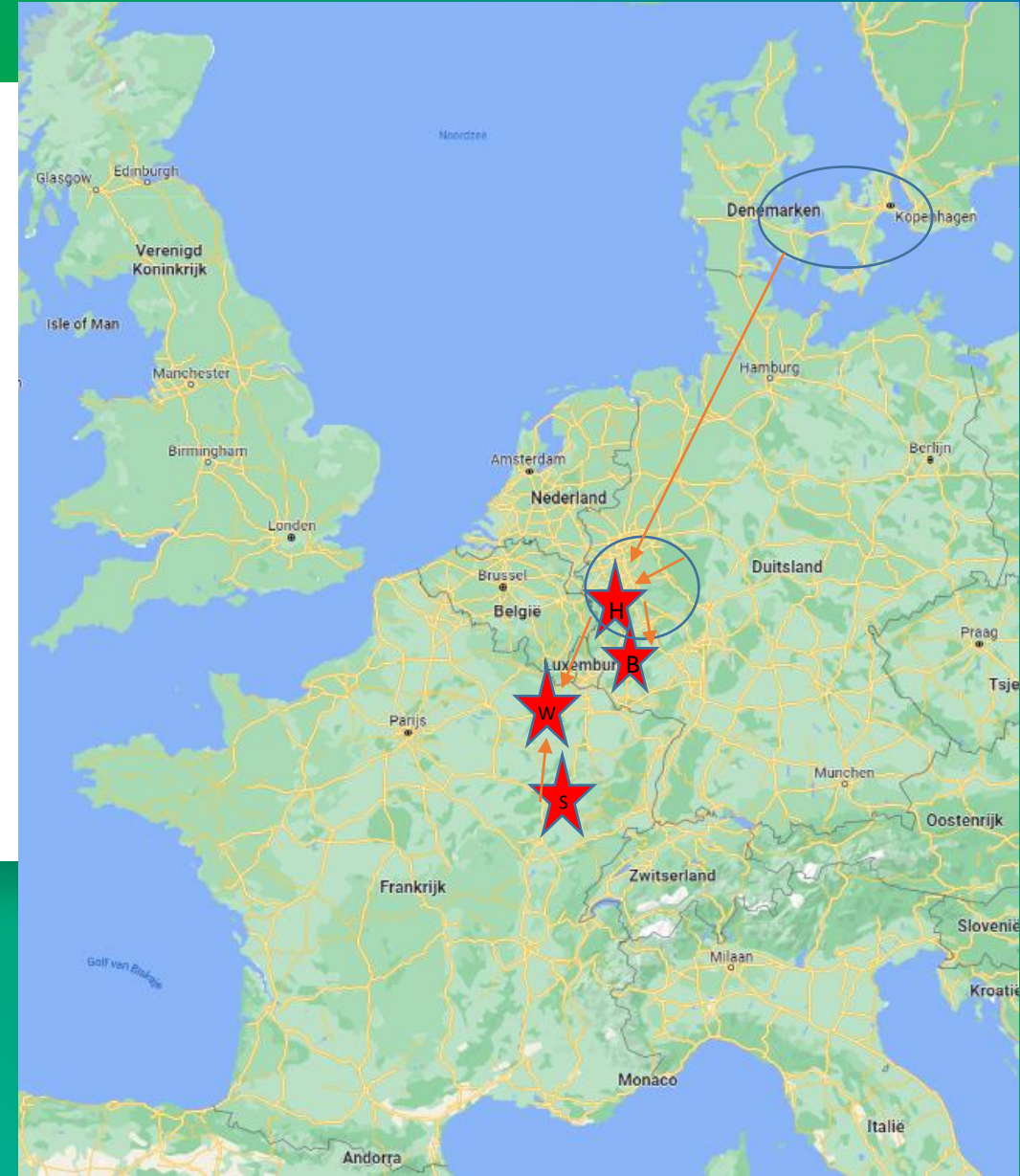
- ▶ Brand owners and retailers bring their **enhanced products commercially** to market in Denmark, France and Germany.
- ▶ Consumers can buy on-shelf products with digitally watermarked packaging, which will enter the waste stream after consumption.
- ▶ **Objective:** test system's reliability to ensure optimum performance.
- ▶ Successful completion of Phase 3 will bring the TRL to **TRL 9** – *actual system proven in operational environment.*



Phase III

Planned test locations & material

- ▶ Committed commercial enhanced samples from brand owners & retailers: **38,000 tons per year**
- ▶ Commercial enhanced pack materials launched in national markets **Denmark, France, Germany**
- ▶ **Locations for industrial tests:**
 - 1 MRF and PRF – Hündgen Entsorgung:
 - MRF: test/capture all enhanced rigid packaging from Germany & Denmark
 - PRF: (input from MRF + on-going supply + spiked volumes): focus on granular sorting
 - 2 recyclers (end to end recycling):
 - Wellman Indorama – Non-food rPET bottle grade: spiked volumes + on-going supply
 - Borealis – Food rPP film grade: spiked volumes + on-going supply



PHASE III – PLAN FOR 1ST 2023 TEST ON DEVELOPMENT OF NON-FOOD R-PET

○ SORTING

- Production of **10 tons of spiking volume** (~ 374k bottles)
- **Mimic real-life conditions**: mix in at Suez MRF (France) and create 3 different blend volumes (food vs non-food PET bottle)
- Run PET blends through Pellenc ST line (with add-on module) at Wellman Verdun to **characterise DW performance** (efficiency, purity and machine robustness)

○ **Pre-assess non-food r-PET quality: SORPTION study of Household and Personal Care products (HPC) into PET**

- Basis: **EFSA challenge test**
- Involve research institute & recycle machine vendors: proof that **recycling process can remove HPC components**



- ▶ Two-passing sorting showed on average:
 - 96% detection rates
 - 95% ejection rates
 demonstrating an impressive performance of the prototype.

- ▶ Proven efficacy of HolyGrail 2.0 technology in
 - separating with **high granularity**, and
 - **reducing impurities** in food-grade PET output streams
 in recycling plants at industrial scale

PHASE III

INDUSTRIAL TEST VALIDATION RESULTS OF PELLENC ST/DIGIMARC PROTOTYPE DETECTION SORTING UNIT

Results of food/non-food PET bottles separation

Fraction	Detection Efficiency (%)	Sorting Efficiency (%)
5% (single-pass sorting)	93.6	91.5
10% (single-pass sorting)	91.3	86.8
20% (single-pass sorting)	91.3	86.7
Average (single-pass)	92.1	88.3
10% (two-pass sorting)	96.0	95.6
20% (two-pass sorting)	95.7	94.6
Average (two-pass)	95.9	95.1

Full Press Release [here](#)

PHASE III – PLAN FOR ADDITIONAL TESTS IN 2023

- **MRF Germany (Hündgen):** with 2 add-on units 1m20 and 2m80 for 3 months testing
 - Purpose: capture all enhanced Rigids from Germany/Denmark including PET rigids (bottles incl SSL + trays), PP rigids, PE rigids, liquid carton boards, paper cups
 - Granular sorting in dedicated stream including non-food PET bottles and surface printed mono-material PP films
- **Recycler (Wellman):**
 - Run **washing test** at Wellman Verdun
 - **Solid stating/pelletizing** at Wellman
 - Assess non-food r-PET **quality** (incl FFU)
- **Recycler (Borealis):** trials on rigid and flexible PO, with key focus on development of food-grade r-PP film

HÜNDGEN  ENTSORGUNG

INDORAMA
VENTURES
WELLMAN INTERNATIONAL LTD

 PELLENC ST

DIGIMARC | 

 **BOREALIS**
Keep Discovering

AIM®
EUROPEAN
BRANDS
ASSOCIATION


HolyGrail 2.0
Intelligent Sorting

ALLIANCE
TO END
PLASTIC
WASTE®

HolyGrail 2.0 Partners



PARTNERSHIPS FOR HG2.0 (SEMI-) INDUSTRIAL TRIALS



Alliance to End Plastic Waste



City of Copenhagen

➤ More information in our press release [here](#)



HolyGrail 2.0 Structure

HG2.0 STRUCTURE BASED ON [HOLYGRAIL 2.0 CHARTER](#) UNDER THE AUSPICES OF AIM, EUROPEAN BRANDS ASSOCIATION:



MEMBERSHIP

HG2.0 Membership Associate & Full Initiative Members

- ▶ **Technical Work Packages:**
Involvement of all members based on expertise and knowledge
WG leaders appointed
Under supervision of Technical Project Management
- ▶ **Leadership Team:**
= Core members representing each of the sectors engaged in the initiative
Leads, coordinates and manages the activities of the initiative
Ensures effective use of membership fees and involvement of member companies
Overlooks the activities and decides on the set-up of technical work packages



HOLY GRAIL 2.0

LEADERSHIP TEAM




Brand manufacturers (4/4)



Retailers (2/4)



MRFs: Materials Recovery Facilities (2/2)



Converters (2/2)



Extended Producer Responsibility Organisations (2/2)



Recyclers (2/2)

LT Chair: Gian De Belder, P&G

HolyGrail 2.0 Structure

HG2.0 STRUCTURE BASED ON [HOLYGRAIL 2.0 CHARTER](#) UNDER THE AUSPICES OF AIM, EUROPEAN BRANDS ASSOCIATION:



MANAGEMENT

- ▶ **Secretariat – AIM as Initiative Facilitator:**
 - Overall management of initiative
 - Contact point for members & external stakeholders
 - Ensuring regular updates / information flow to all HG2.0 members
- ▶ **Technical Project Management:**
 - Drafting technical test plans
 - Coordinating the different technical working groups
 - Overseeing the work on the test sorting lines
 - Supporting members with technical expertise & in their work with technology suppliers
- ▶ **Legal Counsel:**
 - Present at all meetings of Leadership Team and HG2.0 members



HolyGrail 2.0 Structure

HG2.0 ADVISORY GROUP
STRUCTURE BASED ON
[HOLYGRAIL 2.0 ADVISORY
GROUP CHARTER:](#)



ADVICE

● ► Advisory Group:

Panel for dialogue, exchange and input into both the operational implementation of key activities and the overall strategy of HG2.0.

Provides advice to HG2.0 Leadership Team, constituting the public and policy complement to the cross-value chain initiative HolyGrail 2.0.

Comprised of key stakeholders in the Circular Economy debate, including representatives from NGOs, Media, European and national public agencies, European and national policy-makers, other key stakeholders





Innovation, sustainability and digital are the **3 key ingredients** we are combining with smart packaging through **digital watermarks** to achieve the objective of the **Green Deal** towards a **clean, circular and climate neutral economy**.



MICHELLE GIBBONS
DIRECTOR GENERAL, AIM



Digital Watermarks Initiative HolyGrail 2.0



The Digital Watermarks Initiative HolyGrail 2.0 – driven by AIM, the **European Brands Association** and powered by the Alliance to End Plastic Waste – is a pilot project with the objective to prove the **technical viability** of digital watermarks for accurate sorting of packaging waste as well as the **economic viability** of the business case at large scale.



Digital watermarks are **imperceptible codes**, the size of a **postage stamp**, covering the surface of a consumer goods **packaging** and carrying a wide range of attributes. The aim is that once the packaging has entered into a **waste sorting facility**, the digital watermark can be detected and decoded by a **standard high resolution camera** on the sorting line, which then – based on the transferred attributes (e.g. food vs. non-food) – is able to sort the packaging in corresponding streams. This would result in better and more accurate sorting streams, thus consequently in **higher-quality recyclates benefiting the complete packaging value chain**.





CONTACT

Digital Watermarks Initiative HolyGrail 2.0

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EU Transparency register ID no.:

1074382679-01



