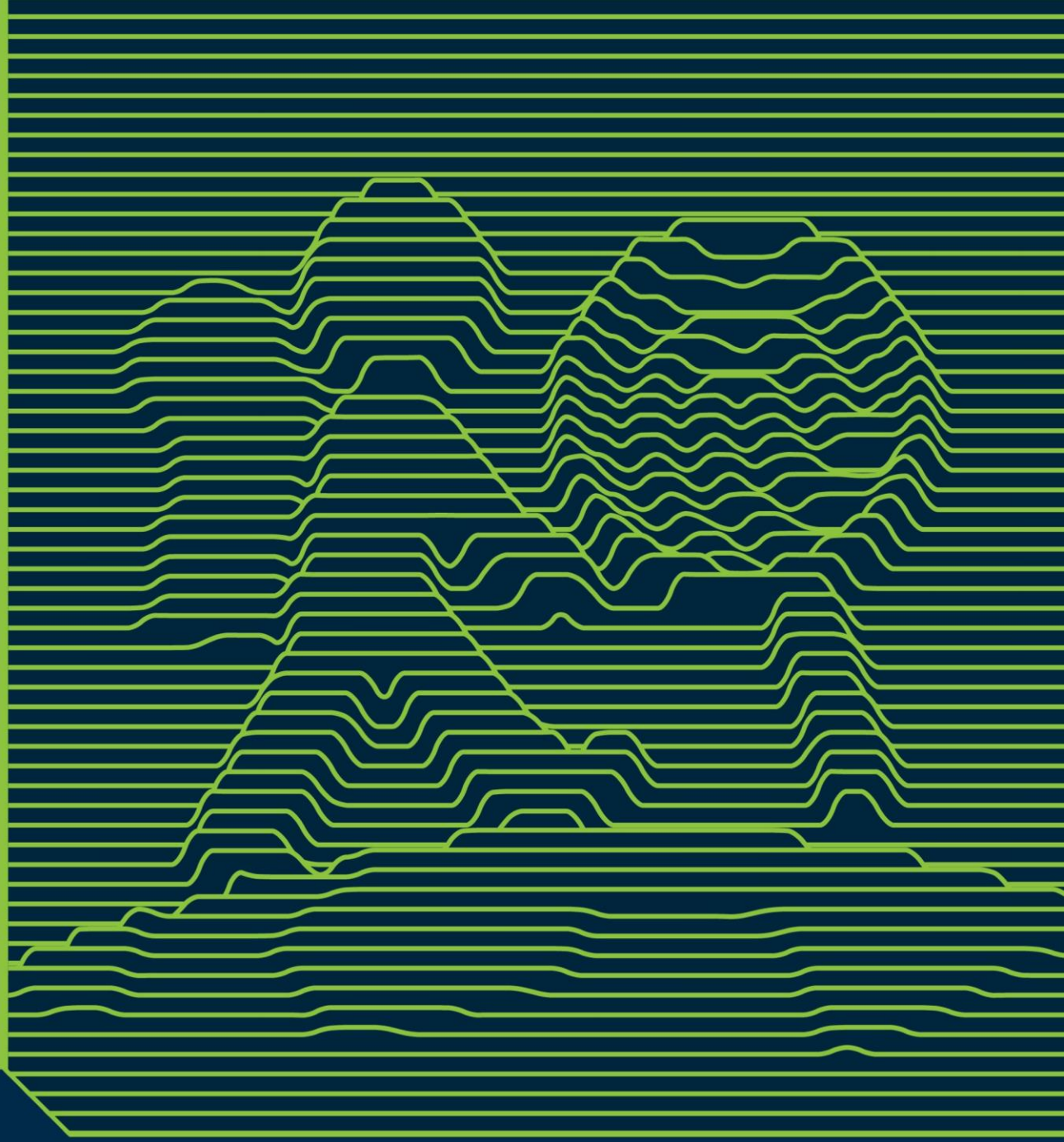
# Technology Foresight on Biometrics for the Future of Travel



**BORDER SECURITY OBSERVATORY**
RESEARCH AND INNOVATION UNIT

FRONTEX

CERIS SSRI EVENT: "**FORESIGHT AND KEY ENABLING TECHNOLOGIES**"

BRUSSELS – 5 MARCH 2024

FRONTEX
EUROPEAN BORDER AND COAST GUARD AGENCY

# Project Overview



# Project Overview

## Research Team

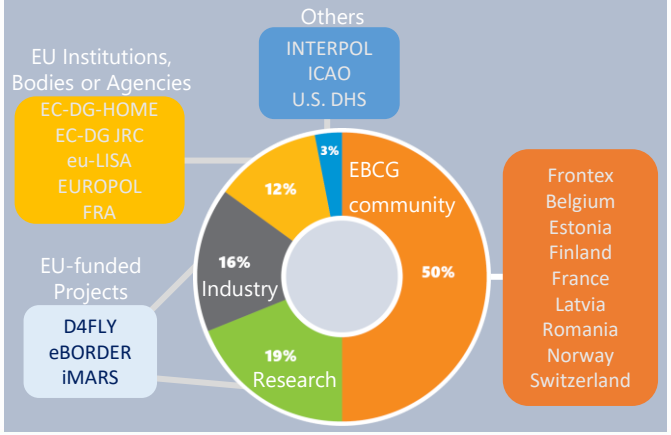
**Steinbeis 2i**
Germany

**4CF**
Poland

**Erre Quadro**
Italy

**Institute of Optoelectronics**
Military University of Technology
Poland

**>40** **Stakeholders actively involved**
(strong focus on EU and EBCG)




2021

**JANUARY**
**Kickoff Meeting**

**APRIL**
**1st Technology Foresight Workshop on Scenario Building**

**MAY**
**Delphi Survey**

**JUNE**
**2nd Technology Foresight Workshop on Roadmapping**

**SEPTEMBER**
**Final Project Meeting**

# Objectives

## Research study

**Research study on the future opportunities** that biometric technologies could provide to the European Border and Coast Guard (EBCG) community

- Identify specific research and innovation activities
- Knowledge on how to maximize future benefits of biometric technologies

## Desired outputs

- **TF Methodology and Supporting Tools**
- **Taxonomy of biometric technologies**
- **Research Study**

# Methodological Framework

| STAGES | | PHASES | STEPS |
|---|---|---|---|
| | | 1. ANALYSIS OF RESEARCH CONTEXT | Identification of Needs |
| EXPLORATION Identify the right things | DISCOVER (Expansion of options) | 2. INSIGHT HUNT | State-of-the-Art Review<br>Clustering of Technologies<br>Identification of Stakeholders<br>Building Scenarios for the Future |
| | DEFINE (Narrowing options down) | 3. FILTERING RESULTS | Filtering by Key Strategic Factors<br>Filtering by Other Relevant Factors<br>Filtering by Future Scenarios |
| UNDERSTANDING Understand things right | DEVELOP (Expansion of understanding) | 4. DEEP ANALYSIS | Modelling the Roadmaps |
| | DELIVER (Actionable insights) | 5. MAPPING CAPABILITIES | Capability Readiness Analysis |

## METHODS

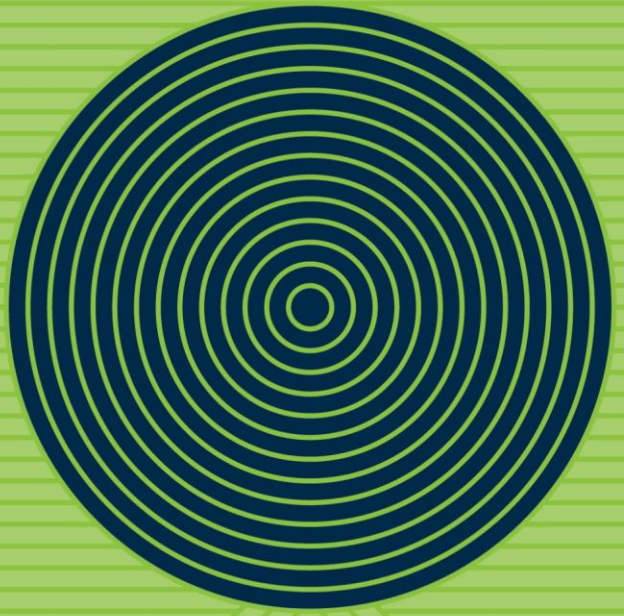
- Matrixes of needs & functional requirements
- Desk research
- Patentometric & bibliometric analyses
- Delphi Survey
- 4CF Matrix
- Rip Van Winkle Method
- Futures Wheel
- Forecasting/Backcasting
- Scenario Analysis
- Weighted Criteria Matrix
- Workshops

## TOOLS

- 4CF HalnyX
- Miro Board
- Domain Terminology Extractor
- Smart Ranker
- Weighted Clusterer

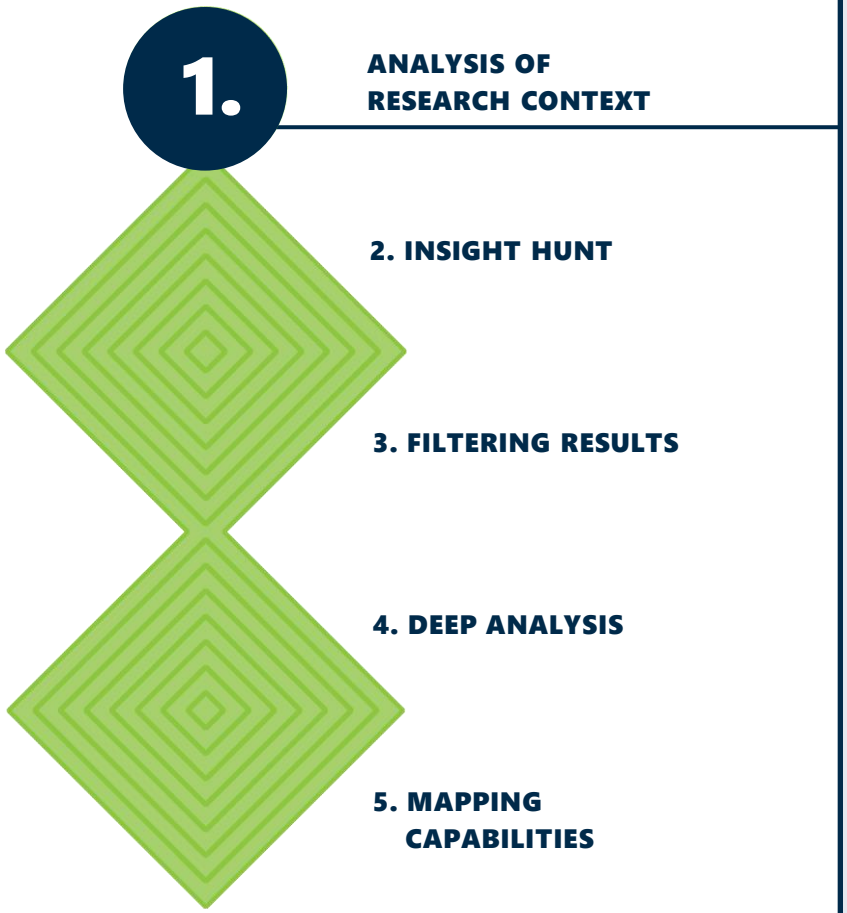
# 1. Analysis of Research Context





# Identification of Needs

## Analysis of Frontex needs for key functions of biometric technologies




### Aim

- Needs analysis to specify the field and scope of the research and to set the goals for the study
- Tailor the Technology Foresight Methodology to Frontex needs

### 4 "must-haves" for biometric technologies identified for reference in later phases of the project

- Seamlessness
- Compliancy with fundamental EU values and regulations
- Applicability within pandemic-specific restrictions
- Low vulnerability to adversary attacks

# 2. Insight Hunt



# State-of-the art Review

## Taxonomies

2. INSIGHT HUNT

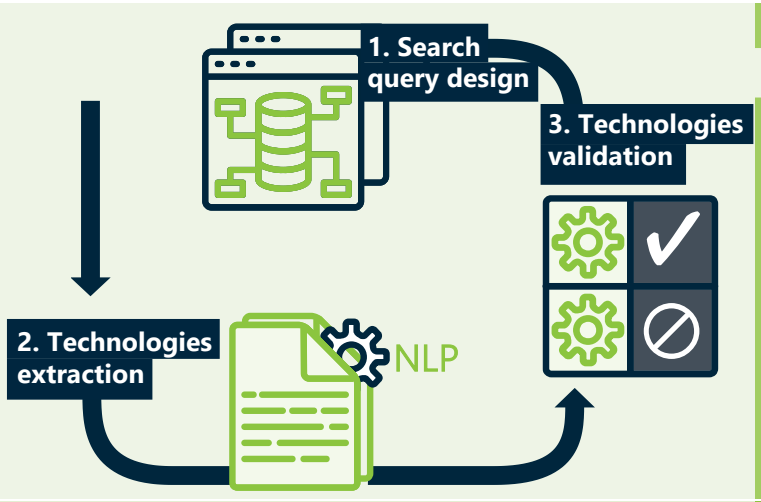
**Aim**

- Establish a common systematic understanding of the biometrics domain
- Create reference documents which could enable future R&I activities

**Output**

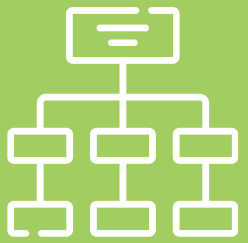
- Taxonomy of biometric technologies
- Taxonomy of biometrics-enabled technological systems

- **Highly iterative** process based on the extraction of terminology from patents and scientific literature
- **Automatic tools** (embedding NLP) for analysis of massive technical and scientific documentation




**Three-level Taxonomy** of Biometric Technologies

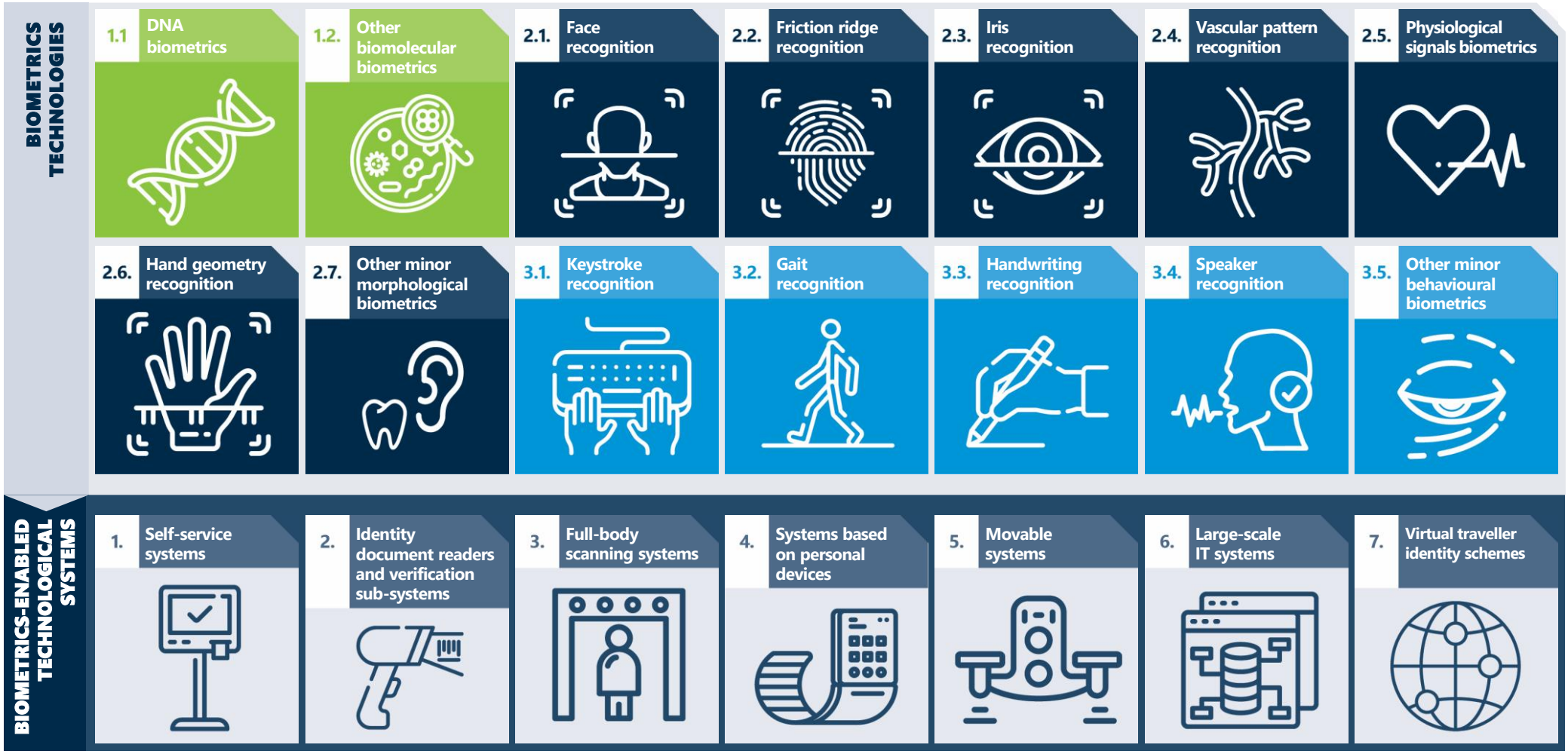
- 57 biometric technologies
  - 5 biomolecular
  - 39 morphological
  - 13 behavioural



**Two-level Taxonomy** of Biometrics-Enabled Technological Systems

# State-of-the art Review

## Taxonomies



# Clustering of Technologies

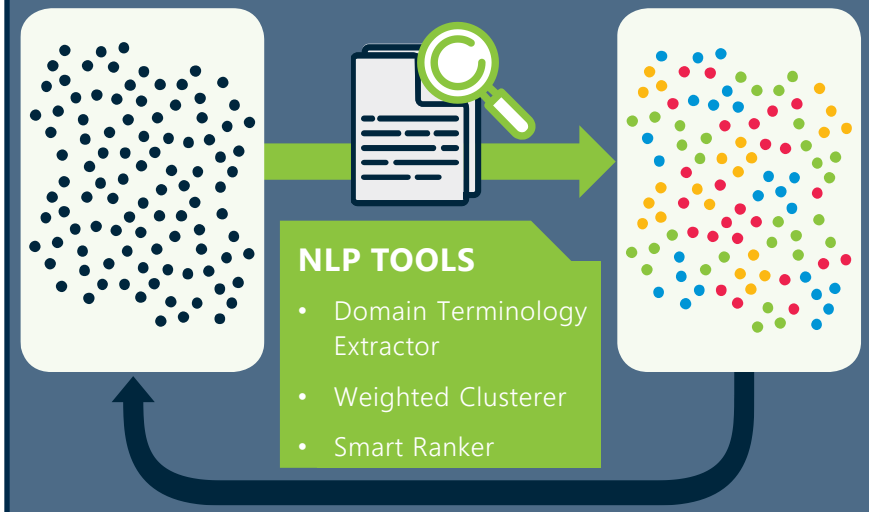
## Identification of Technological Clusters

**2.**
**INSIGHT HUNT**

### Aim

- Group the large set of biometric technologies into **clusters** to assure the usability of the taxonomy in the different phases of the Tech Foresight
- Create homogeneous datasets of patents and scientific publications suitable to conduct patentometric and bibliometric analyses

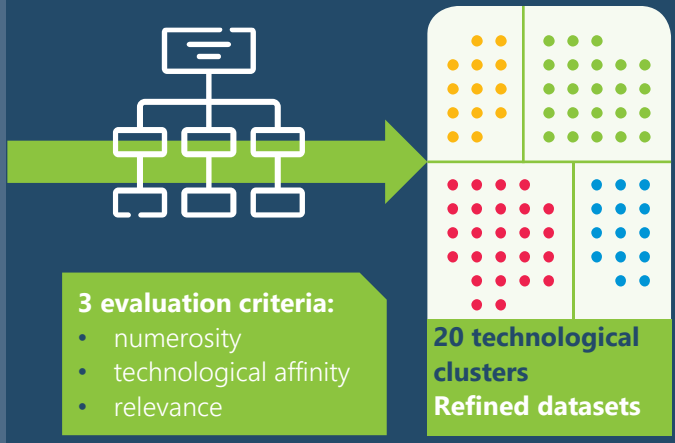
**PRELIMINARY AUTOMATIC STEP**



**NLP TOOLS**

- Domain Terminology Extractor
- Weighted Clusterer
- Smart Ranker

**CONTROL STEP**



**3 evaluation criteria:**

- numerosity
- technological affinity
- relevance

**20 technological clusters**
**Refined datasets**

# Clustering of Technologies

## Identification of Technological Clusters

1. DNA biometrics
2. Infrared face recognition
3. 2D face recognition in the visible spectrum
4. 3D face recognition
5. Infrared friction ridge recognition
6. 3D friction ridge recognition
7. Contactless friction ridge recognition
8. Contact-based friction ridge recognition
9. Iris recognition in the NIR spectrum
10. Iris recognition in the visible spectrum
11. Iris recognition at a distance
12. Eye vein recognition
13. Hand vein recognition
14. Heart signal recognition
15. Hand geometry recognition
16. Periocular recognition
17. Keystroke recognition
18. Gait recognition
19. Handwriting recognition
20. Speaker recognition

# Clustering of Technologies

## Patentometric and bibliometric analyses of Clusters

### Aim

- **Analyse the lifecycle** of 20 Biometric Technological Clusters to gather information about their evolution
- **Theory of Technology Lifecycle applied**
- Datasets of patent families and scientific publications were used to **study technological evolution**

**Proprietary patent database**
(based on EPO's Database)

**OpenAIRE database**
(scientific publications)

**CORDIS database of EU-funded projects**

**DATA ANALYSIS**

**Technological life-cycle assessment**

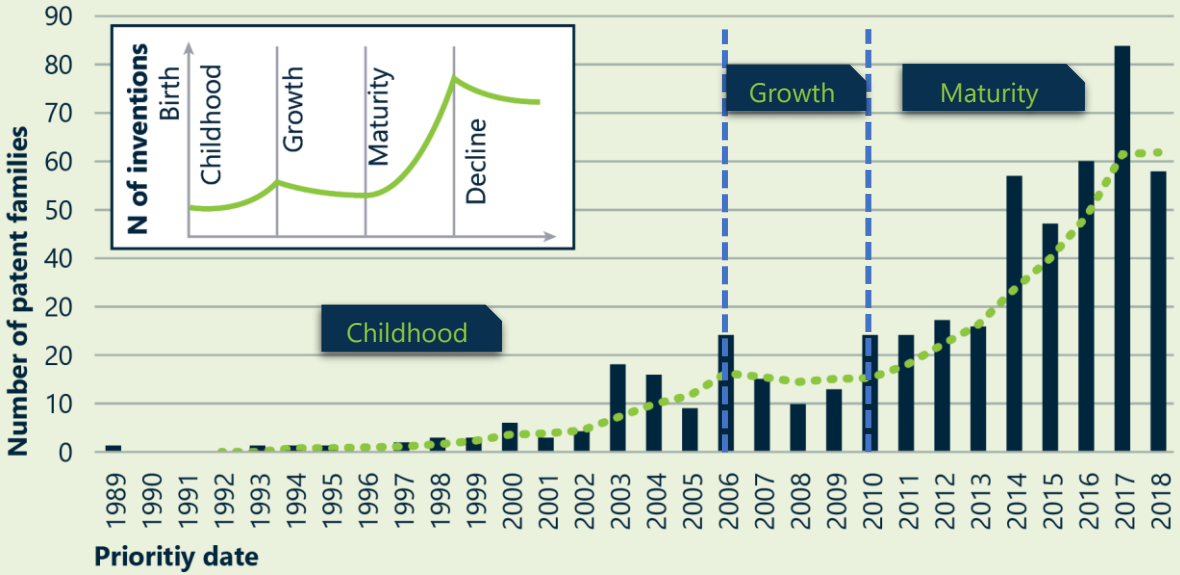
**Geographical distribution of R&D, manufacturing and commercial activities**

**Most prolific R&D entities**

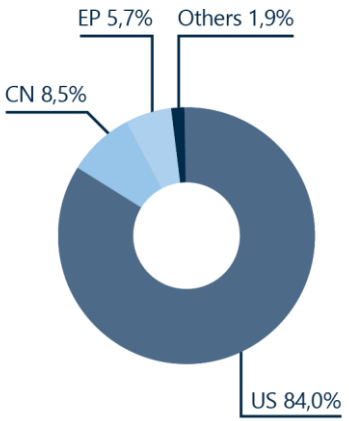
# Clustering of Technologies

## Patentometric and bibliometric analyses on Clusters

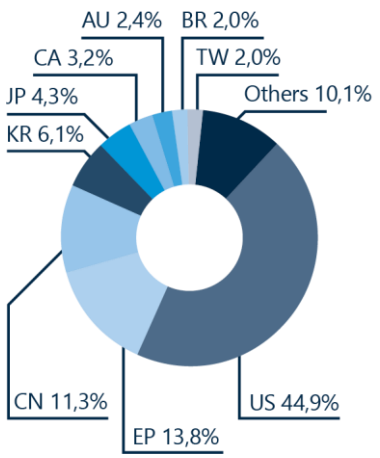
### 3D face recognition




Geographic distribution of **priority patents**




Geographic distribution of **all patents**




| Assignee | Number of patent families | % of the total |
|---|---|---|
| Microsoft | 21 | 3.8 |
| Amazon Technologies | 19 | 3.4 |
| Google | 18 | 3.2 |
| Apple | 13 | 2.3 |

| Publisher | Number of scientific publications | % of the total |
|---|---|---|
| IEEE | 87 | 32.3 |
| Springer | 34 | 12.6 |
| Elsevier | 25 | 9.3 |

# Building Scenarios for the Future

## Scenarios for the future of travel, border checks and biometrics in 2040

2.
INSIGHT HUNT

### Aim

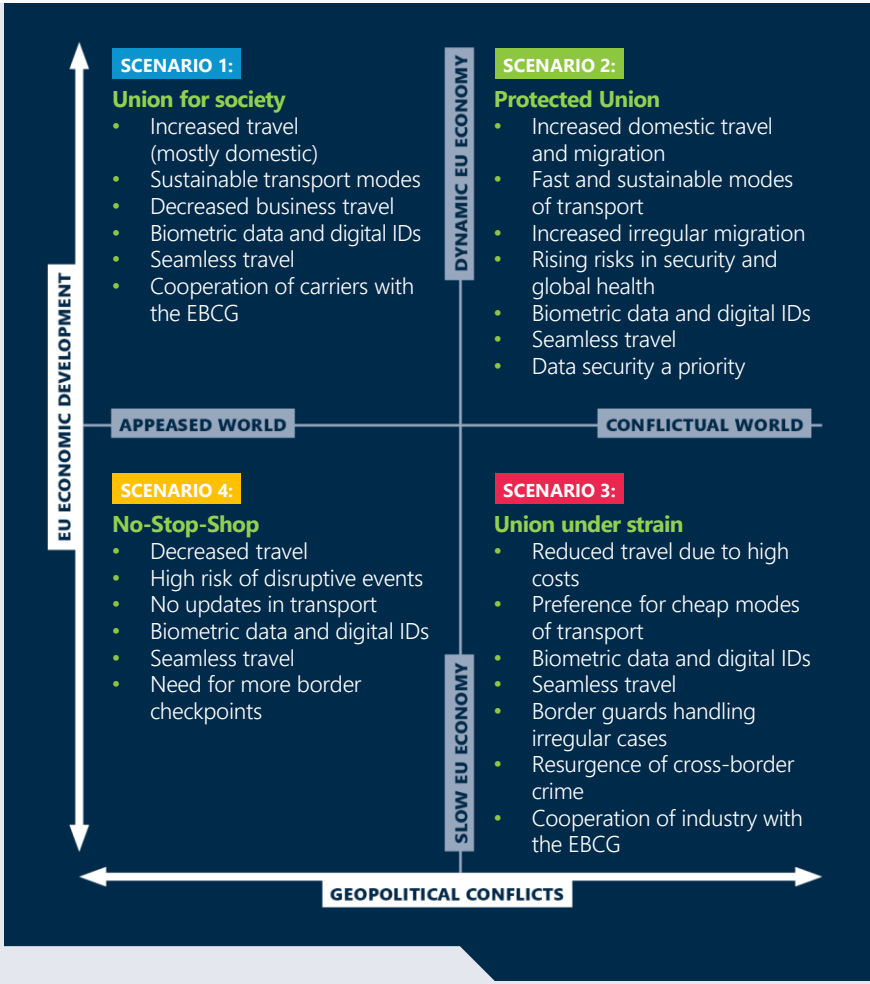
- Reframing visions of the future in order to challenge them
- Assessing how alternative futures might influence the evolution of biometrics.

### Choice of scenarios

- Based on JRC's study "*The Future of Customs in the EU 2040: A foresight project for EU policy*"[1]
- Adapted to incorporate aspects relevant to the travel and border check context

### Use of scenarios

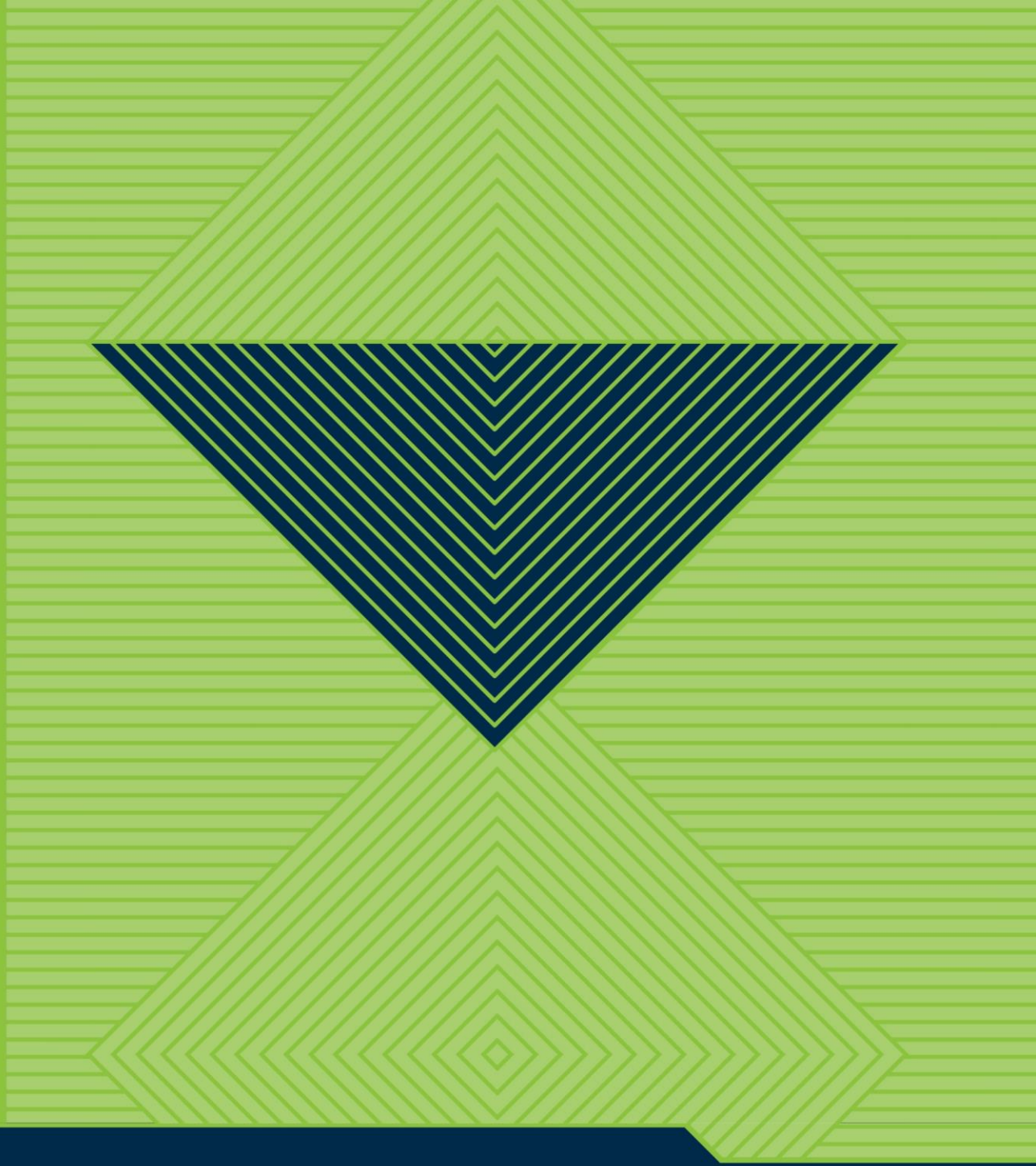
- Roadmapping
- Mapping capabilities




[1] Ghiran A., Hakami A., Bontoux L., Scapolo, F. The Future of Customs in the EU 2040: A foresight project for EU policy, EUR 30463 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-26299-2, doi:10.2760/29195, JRC121859.

# 3. Filtering Results





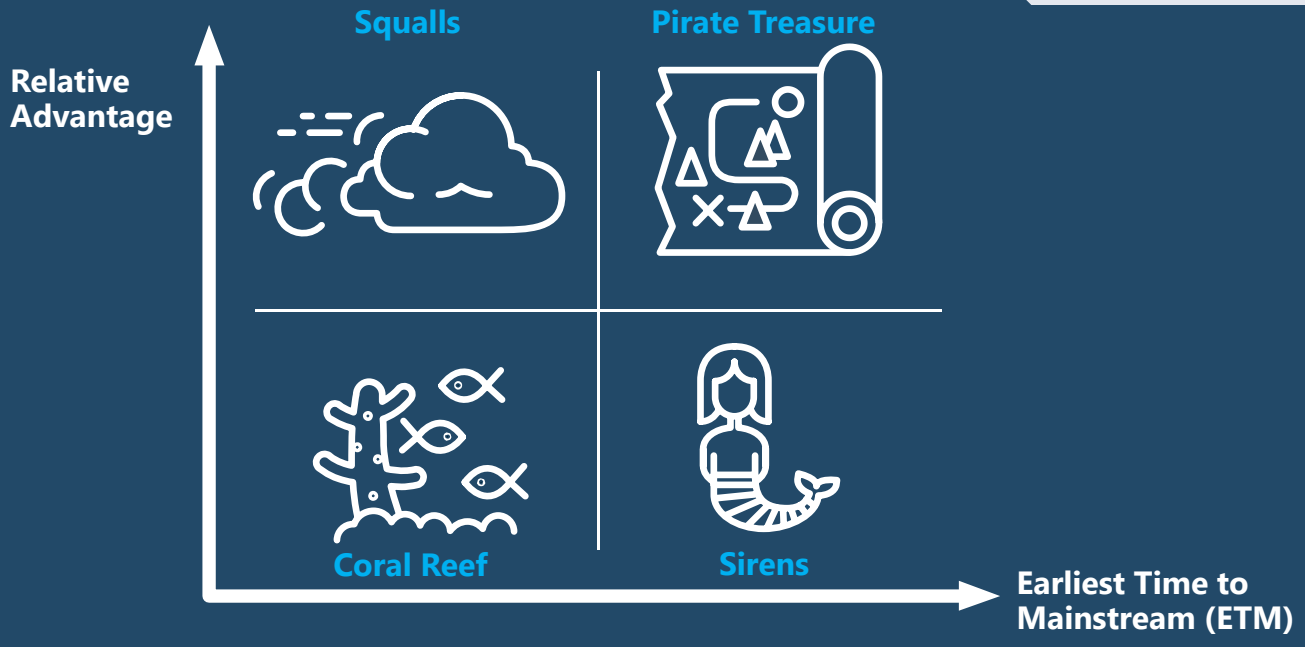
# Filtering by Key Strategic Factors

## Prioritisation of biometric technologies – The Delphi Survey

FILTERING RESULTS
3.

**Aim**

- Select the Key biometric Technological Clusters – KTCs
- Quantitative assessment of the 20 Technological Clusters using 2 metrics: **Relative Advantage** and **Earliest Time to Mainstream** by a **real-time Delphi**
  - Exploit collective intelligence, not only statistical distribution of answers
  - Stimulate consensus-oriented structured discussions
  - Collect experts' opinions



# Filtering by Other Relevant Factors

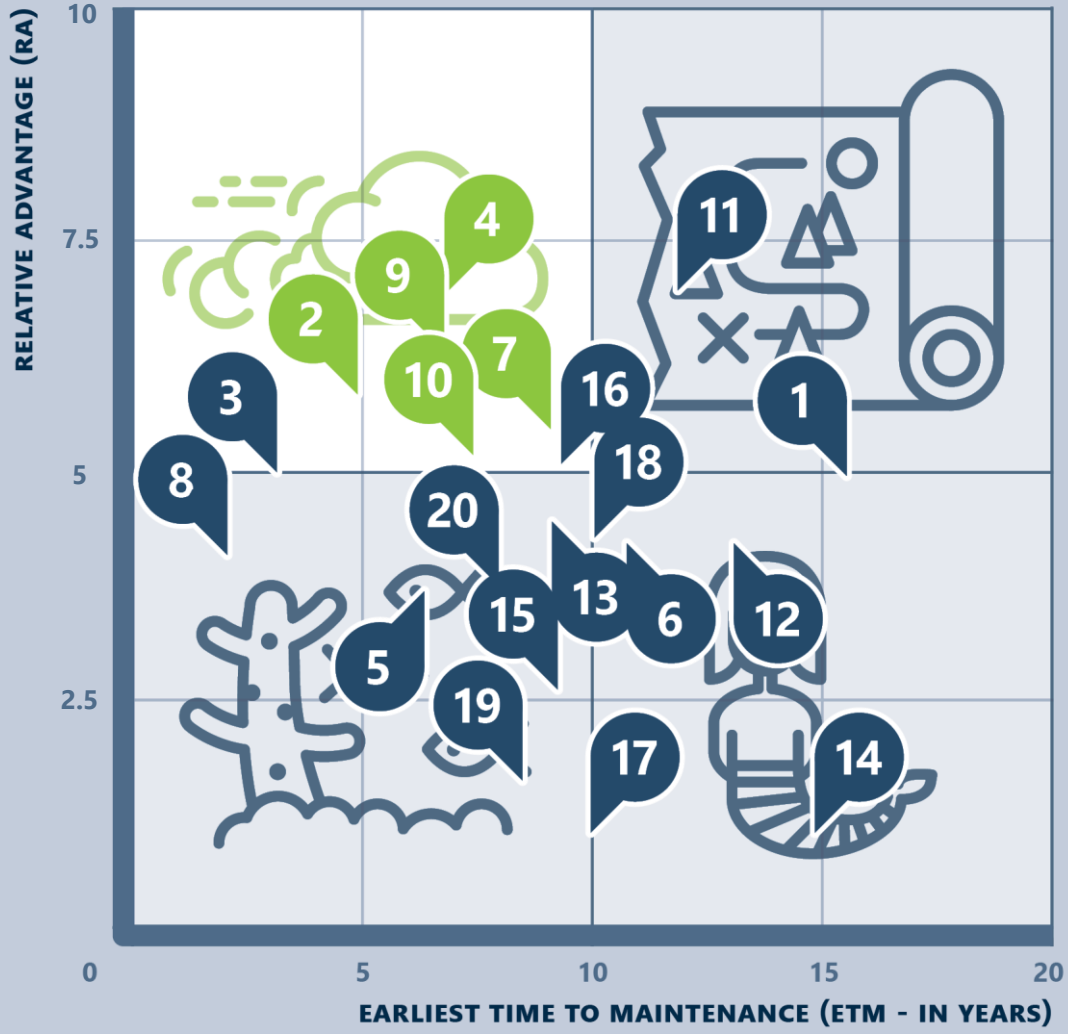
**FILTERING RESULTS**
**3.**

**ADDITIONAL CHECKS FOR**

- ✓ redundancy
- ✓ vulnerability to adversary attacks
- ✓ "must-haves" from the needs analysis

**FINAL SELECTION OF 5 KTC**

2. Infrared face recognition
4. 3D face recognition
7. Contactless friction ridge recognition
9. Iris recognition in the NIR spectrum
10. Iris recognition in the visible spectrum



# 4. Deep Analysis



# Roadmaps of key biometric technological clusters


## Aim

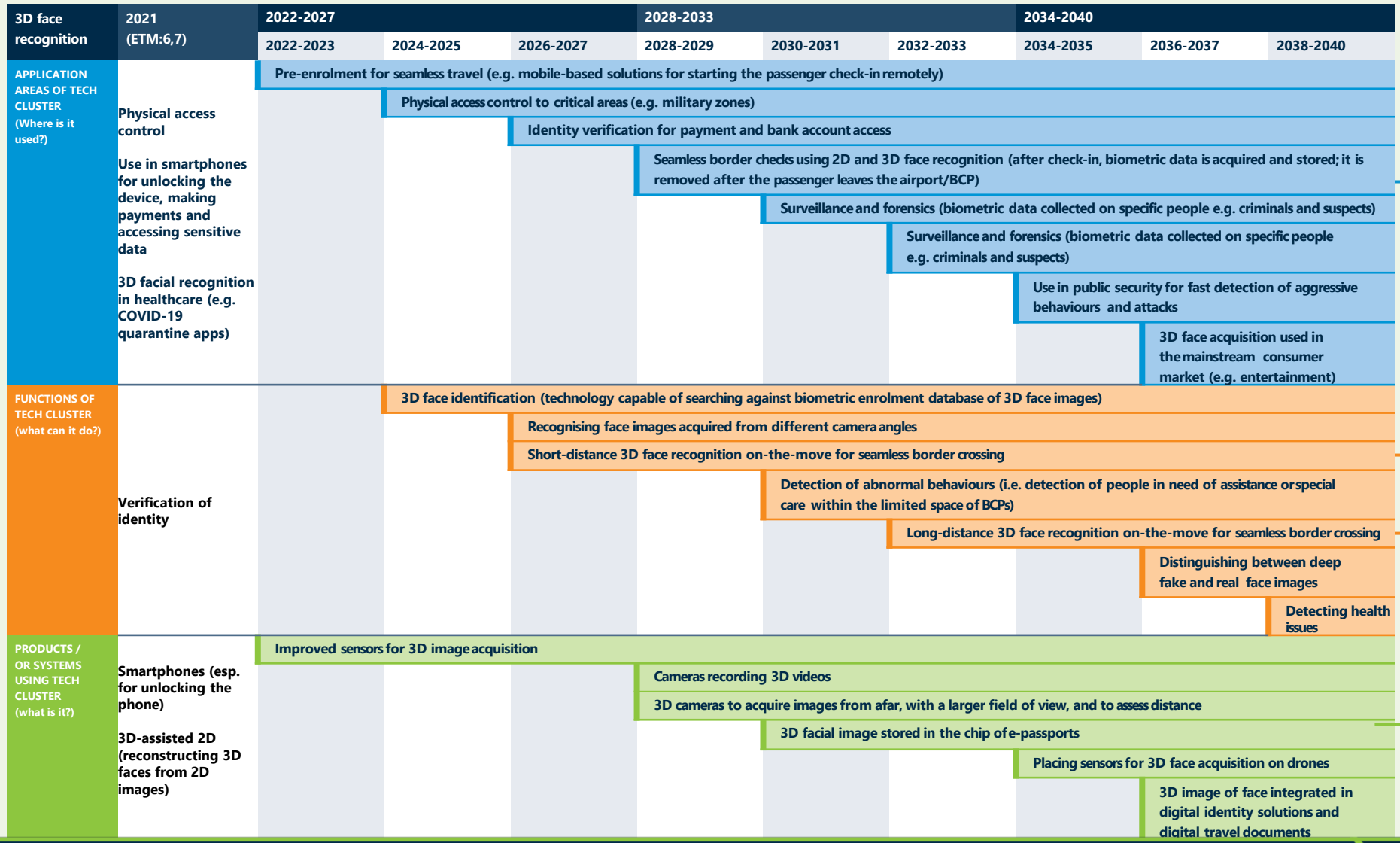
- In-depth analysis of the key technological clusters
- Envisage potential future developments in terms of:
  - Applications
  - Functions
  - Products and systems

## Outcomes (for each KTC)

- Visual technology roadmap chart
- List of expected key opportunities and challenges in the today-2040 timeframe
- Comparative analysis to study how the hypothetical scenarios might influence the developments envisaged in the roadmaps

# Roadmaps of key biometric technological clusters

## Visual technology roadmap charts – 3D face recognition




**EXAMPLE DEVELOPMENTS**

**2028 – 2040**
Seamless border checks using 2D and 3D face recognition (after check-in, biometric data is acquired and stored; it is removed after the passenger leaves the airport/BCP)

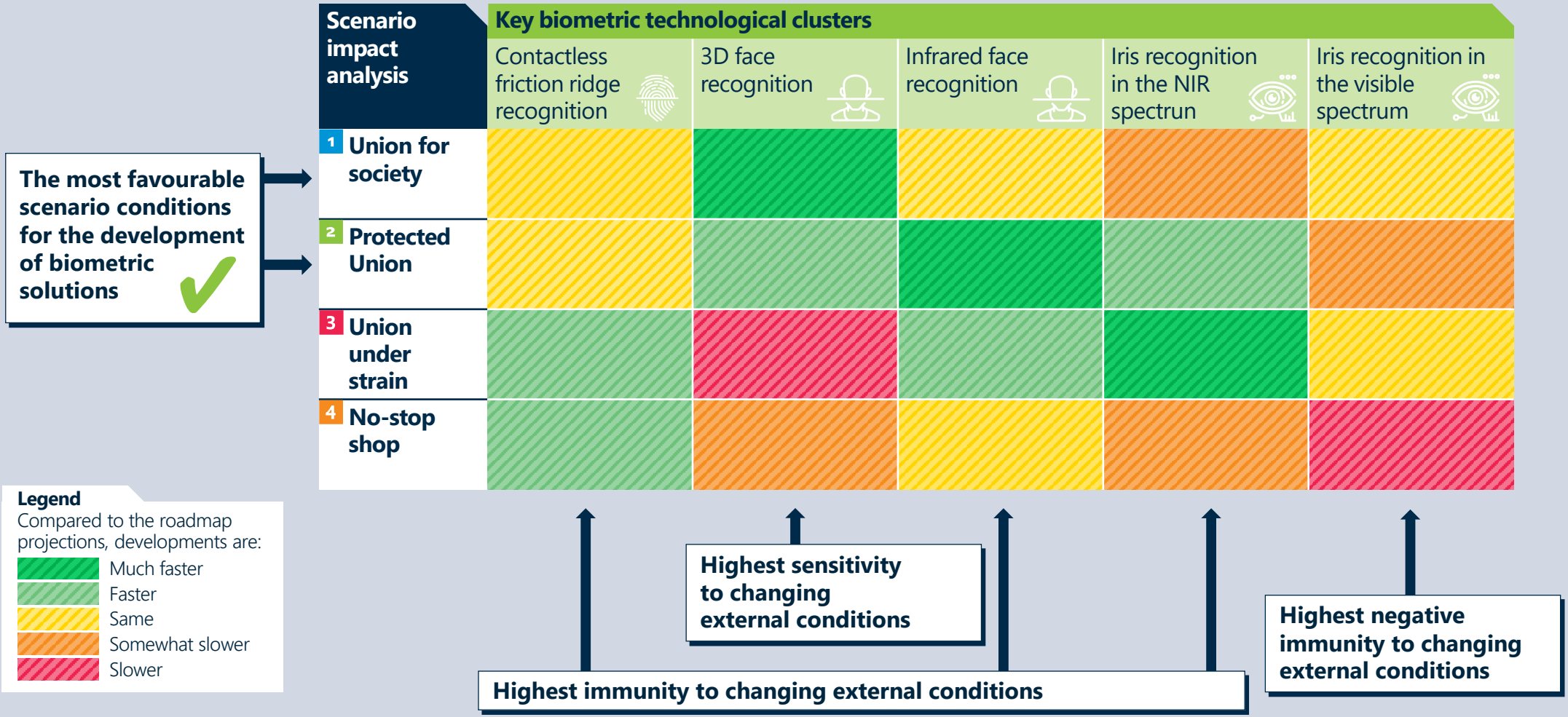
**2026 – 2040**
Short-distance 3D face recognition on-the-move for seamless border crossing

**2032 – 2040**
Long-distance 3D face recognition on-the-move for seamless border crossing

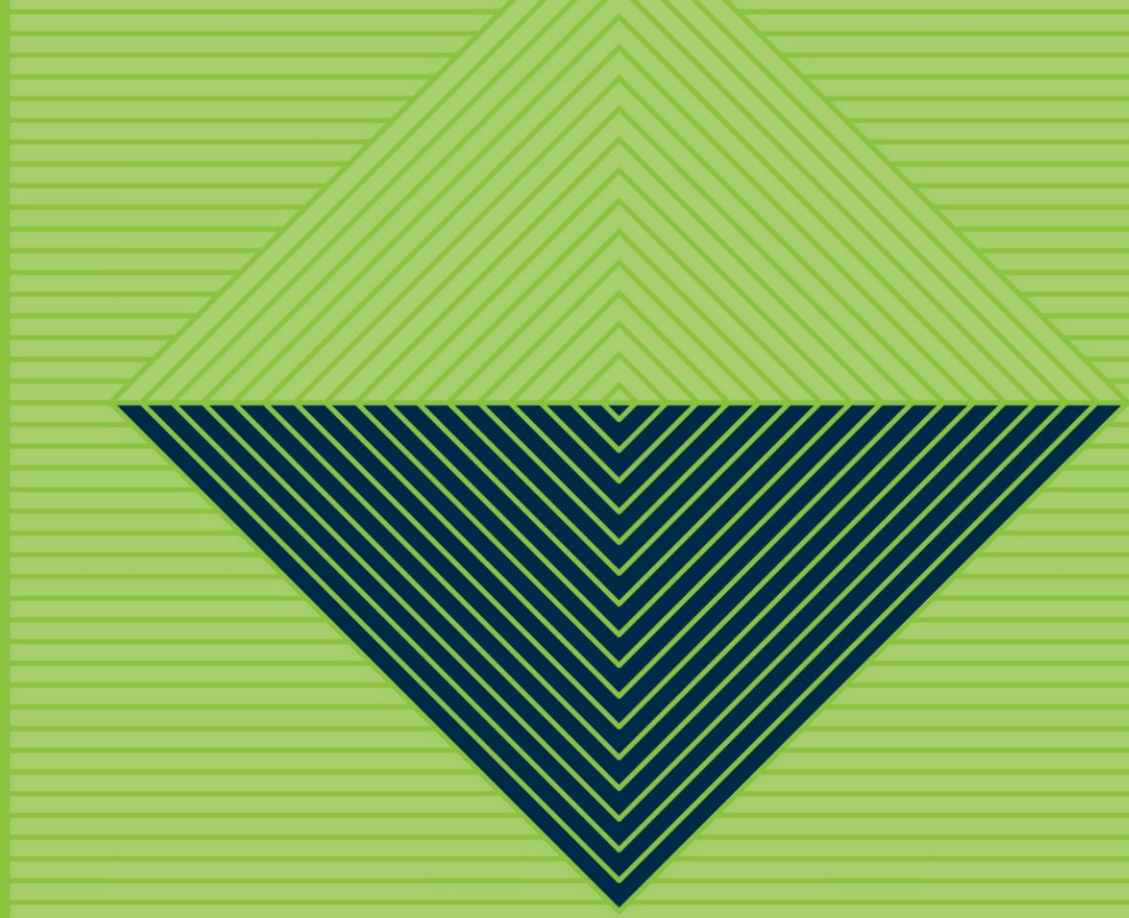
**2030 – 2040**
3D facial image stored in the chip of e-passports

# Roadmaps of key biometric technological clusters

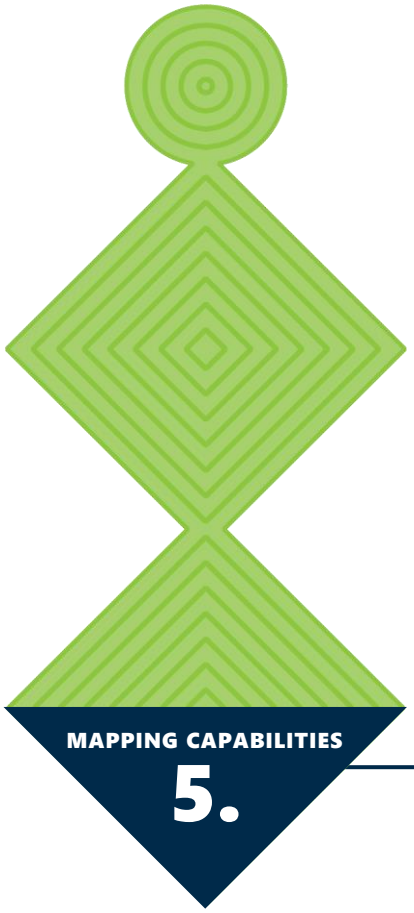
## Cross-cluster comparison of scenario impact



# 5. Mapping Capabilities



# Capability Readiness Analysis




## Aim

- Explore existing EU capability landscape
- Identify capability gaps and opportunities across the various timeframes and scenarios

## Outcomes (for each KTC)

- Capability readiness heatmap

**METHODOLOGY**

| Step 1 | Step 2 | Step 3 | Step 4 | Step 5 |
|---|---|---|---|---|
| Identification of objectives | Identification of capabilities | Identification of capability-related needs | Assessment of capability readiness | Identification of capability gaps and opportunities |

# Capability Readiness Analysis

## Heatmaps – 3D face recognition

***Capability Gaps***
*Formulated need is not or will not be met at all*

**Legend**

- Not met at all
- Partially met
- Completely met

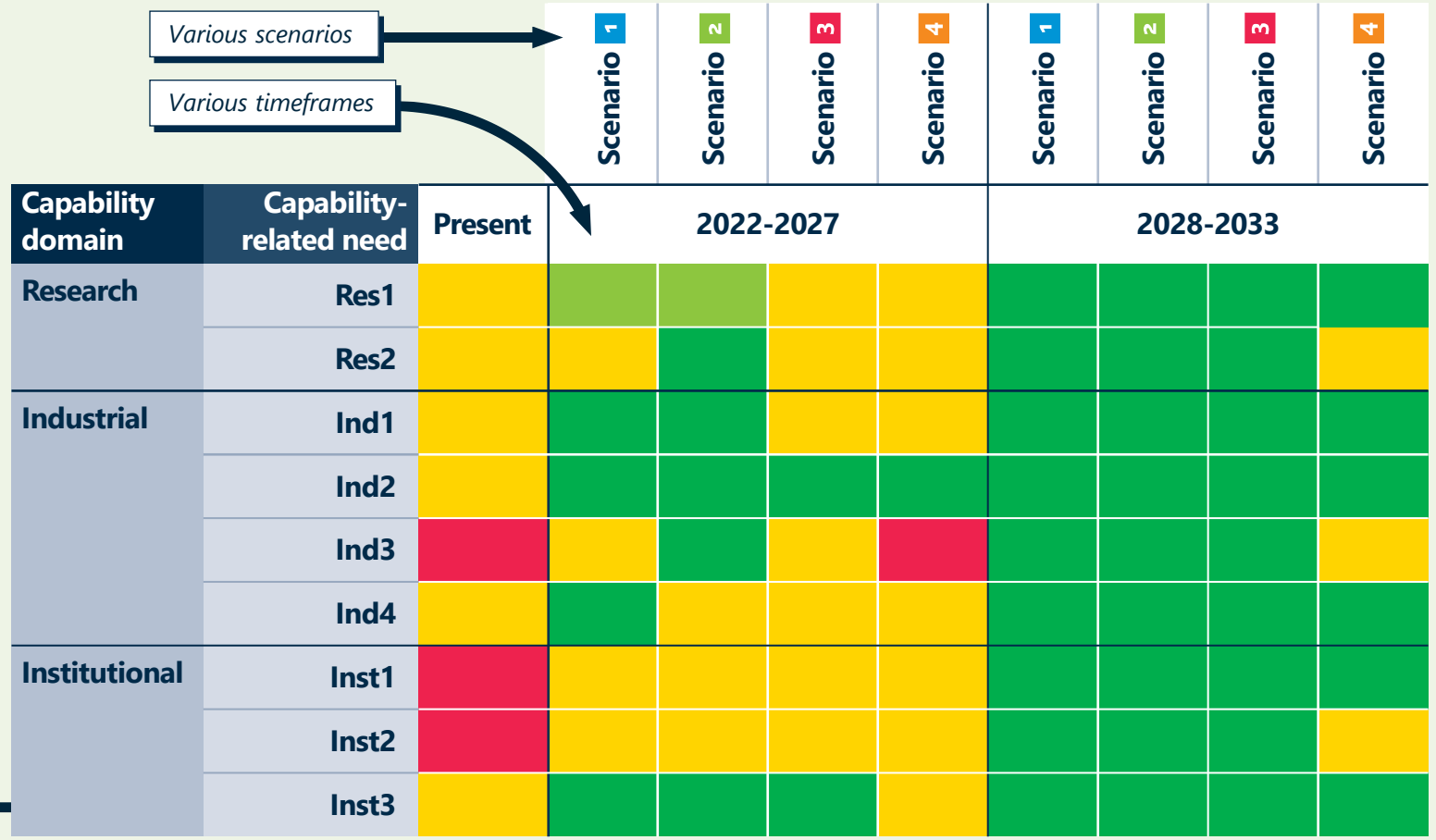
***Capability Opportunities***
*Formulated need is/will be completely met*

***Capability readiness***
*Degree to which specific needs are/will be met*

*Cluster-specific needs in **3 domains**: Research, Industry, Institutions*

*Various scenarios*

*Various timeframes*



# Conclusions

Project Overview

1. Analysis of Research Context

2. Insight Hunt

3. Filtering Results

4. Deep Analysis

5. Mapping Capabilities

# Main Outcomes

**Each of the phases of this complex Research Study produced its own set of future-oriented insights** with the intention of supporting the EBCG community in decision-making processes that:

**exploit opportunities**

**mitigate associated threats**

**result in the implementation of new biometrics-enabled technological solutions**

## 5 Key Technological Clusters

**Infrared Face Recognition**

**3D Face Recognition**

**Contactless Friction Ridge Recognition**

**Iris Recognition in the NIR Spectrum**

**Iris Recognition in the Visible Spectrum**

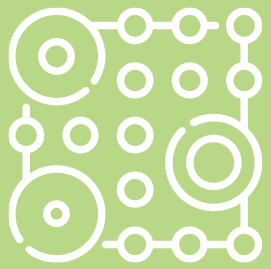
# Main Outcomes

**Set of scenarios for the future of travel and border checks**

DOWNLOAD Executive Summary

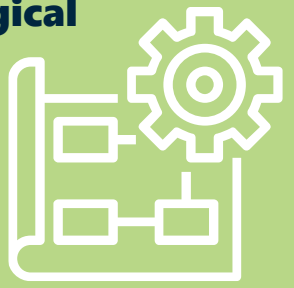
DOWNLOAD Research Study

**Prioritisation Matrix of biometric technological clusters**



**Set of roadmaps developed for the key biometric technological clusters**

**Heatmaps reflecting capability readiness for the key biometric technological clusters**

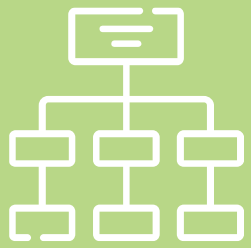


**Technology Foresight Manual** describing the TF Process, the Methods and the Tools

DOWNLOAD Annex I

**Taxonomy of Biometric Technologies and Biometrics-Enabled Technological Systems**

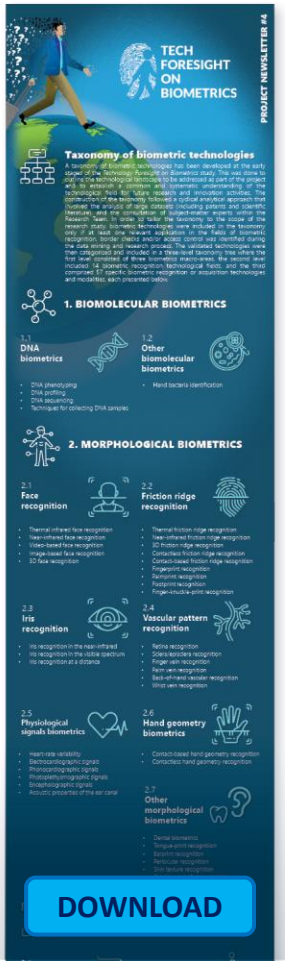
DOWNLOAD Annex II



**Analyses conducted over the patents, scientific literature and EU-funded projects**

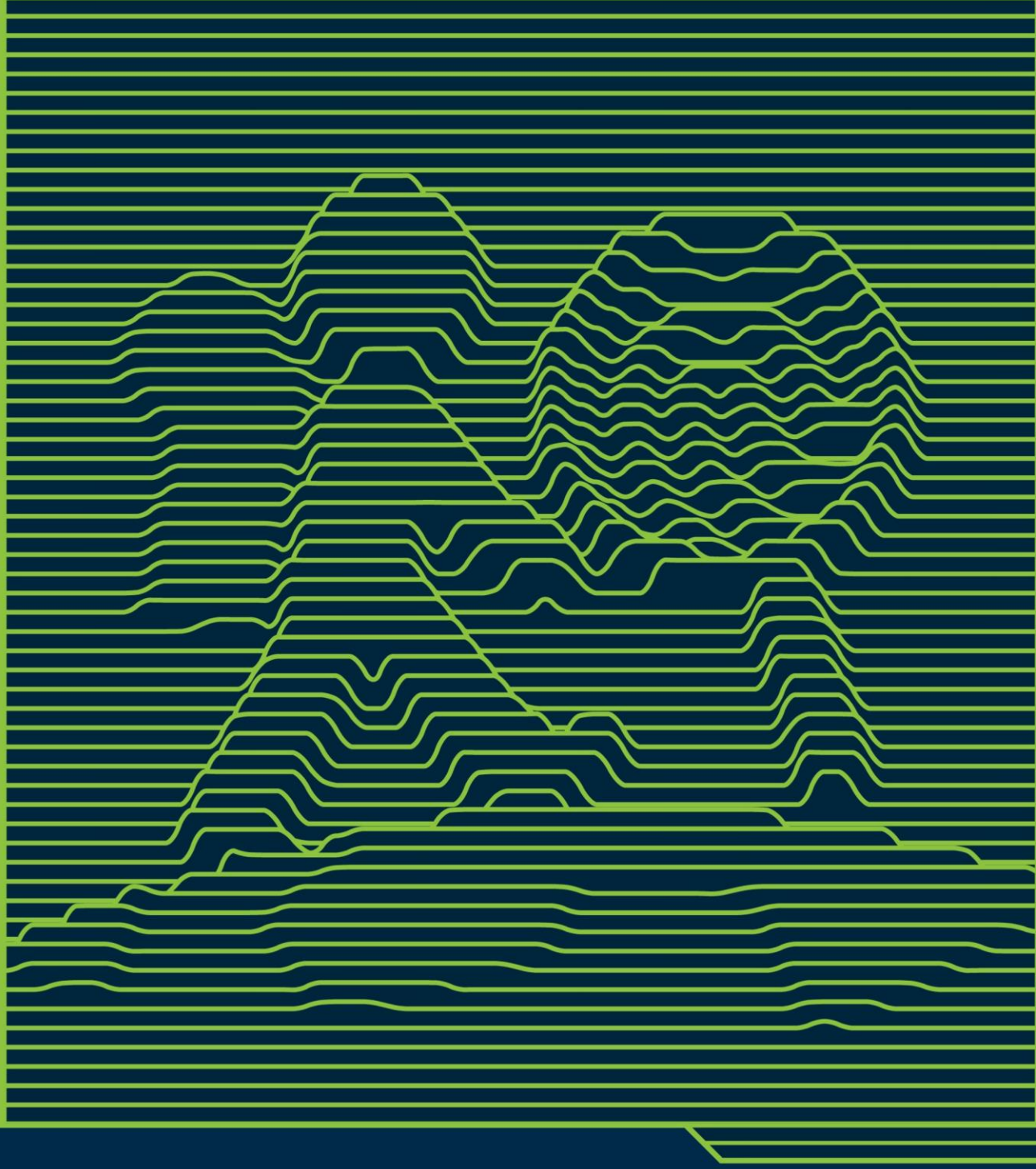
DOWNLOAD Annex III

# Project Newsletters

| Project Fiche | NEWSLETTER #1 - METHODOLOGY | NEWSLETTER #2 – SCENARIO ANALYSIS | NEWSLETTER #3 – SCENARIO ADAPTATION | NEWSLETTER #4 – TAXONOMY | NEWSLETTER #5 – 4CF MATRIX | NEWSLETTER #6 – RESEARCH STUDY |
|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |
| DOWNLOAD | DOWNLOAD | DOWNLOAD | DOWNLOAD | DOWNLOAD | DOWNLOAD | DOWNLOAD |

# Thank you for your attention!

If you have any questions regarding this research study please contact Frontex Research and Innovation at **research@frontex.europa.eu**



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