

3rd International Conference in  
**Asphalt Recycling Technologies**

21 and 22 September 2026  
TIVOLI Business & Event Bereich  
Aachen, Germany

**Asphalt Recycling in practice:**  
Proven methods | New challenges | Real solutions

**BALANCING SUSTAINABILITY  
AND PERFORMANCE IN  
HIGH-RAP ASPHALT  
MIXTURES**



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**ART 2026**  
*Reclaim. Reuse. Rebuild Smarter.*



**THE RAP CHALLENGE**



**ENGINEERING HIGH RAP**

**PERFORMANCE & SUSTAINABILITY**



**FROM THEORY TO PRACTICE**



# History – Some important dates

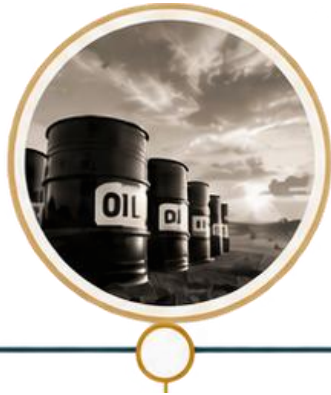
A LONG TRACK RECORD OF SUCCESS

1915



Asphalt pavement recycling dates back to **1915**  
(Kandhal & Mallick, 1977)

1973



It did not become a common practice until the early 1970s, when asphalt binder prices skyrocketed as a result of the **Arab oil embargo in 1973**

1970s



The paving industry reacted by developing **recycling technologies** to reduce the demand for asphalt binder and the cost of asphalt mixtures

Today



Many practices first developed during this period **are still in use today** and have become a routine part of pavement construction and rehabilitation operations



Milled material from asphalt pavement is known as **RAP (Reclaimed Asphalt pavement)**

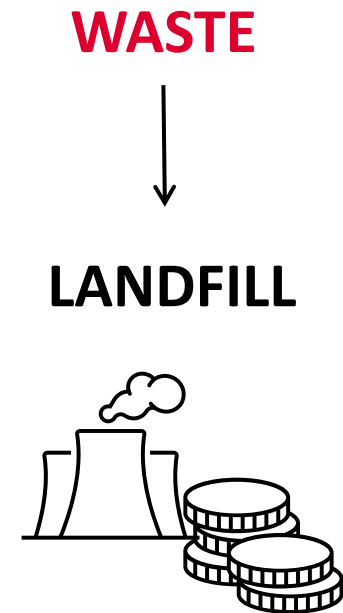
# Reclaimed Asphalt production in Europe today

FROM YESTERDAY'S ROADS TO TOMORROW'S SOLUTIONS

| Country       | Total amount of site-won asphalt generated in 2024 in tonnes | Amount of reclaimed asphalt available to be used by the asphalt industry in 2024 in tonnes | % of available reclaimed asphalt used in |                                  |                          |                        |                     |                                      |                                               |
|---------------|--------------------------------------------------------------|--------------------------------------------------------------------------------------------|------------------------------------------|----------------------------------|--------------------------|------------------------|---------------------|--------------------------------------|-----------------------------------------------|
|               |                                                              |                                                                                            | Hot and Warm Mix Asphalt Production      | Half Warm Mix Asphalt Production | On-Site Cold Recycling** | Plant Cold Recycling** | Unbound Road Layers | Other Civil Engineering Applications | Put to Landfill / Other Applications/ Unknown |
| Austria       | 2.200.000                                                    | no data                                                                                    | no data                                  | no data                          | no data                  | no data                | no data             | no data                              | no data                                       |
| Belgium       | 2.000.000*                                                   | 1.350.000                                                                                  | no data                                  | no data                          | no data                  | no data                | no data             | no data                              | no data                                       |
| Croatia       | 320.000*                                                     | 300.000*                                                                                   | 27                                       | 0                                | 0                        | 15                     | 45                  | 0                                    | 13                                            |
| Czech Rep     | 2.900.000                                                    | 2.500.000                                                                                  | 30                                       | no data                          | 25                       | no data                | 10                  | 5                                    | 30                                            |
| Denmark       | 1.374.000*                                                   | 1.174.000                                                                                  | no data                                  | no data                          | no data                  | no data                | 2                   | no data                              | no data                                       |
| Estonia       | no data                                                      | 28.976                                                                                     | no data                                  | no data                          | no data                  | no data                | no data             | no data                              | no data                                       |
| France        | 9.529.600                                                    | 8.200.000                                                                                  | 76                                       | no data                          | 5                        | 5                      | no data             | no data                              | no data                                       |
| Germany       | 14.100.000                                                   | 12.900.000                                                                                 | 87                                       | 4                                | 0                        | 0                      | 8                   | 0                                    | 1                                             |
| Great Britain | 5.260.000                                                    | no data                                                                                    | no data                                  | no data                          | no data                  | no data                | no data             | no data                              | no data                                       |
| Hungary       | 214.333                                                      | 310.734                                                                                    | 96                                       | 0                                | 0                        | 0                      | 3                   | 1                                    | 0                                             |
| Ireland       | 600.000*                                                     | 600.000*                                                                                   | 70*                                      | no data                          | no data                  | no data                | no data             | no data                              | no data                                       |
| Italy         | 17.000.000                                                   | 10.400.000                                                                                 | no data                                  | no data                          | no data                  | no data                | no data             | no data                              | no data                                       |
| Norway        | 1.642.000                                                    | 1.039.000                                                                                  | 63                                       | 0                                | 0                        | 0                      | 30                  | no data                              | 0                                             |
| Slovenia      | 450.000*                                                     | 145.000                                                                                    | 45                                       | 0                                | 11                       | 0                      | 15                  | 14                                   | 15                                            |
| Spain         | 2.750.000                                                    | 2.350.000                                                                                  | 72                                       | 0                                | 5                        | 0                      | 22                  | 1                                    | 1                                             |
| Switzerland   | 1.650.000*                                                   | no data                                                                                    | 89*                                      | <1%*                             | <1%*                     | <1%*                   | <2%*                | <3%*                                 | 6*                                            |
| Turkiye       | 2.214.400                                                    | 1.993.000                                                                                  | 1                                        | 0                                | 0                        | 0                      | 99                  | 0                                    | 0                                             |

| Total Re-use | Total Recycling | Put to Landfill/Other Application/Unknown |
|--------------|-----------------|-------------------------------------------|
| 50           | 45              | 5*                                        |
| 65           | 30              | 5                                         |
| 27           | 60              | 13                                        |
| 55           | 15              | 30                                        |
| 97           | 3               | no data                                   |
| 100          | 0               | 0                                         |
| 86           | 14              | 0                                         |
| 91           | 8               | 1                                         |
| 100***       |                 | 0                                         |
| 95           | 4               | 1                                         |
| 65*          | 20*             | 15*                                       |
| no data      | no data         | no data                                   |
| 63           | 37              | 0                                         |
| 56           | 29              | 15                                        |
| 78           | 21              | 1                                         |
| 89*          | 5*              | 6*                                        |
| 1            | 99              | 0                                         |

## “Reclaimed Asphalt RAP”



Source: EATA – «Asphalt in figures», 2024

# Reclaimed Asphalt production in Europe today

FROM YESTERDAY'S ROADS TO TOMORROW'S SOLUTIONS



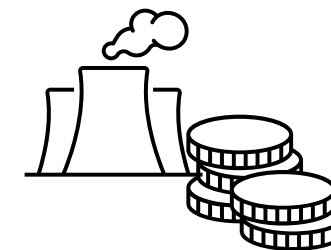
“Reclaimed Asphalt RAP ”

≈ 17 Mt/year only in Italy\*

**WASTE**



**LANDFILL**

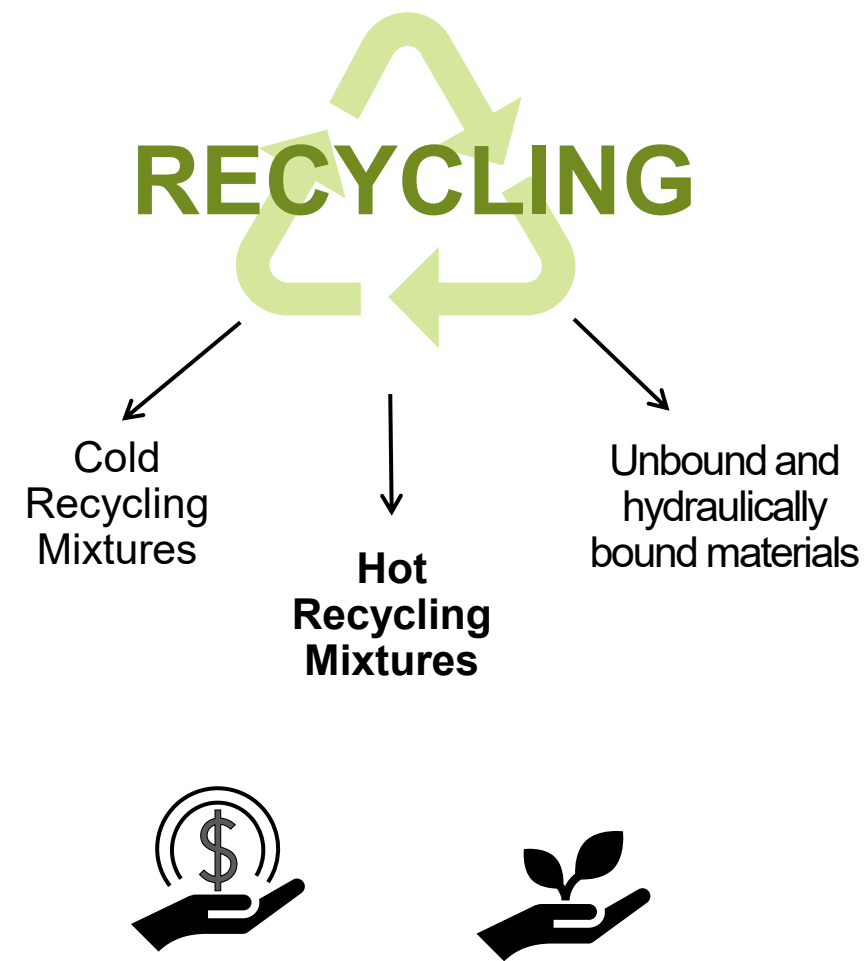


\*Siteb, 2026 and EATA – «Asphalt in figures», 2024

# Reclaimed Asphalt for Sustainable Infrastructures



# What if Reclaimed Asphalt is not waste, but a resource?



# The challenge we all know: SUSTAINABILITY vs PERFORMANCE

MORE RAP BRINGS CLEAR SUSTAINABILITY BENEFITS — BUT TIGHTER PERFORMANCE MARGINS

## SUSTAINABILITY

- Less virgin materials
- Less Waste
- Resource efficiency
- Circularity



## PERFORMANCE

- Aged binder / stiffness
- Variability
- Narrower design margins

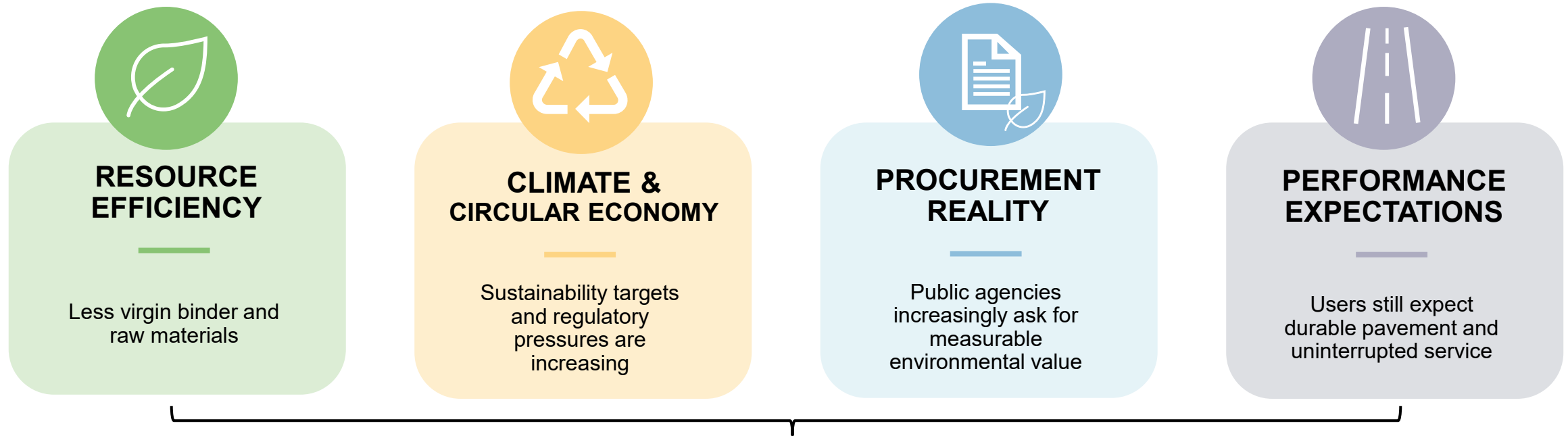
## ENGINEERING CONTROL

Characterisation • Mix design • Additives • Process control • Technologies

**The real objective is not to maximize RAP content in itself, but to deliver reliable performance with higher recycled content**

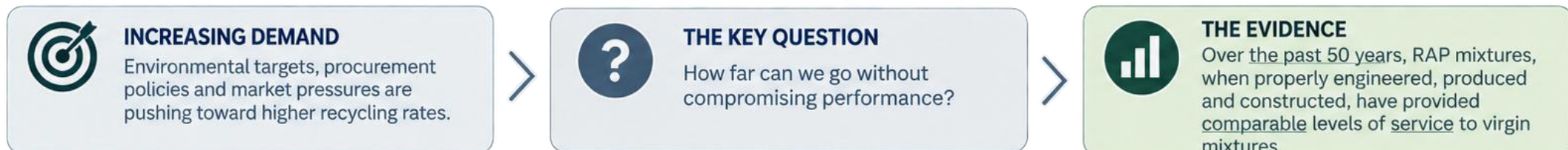
# Why this matters now

MULTIPLE DRIVERS, A CLEAR DIRECTION



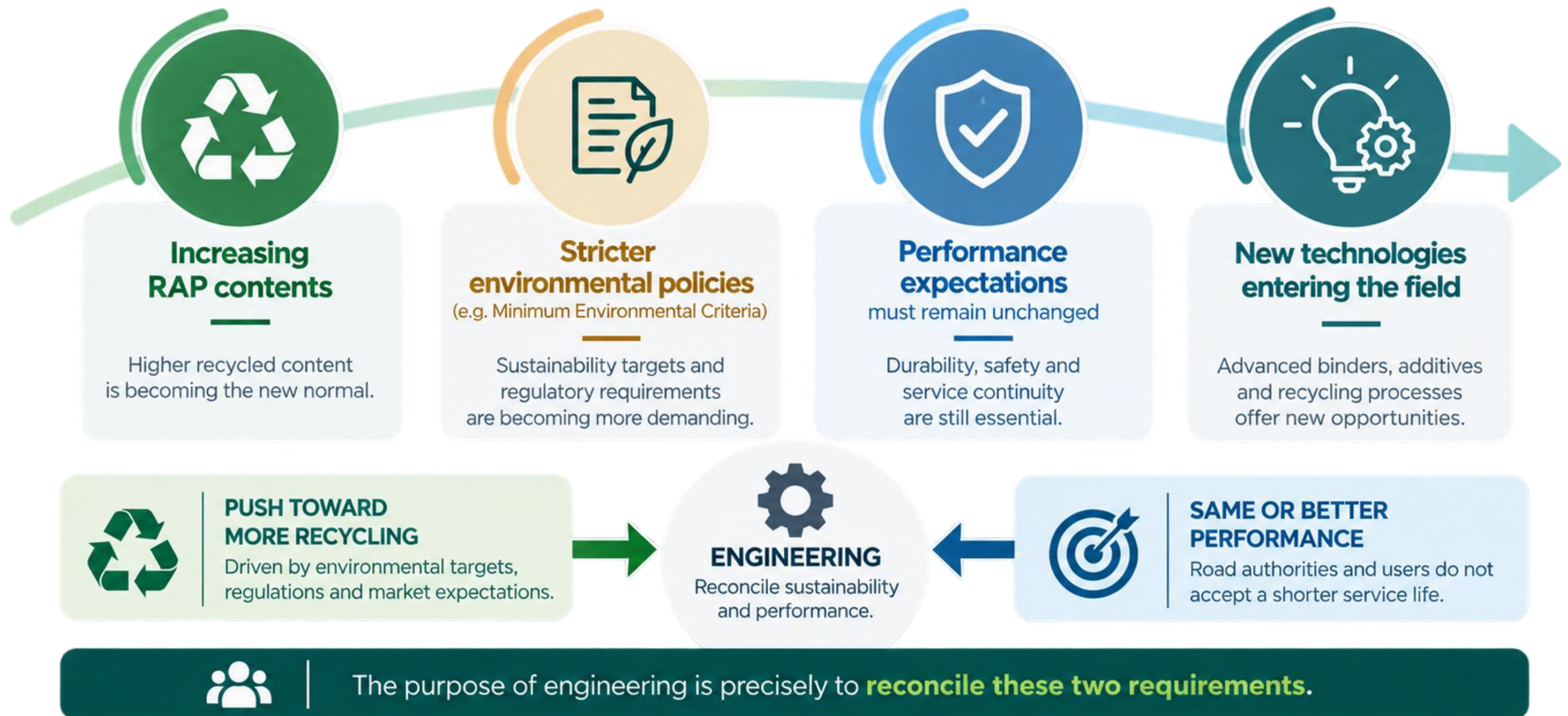
## Recycling is becoming a **strategic requirement**

Higher recycled content must now deliver environmental value without compromising pavement performance



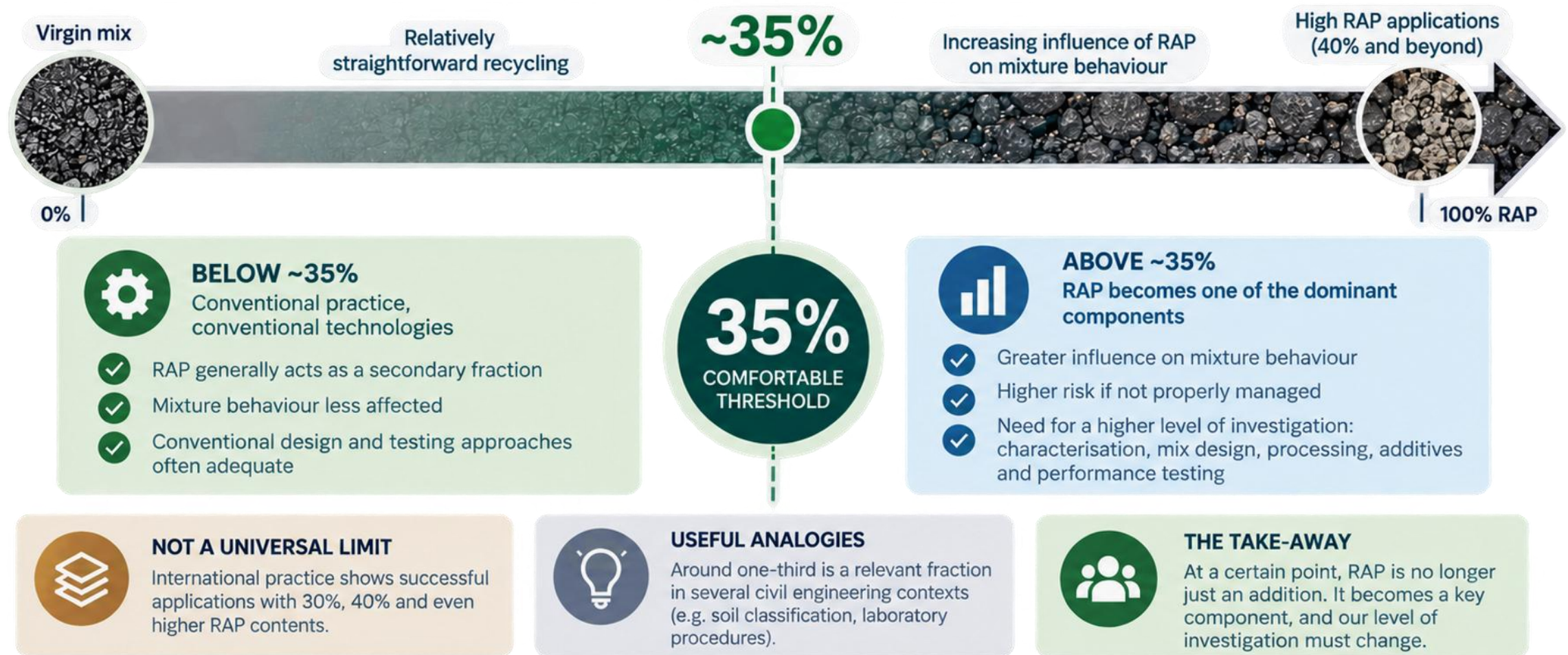
# A changing landscape

NEW DRIVERS, HIGHER AMBITIONS, GREATER COMPLEXITY



# The 35% RAP content comfortable threshold

AN ENGINEERING REFERENCE POINT, NOT A UNIVERSAL LIMIT



The 35% threshold is not a limit, but a **reference point** to guide a more robust engineering approach

# The 35% RAP content comfortable threshold

AN ENGINEERING REFERENCE POINT, NOT A UNIVERSAL LIMIT



## THE TAKE-AWAY

At a certain point, RAP is no longer just an addition. It becomes a key component, and our level of investigation must change.



## UNI/TS 11688:2017

“Criteri di qualificazione e impiego del conglomerato bituminoso di recupero proveniente dalla rimozione delle pavimentazioni esistenti”

“Criteria for the qualification and use of Reclaimed Asphalt Pavement (RAP) obtained from existing pavement removal”

prospetto 1 Caratteristiche del cumulo di conglomerato bituminoso di recupero in base all'impiego

| CARATTERISTICHE DEL CUMULO                |                                                                     |                                            | IMPIEGHI DEL CONGLOMERATO BITUMINOSO DI RECUPERO |                          |                           |                          |             |                                                |
|-------------------------------------------|---------------------------------------------------------------------|--------------------------------------------|--------------------------------------------------|--------------------------|---------------------------|--------------------------|-------------|------------------------------------------------|
|                                           |                                                                     |                                            | LAVORATO (granulato)                             |                          |                           | NON LAVORATO (tal quale) |             |                                                |
|                                           |                                                                     |                                            | CB a caldo (serie UNI EN 13108)                  |                          |                           | CB a freddo              |             |                                                |
| CARATTERISTICA                            |                                                                     |                                            | RA≤10% (usura)                                   | 10%<RA<50% (usura)       | RA≥50% (tutti gli strati) | fondazione               | base-binder | Aggregati (legati e non legati) (UNI EN 13242) |
| RIFERIMENTI NORMATIVI                     |                                                                     |                                            | RA≤20% (base binder)                             | 20%<RA<50% (base binder) |                           |                          |             | Lavorazioni in situ <sup>b)</sup>              |
| Designazione del conglomerato di recupero | Distribuzione granulometrica                                        | UNI EN 933-1                               | SI                                               | SI                       | SI                        | SI                       | SI          | SI                                             |
|                                           | Designazione granulometrica                                         | UNI EN 13108-8                             | SI                                               | SI                       | SI                        | SI                       | SI          | SI                                             |
| Composizione del conglomerato di recupero | Contenuto legante                                                   | UNI EN 12697-1                             | SI                                               | SI                       | SI                        | SI                       | SI          | SI                                             |
|                                           | Dimensione massima (U <sub>RA</sub> )                               | UNI EN 12697-2, UNI EN 13043               | SI                                               | SI                       | SI                        | SI                       | SI          | SI                                             |
| Legante                                   | Tipo di legante                                                     | Evidenze documentali                       | SI                                               | SI                       | SI                        | SI                       | SI          | SI                                             |
|                                           | Proprietà legante (Penetrazione - rammollimento / Viscosità)        | UNI EN 1426<br>UNI EN 1427<br>UNI EN 13302 | nr                                               | SI                       | SI                        | nr                       | nr          | nr                                             |
| Aggregato                                 | Granulometria                                                       | UNI EN 12697-2                             | SI                                               | SI                       | SI                        | SI                       | SI          | SI                                             |
|                                           | Resistenza frammentazione (LA)                                      | UNI EN 1097-2                              | nr                                               | nr                       | SI                        | nr                       | SI          | nr                                             |
|                                           | Forma e appiattimento                                               | UNI EN 933-3, UNI EN 933-4                 | nr                                               | nr                       | SI                        | nr                       | SI          | nr                                             |
|                                           | Resistenza levigazione (VL) (solo per strati superficiali di usura) | UNI EN 1097-8                              | nr                                               | nr                       | SI <sup>a)</sup>          | na                       | na          | na                                             |
| Materie estranee                          | Materiali Gruppo 1                                                  | UNI EN 12697-42                            | SI                                               | SI                       | SI                        | SI                       | SI          | SI                                             |
|                                           | Materiali Gruppo 2                                                  |                                            | SI                                               | SI                       | SI                        | SI                       | SI          | SI                                             |
| Omogeneità cumulo (variabilità o scarto)  | Contenuto di legante                                                | -                                          | nr                                               | SI                       | SI                        | nr                       | SI          | nr                                             |
|                                           | Caratteristiche del legante                                         | -                                          | nr                                               | SI                       | SI                        | nr                       | SI          | nr                                             |
|                                           | Distribuzione granulometrica                                        | -                                          | nr                                               | SI                       | SI                        | nr                       | SI          | nr                                             |

NOTE:

a) I requisiti evidenziati in grassetto sono richiesti secondo la norma UNI EN 13108-8.

b) Da determinare in fase di progetto

SI = Requisito richiesto

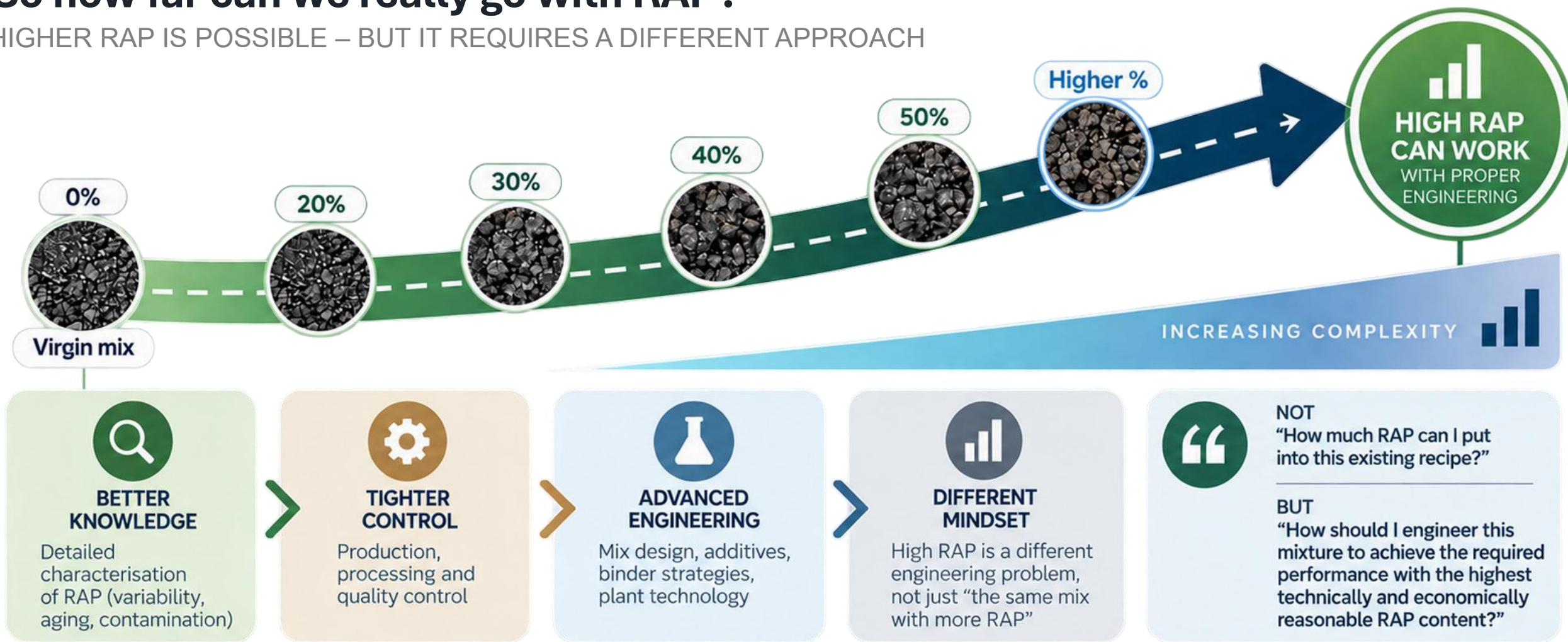
nr = Requisito non richiesto

na = Requisito non applicabile

HMA

# So how far can we really go with RAP?

HIGHER RAP IS POSSIBLE – BUT IT REQUIRES A DIFFERENT APPROACH



There is **no single technological barrier**, only a **progressive increase of complexity**

# No limits with the right steps

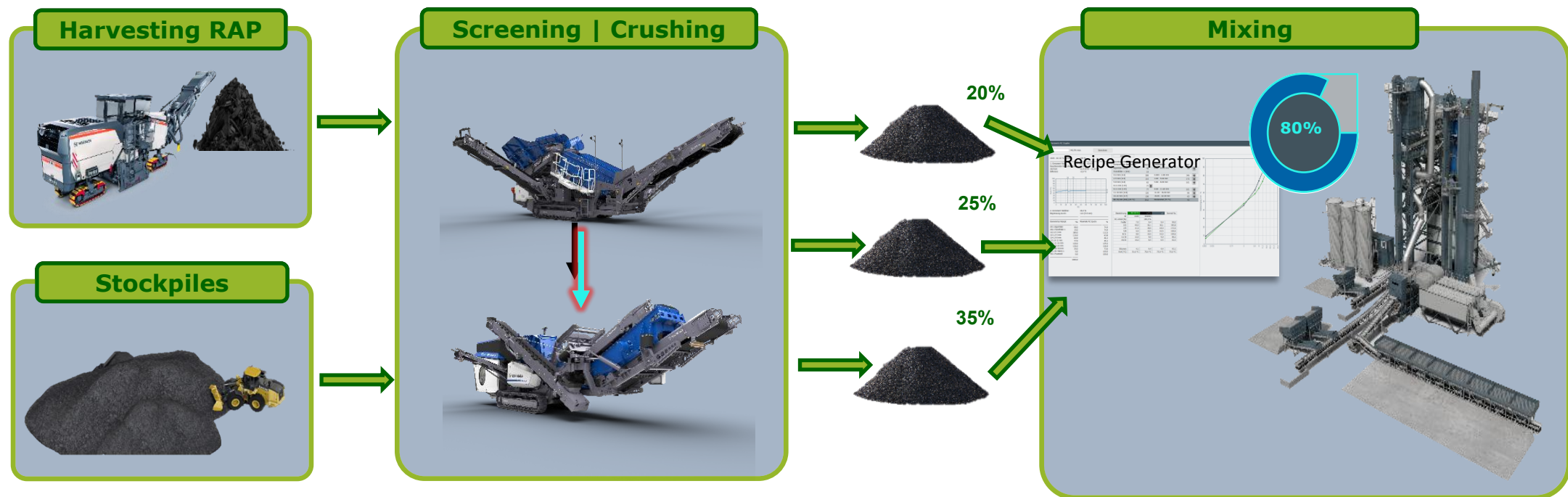
HIGHER RAP CONTENT STARTS LONG BEFORE MIX DESIGN



Invest in **RAP quality today** to unlock **higher recycling** tomorrow

# To push RAP higher, technology production must evolve

HIGHER RECYCLING REQUIRE MORE THAN CONVENTIONAL SOLUTIONS



# The central role of mix design and production plants

FROM LABORATORY DESIGN TO CONSISTENT, EFFICIENT AND SUSTAINABLE PRODUCTION



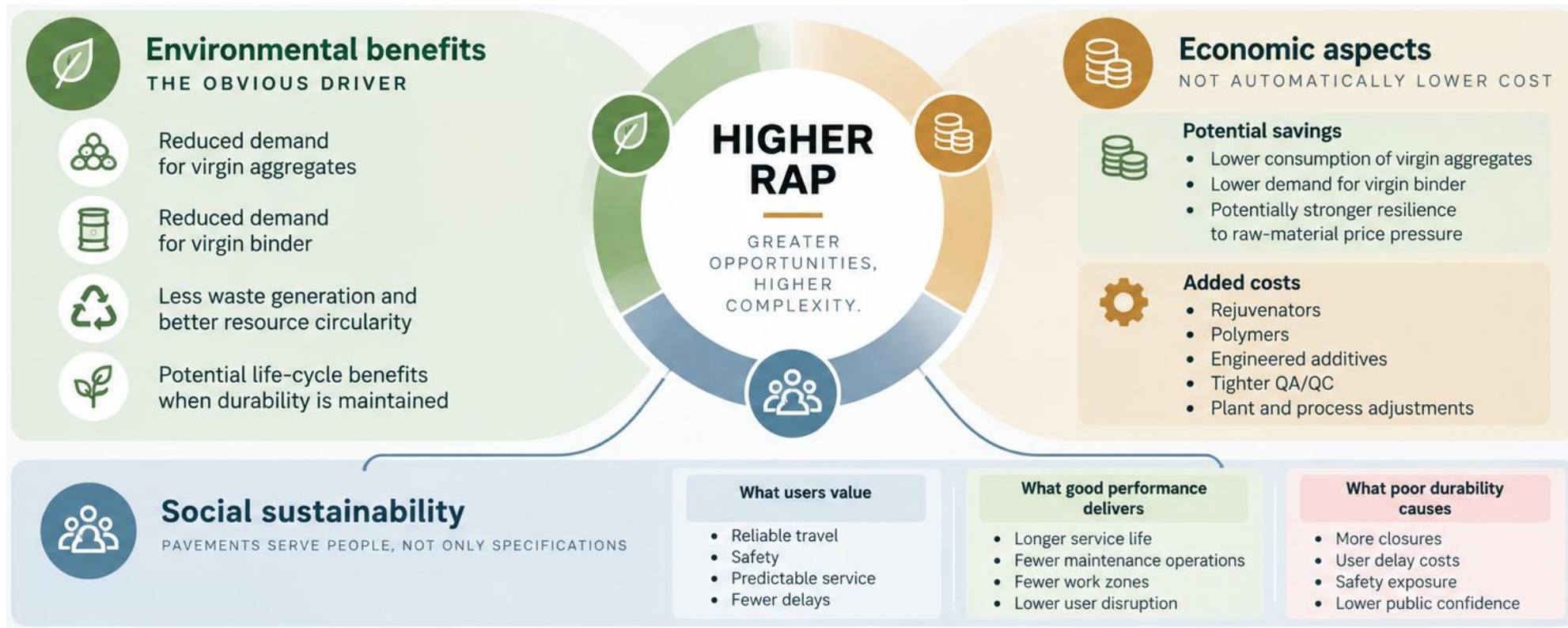
# Additives and Rejuvenators

BALANCING PROPERTIES FOR HIGH-RAP PERFORMANCE



# Sustainability: benefits and realities

HIGHER RAP BRINGS OPPORTUNITIES – BUT IS NOT A FREE LUNCH



## A critical nuance

Environmental (and economic) gains are not automatic. They depend on the full system: RAP processing, haul distances, plant operations, additives, and especially service life. A recycled mixture that fails early may lose a substantial part of its environmental advantage

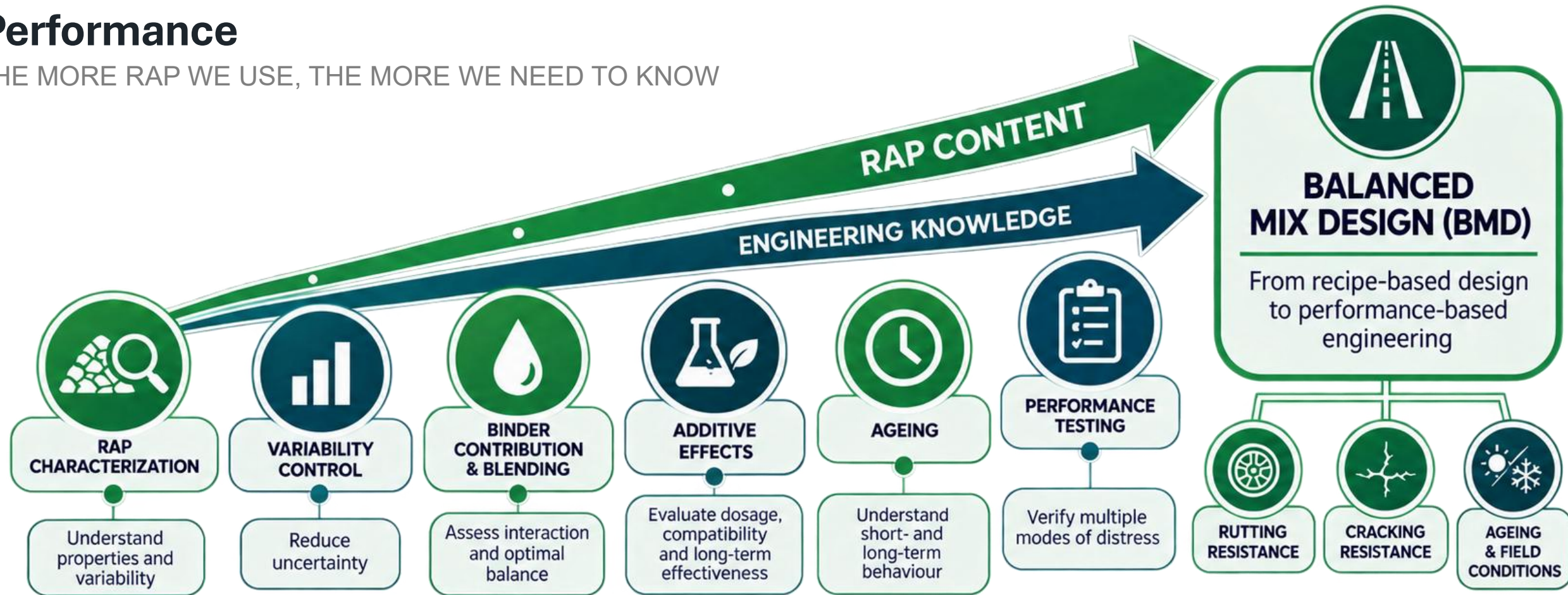


## High RAP becomes truly sustainable

when performance gains justify the added technological effort – delivering value over the full life cycle

# Performance

THE MORE RAP WE USE, THE MORE WE NEED TO KNOW



The price of high RAP is not lower performance, **is better engineering**

# The key role of different types of additives and rejuvenators

DIFFERENT ADDITIVES, DIFFERENT RESULTS

**Re-using / Recycling agents** can be divided into two groups:

- ❑ **Rejuvenating agents** that, besides the physical properties, are capable of restoring/revitalizing the chemical structure of the aged bitumen within RA (at least to some extent). This is in fact needed to guarantee the **durability** of recycled asphalt
- ❑ **Softening agents (Flux oils)** that are effective for recovering the physical parameters of aged bitumen within RA by increasing the viscosity



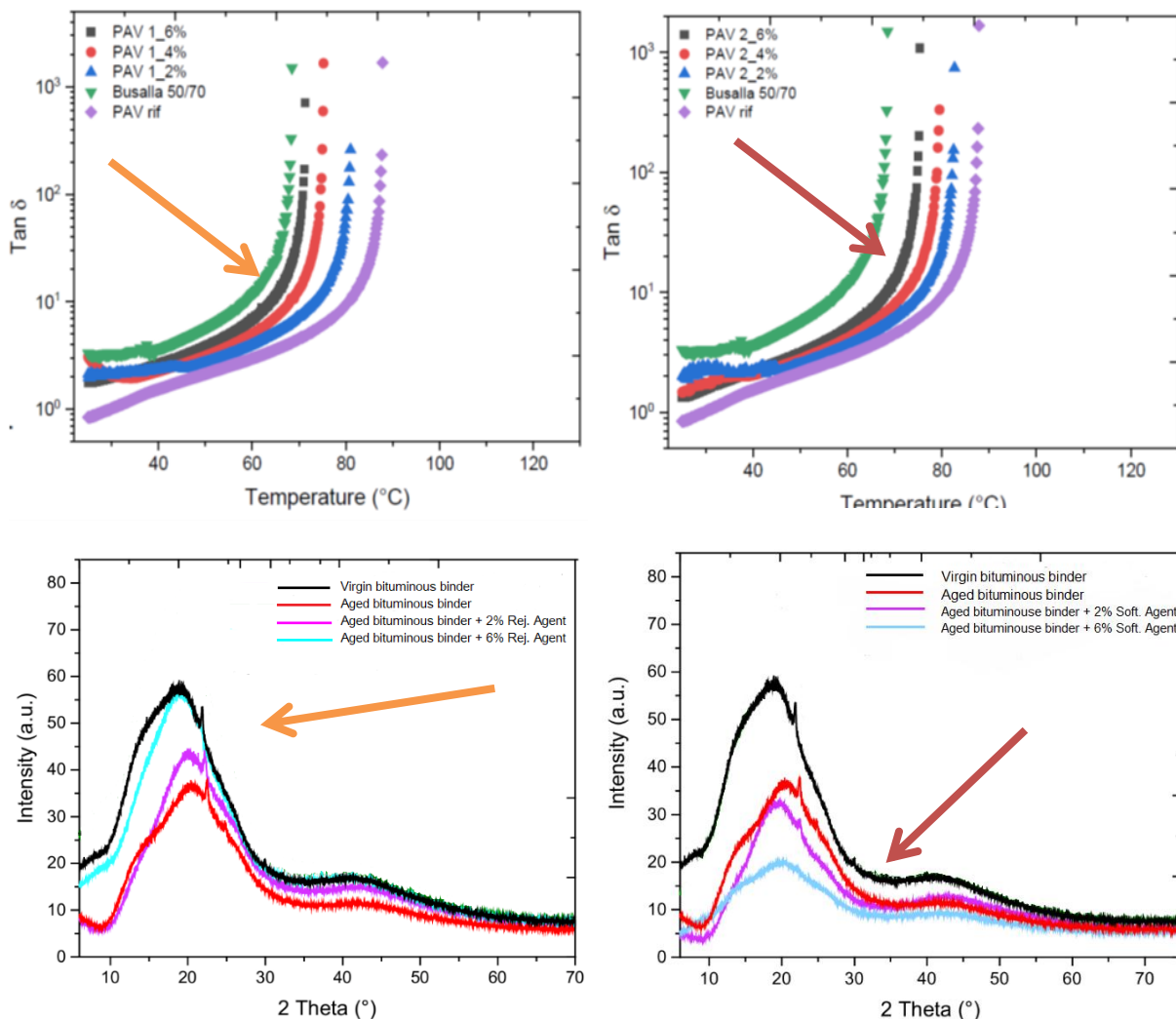
**According to EN Standard 15697:2014 Bitumen and bituminous binders – Terminology**

**Flux oil:** Relatively involatile fluid (oil) used in the manufacture of fluxed bitumen

**Fluxed bitumen:** Bitumen whose viscosity has been reduced by the addition of a fluxed oil(s)

# Rejuvenators vs Flux oils

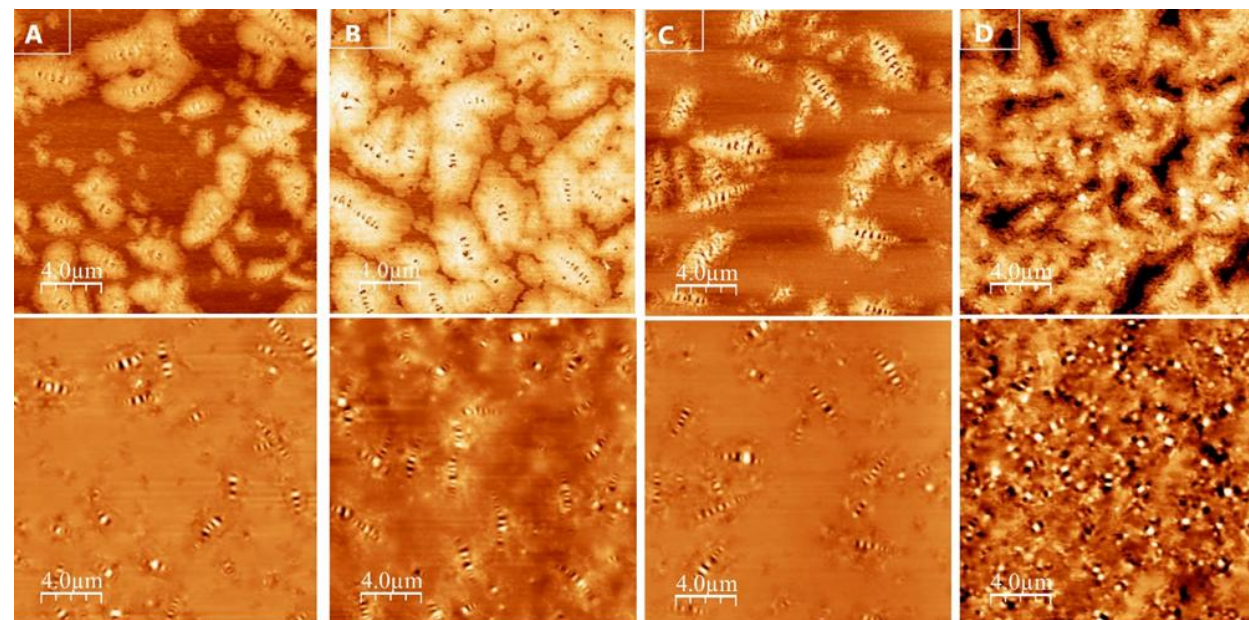
## A CLASSIFICATION PROTOCOL



Virgin Bitumen

(non-aged)

Aged Bitumen

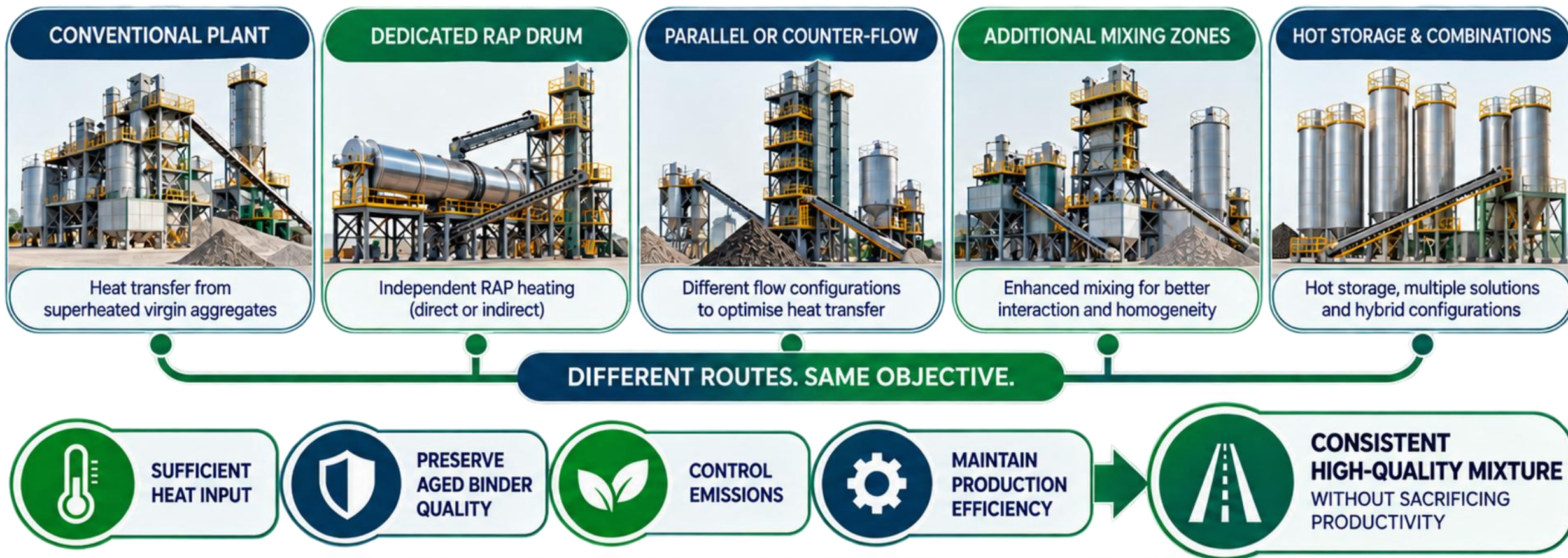


Aged Bit.  
+ Rejuvenator

Aged Bit.  
+ Flux oil

# The key role of asphalt plant technology

DIFFERENT CONFIGURATIONS, SAME OBJECTIVE



What matters is the ability to **control the temperature, moisture and dosage**

# From bitumen aging to asphalt aging

CEN/TS 12697-52:2025 - Bituminous mixtures - Test methods - Part 52: Conditioning to address oxidative ageing



# Case studies

HIGH RAP EXPERIENCES IN ITALIAN TRANSPORT INFRASTRUCTURES



**Highly Trafficked Motorway  
with 70% RAP**



**Railway sub ballast with  
High RAP**



# Highly Trafficked Motorway with 70% RAP

HIGH RAP MOVES FROM POSSIBILITY TO PRACTICE



- **Construction** 2023
- **Type of Road:** Motorway
- **Layer :** Inlay base/binder course
- **Type of asphalt:** dense-graded mix
- **Bitumen content:** binder course: 4.65%;  
base course: 4.1%
- **Layer thickness:** 40mm
- **Paving bitumen:** 50/70
- **Reclaimed asphalt:** +67%
- **Rejuvenator:** Bio-based mixture of vegetal oils
- **Dosage:** 0.15% on the weight of RA



# Highly Trafficked Motorway with 70% RAP

HIGH RAP MOVES FROM POSSIBILITY TO PRACTICE

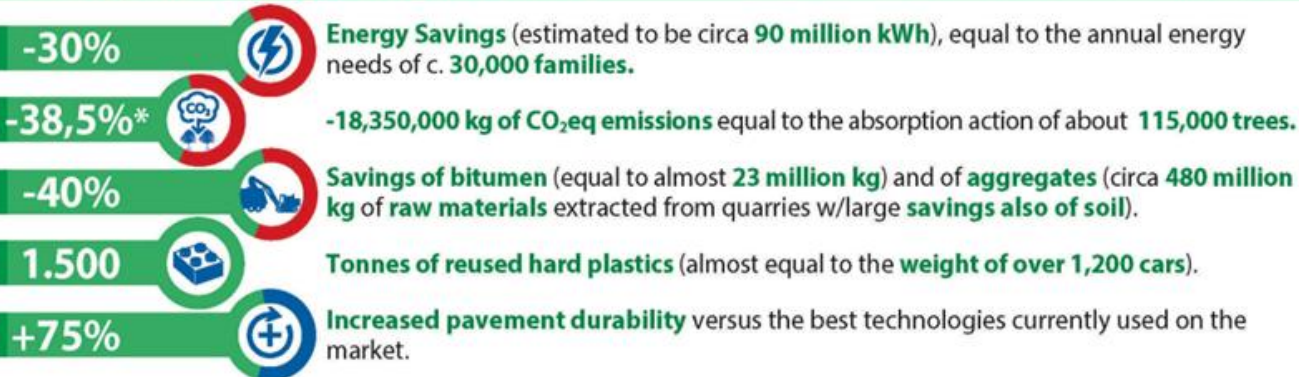
## A4 Turin-Milan: 1st Green & Hi-Tech Motorway in Europe w/graphene, recovered hard plastics and 70% recycled asphalt

The repaving of 250 km of slow lane (125 + 125) of the A4 To-Mi Motorway, managed by ASTM Group, is underway. GIPAVE® and 70% recycled asphalt will make the highway super-sustainable and safer.



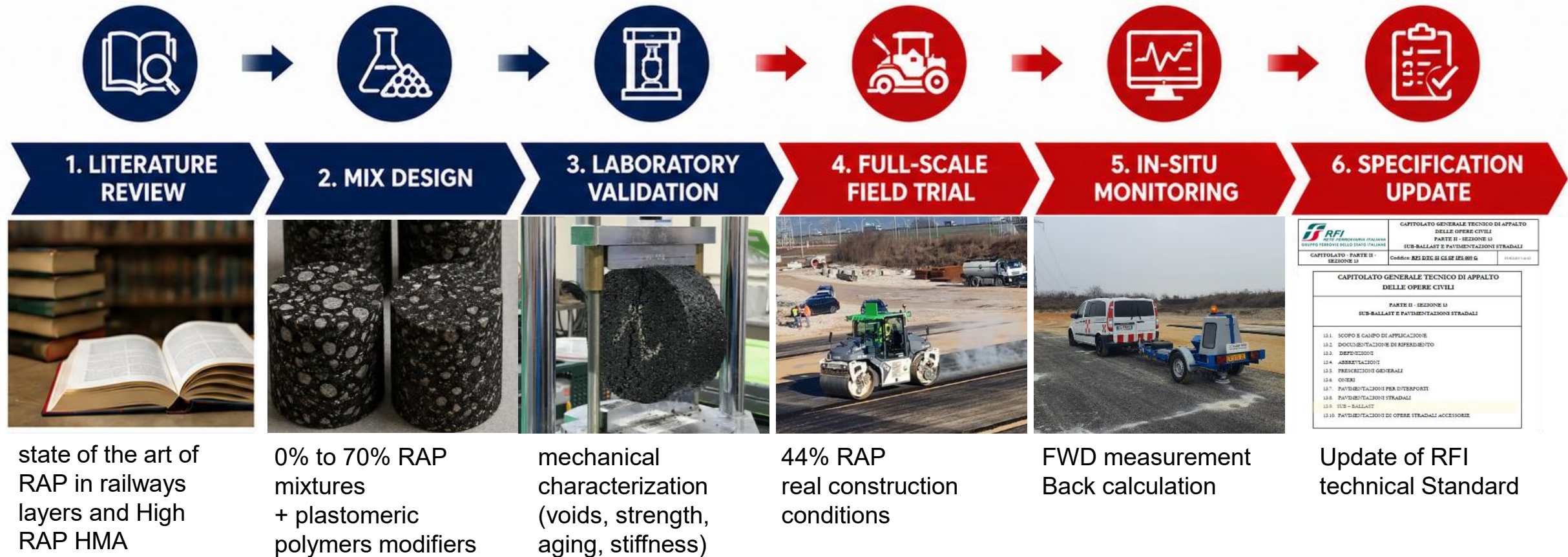
### The big advantages for the environment

\*Source: Studio di Alma Mater Studiorum di Bologna



# Sustainable railway sub-ballast

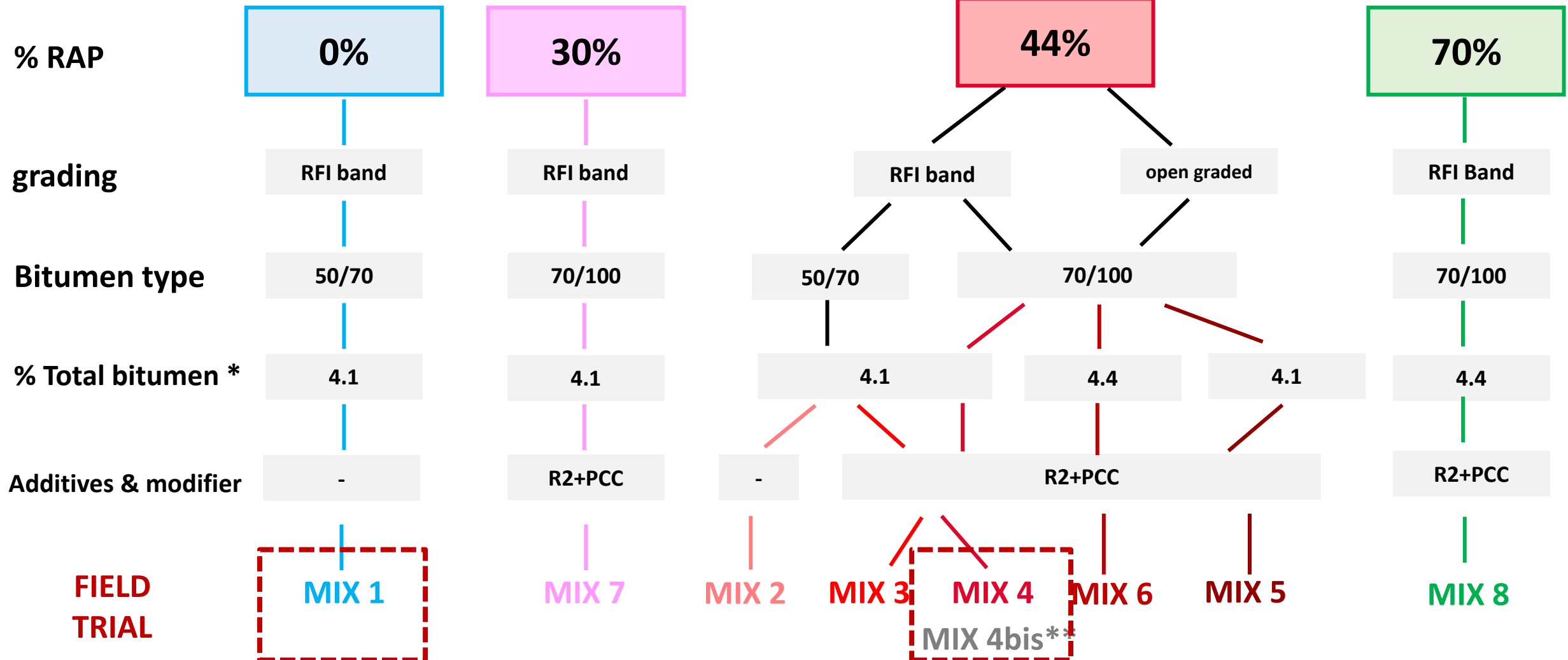
FROM LABORATORY, TO FIELD, TO NEW TECHNICAL SPECIFICATIONS



# Sustainable railway sub-ballast

LABORATORY MIXTURES

\* Neat bitumen + RAP bitumen  
\*\*with R1+GRP





# Sustainable railway sub-ballast

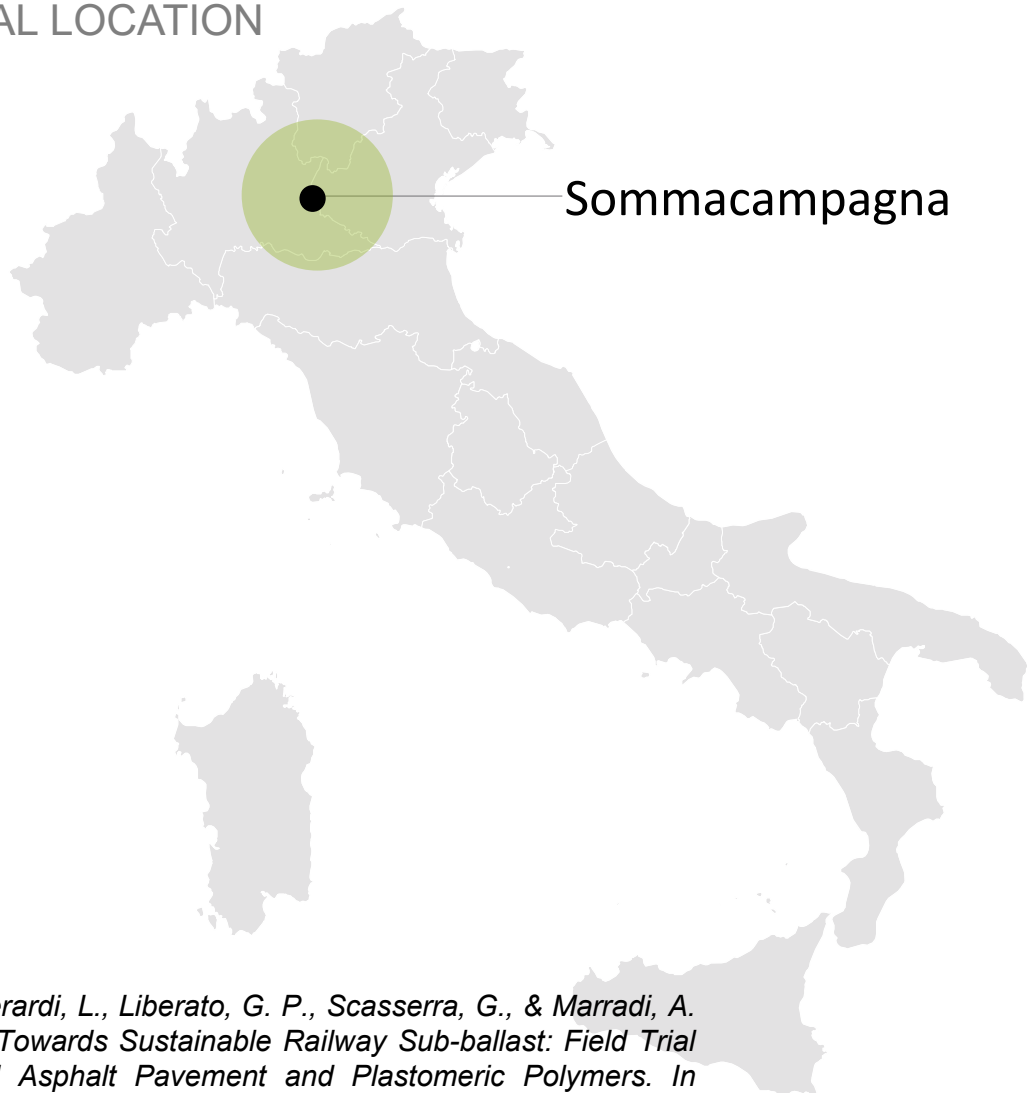
## LABORATORY TESTING

| ID miscela                                                                                                                                                                | MIX 1_Lab2 | MIX1     | MIX7     | MIX2            | MIX3            | MIX4            | MIX6            | MIX5            | MIX8            |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|----------|----------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| <b>PHYSICAL-MECHANICAL CHARACTERIZATION ACCORDING TO RFI TECHNICAL GUIDELINES</b>                                                                                         |            |          |          |                 |                 |                 |                 |                 |                 |
| Voids                                                                                                                                                                     | M          | M        | M        | M               | M               | M               | M               | M               | M               |
| Marshall test                                                                                                                                                             | M          | M        | M        | M               | M               | M               | M               | M               | M               |
| Marshall Stability Losss                                                                                                                                                  | M          | M        | M        | M               | M               | M               | M               | M               | M               |
| Indirect Tensile Strength @ 20 °C                                                                                                                                         | M          | M        | M        | M               | M               | M               | M               | M               | M               |
| Indirect Tensile Stiffness Modulus @ 20 e 30 °C                                                                                                                           | M          | M        | M        | M               | M               | M               | M               | M               | M               |
| <b>ADDITIONAL PHYSICAL-MECHANICAL CHARACTERIZATION</b>                                                                                                                    |            |          |          |                 |                 |                 |                 |                 |                 |
| Voids at N1, N2, N3                                                                                                                                                       |            | G        | G        | G               | G               | G               | G               | G               | G               |
| Indirect Tensile Strength @ 25 °C                                                                                                                                         | M          | M, G(N2) | M, G(N2) | M, G(N2), G(N3) | M, G(N2), G(N3) | M, G(N2), G(N3) | M, G(N2), G(N3) | M, G(N2), G(N3) | M, G(N2), G(N3) |
| Indirect Tensile Stiffness Modulus @ 5, 20, 40 °C                                                                                                                         |            | G(N2)    | G(N2)    | G (N2), G(N3)   | G (N2), G(N3)   | G(N2), G(N3)    | G(N2), G(N3)    | G(N2), G(N3)    | G(N2), G(N3)    |
| ITSR a 25 °C                                                                                                                                                              |            | G(N2)    | G(N2)    | G (N2), G(N3)   | G (N2), G(N3)   | G(N2), G(N3)    | G(N2), G(N3)    | G(N2), G(N3)    | G(N2), G(N3)    |
| Resistance to permanent deformation                                                                                                                                       |            | R        | R        | R               | R               | R               | R               |                 | R               |
| Indirect Tensile Strength @ 20 °C – STA+LTA                                                                                                                               |            |          | M        | M               | M               | M               |                 |                 | M               |
| Indirect Tensile Strength @ 25 °C – STA+LTA                                                                                                                               |            |          | M        | M               | M               | M               |                 |                 | M               |
| Indirect Tensile Stiffness Modulus @ 20 e 30 °C – STA+LTA                                                                                                                 |            |          | M        | M               | M               | M               |                 |                 | M               |
| * Letters identify the compaction methodology adopted to obtain the specimens: <b>M</b> =Marshall compaction, <b>G</b> = giratory compaction, <b>R</b> = roller compactor |            |          |          |                 |                 |                 |                 |                 |                 |



# Sustainable railway sub-ballast

FIELD TRIAL LOCATION



Sommacampagna



Construction site for the high-speed Brescia Est – Verona AV/AC line with subgrade in line configuration (super-compacted)

Mignini, C., Berardi, L., Liberato, G. P., Scasserra, G., & Marradi, A. (2026, June). Towards Sustainable Railway Sub-ballast: Field Trial with Recycled Asphalt Pavement and Plastomeric Polymers. In RILEM International Symposium on Bituminous Materials (pp. 197-203). Cham: Springer Nature Switzerland.

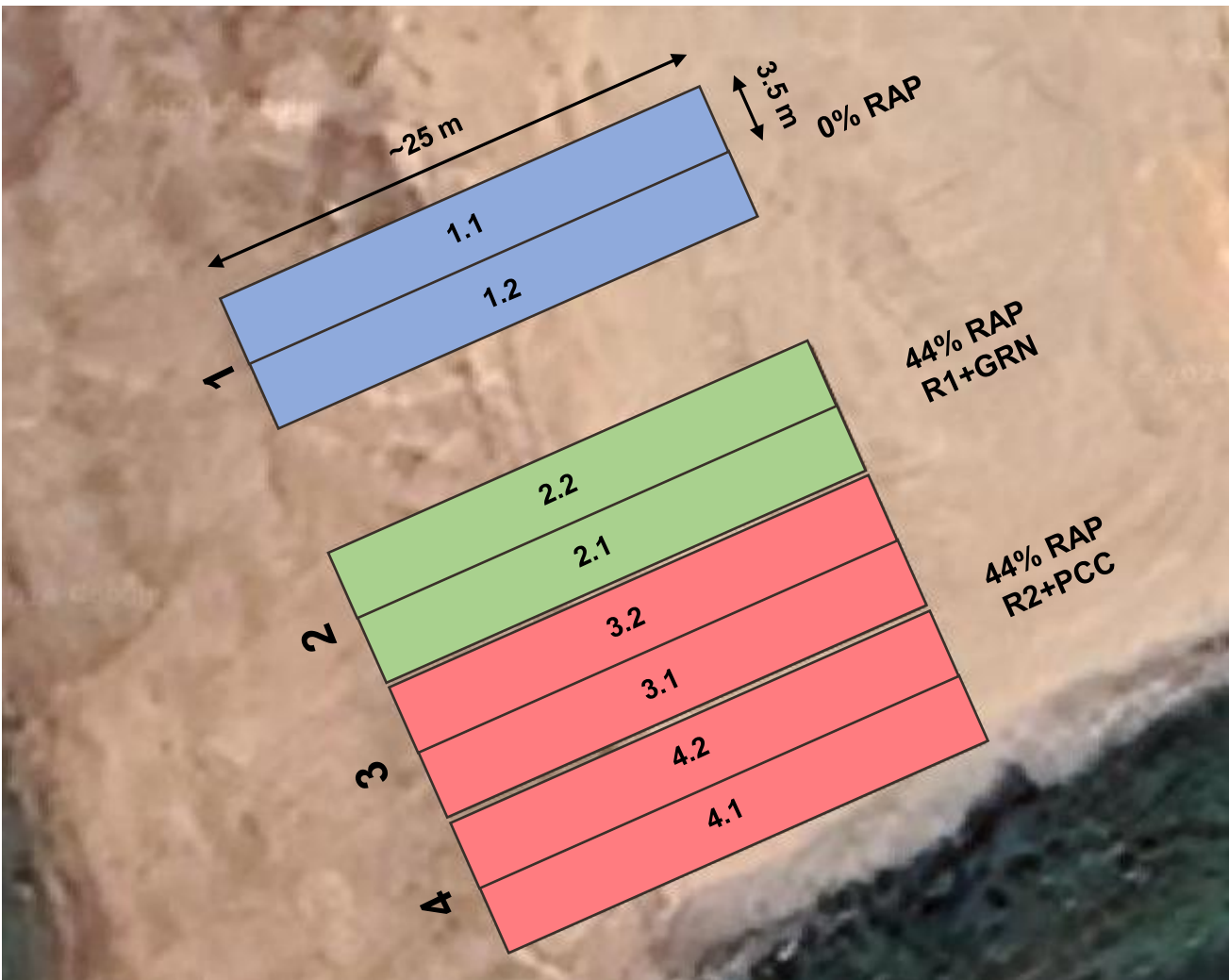
# Sustainable railway sub-ballast

FIELD TRIAL – 14/15 December 2023



# Sustainable railway sub-ballast

## FIELD TRIAL ORGANIZATION





# SUSTAINABLE RAILWAY SUB-BALLAST

## FIELD TRIAL OUTCOMES



**High RAP sub-ballast (44% RAP) successfully met the RFI requirements** in laboratory and field conditions



**The addition of Plastomeric modifiers and rejuvenators improved the mechanical performance,** providing higher strength and stiffness than conventional mixtures



**Field validation confirmed laboratory findings:** Despite unfavourable construction conditions, RAP sections exhibited higher moduli



**RFI technical guidelines update:** From 2025 the use of RAP in sub-ballast in Italy is permitted

|                                                                                                                                                          |                                                                                                                                |
|----------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|
| <br>RETE FERROVIARIA ITALIANA<br>GRUPPO FERROVIE DELLO STATO ITALIANE | CAPITOLATO GENERALE TECNICO DI APPALTO<br>DELLE OPERE CIVILI<br>PARTE II - SEZIONE 13<br>SUB-BALLAST E PAVIMENTAZIONI STRADALI |
| CAPITOLATO - PARTE II -<br>SEZIONE 13                                                                                                                    | Codifica: RFI DTC SI CS SP IFS 009 G<br>FOGLIO 1 di 62                                                                         |

| CAPITOLATO GENERALE TECNICO DI APPALTO<br>DELLE OPERE CIVILI                                                                                                                                                                                                                                                              |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| PARTE II - SEZIONE 13<br>SUB-BALLAST E PAVIMENTAZIONI STRADALI                                                                                                                                                                                                                                                            |
| 13.1. SCOPO E CAMPO DI APPLICAZIONE<br>13.2. DOCUMENTAZIONE DI RIFERIMENTO<br>13.3. DEFINIZIONI<br>13.4. ABBREVIAZIONI<br>13.5. PRESCRIZIONI GENERALI<br>13.6. ONERI<br>13.7. PAVIMENTAZIONI PER INTERPORTI<br>13.8. PAVIMENTAZIONI STRADALI<br>13.9. SUB - BALLAST<br>13.10. PAVIMENTAZIONI DI OPERE STRADALI ACCESSORIE |



| Rev. | Data       | Descrizione                | Redazione    | Verifica Tecnica | Autorizzazione |
|------|------------|----------------------------|--------------|------------------|----------------|
| G    | 20/12/2024 | Emissione per Applicazione | G.M. D'Amico | A. Ruffini       | F. Iacobini    |



### CIRCULARITY

Maximizing the use of recycled materials (RAP) for a circular railway system.



### PERFORMANCE

Equal or superior mechanical performance compared to conventional solutions.



### STANDARD IMPLEMENTATION

From research to practice: contributing to the update of RFI technical specifications.

# Future situation – Italian road construction

FROM ENVIRONMENTAL COMPLIANCE TO PERFORMANCE-DRIVEN SUSTAINABILITY



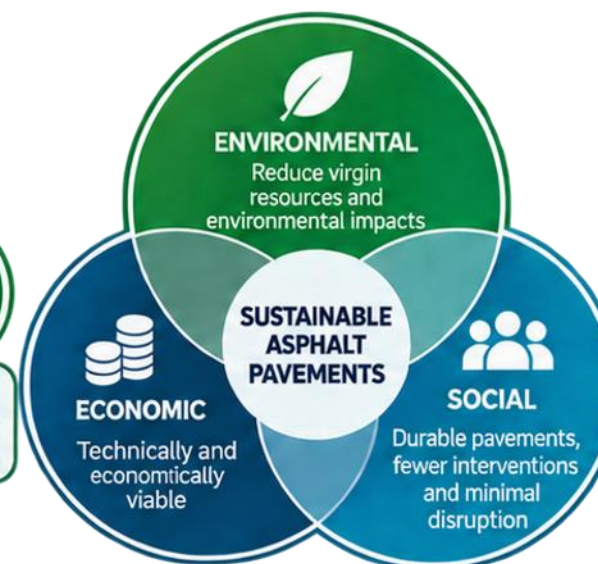
Policy can accelerate recycling. **Performance is what makes recycling credible**

# Conclusions

BEYOND RAP PERCENTAGE: ENGINEERING FOR PERFORMANCE AND SUSTAINABILITY



## FROM MORE RECYCLING TO BETTER RECYCLING



# Thank you!

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