CO_2 Quantification for Typical Mobile Machine Application Processes in Road Building, Earthmoving

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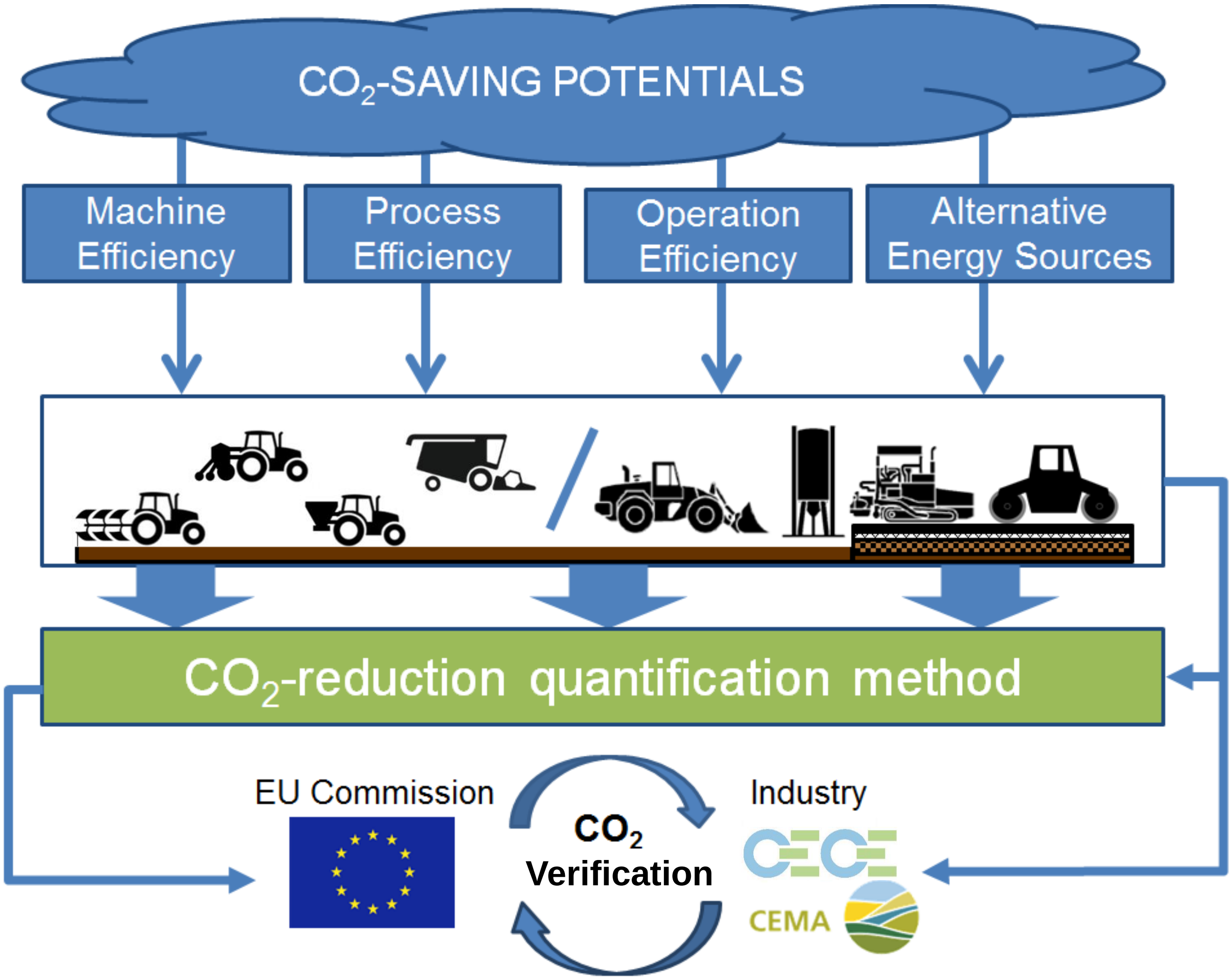
Outline

- I. CO_2- quantification method
- II. Application on a representative example
- III. Sample calculation
- IV. Results
- V. Conclusion

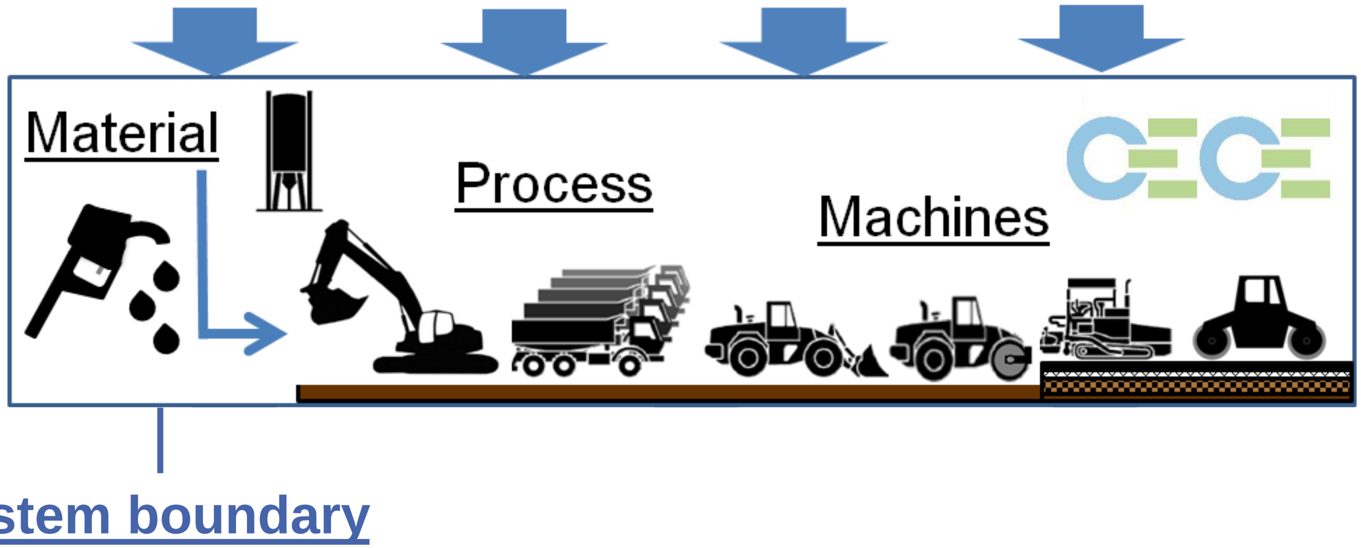
I. CO_2- quantification method
A. *Common method*



Picture source: Liebherr & Wirtgen & CEMA

I. CO_2- quantification method

A. *CECE - CO_2 quantification method*



CO_2 from:

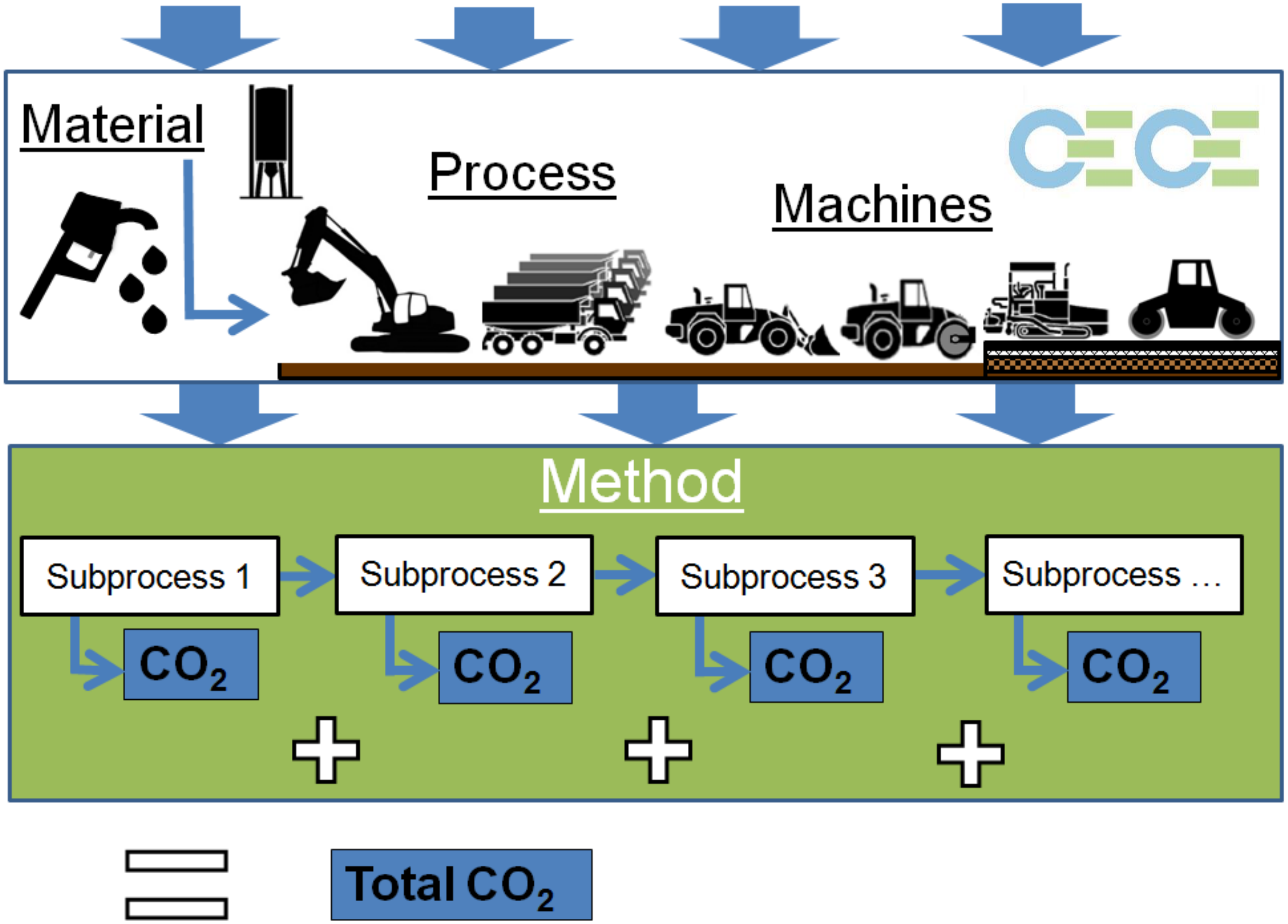
- Production of construction material
- Transport of material to and from the site
- Construction machines
- Production process of primary energy carrier (only from database)

Picture source: Liebherr & Wirtgen

I. II. III. IV. V.

I. CO_2- quantification method

A. *CECE - CO_2 quantification method*



Picture source: Liebherr & Wirtgen

I. II. III. IV. V.

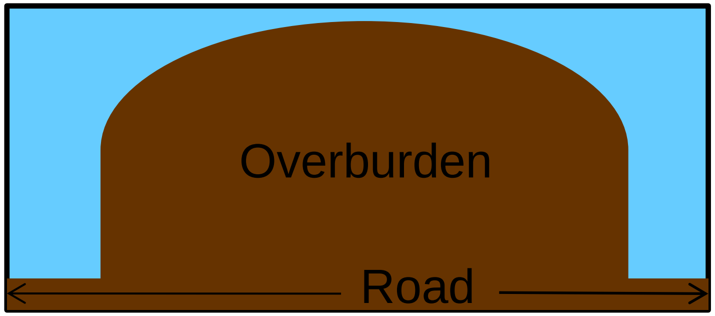
II. Application on a representative example

- Proceeding:
  - Application of the **method**
  - For a **road construction**
  - For the time scale **past (1990-2009) – present (2010-2013)- future (2014-2020)**

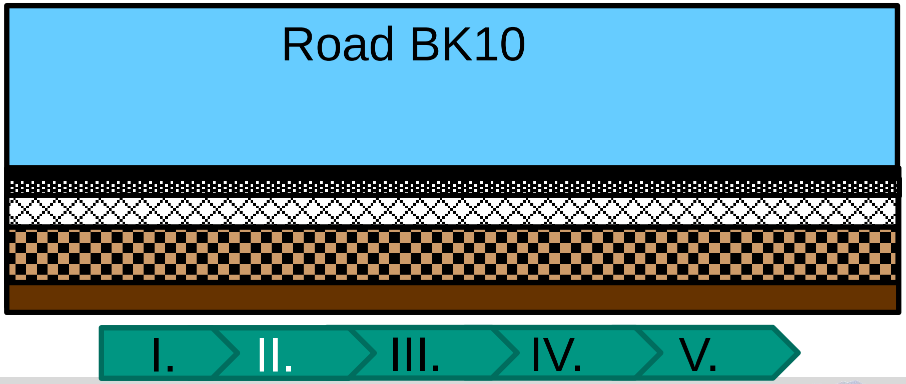
- Representative example:

Construction of a road BK10 in Karlsruhe

Earthmoving



Road building



I. CO_2- quantification method

- <u>Background:</u>

EU objective: reduction of CO_2 emissions in construction sites

- <u>CECE Aim:</u>

Show a market driven reduction of CO_2 emissions

- <u>Procedure:</u>

A. Similar approach as CEMA → convince EU

B. Develop a method to quantify
<u>the **attained** and **potential CO_2-reduction**</u>

I. II. III. IV. V.

II. Procedure for the CO_2 quantification

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Determination of:

Earthmoving / Pavement

1. Work tasks
   (e.g. earth moved / road type)
2. Conditions / Requirements
   (e.g. soil class / thickness of the layers)
3. Construction site & working conditions
4. Material
5. Machines (on the construction site)
6. Number of machines
7. Distance driven by the machines

Machine efficiency

+

Process efficiency

+

Operation efficiency

+

Alternative energy sources

→ **CO_2**

I. II. III. IV. V.

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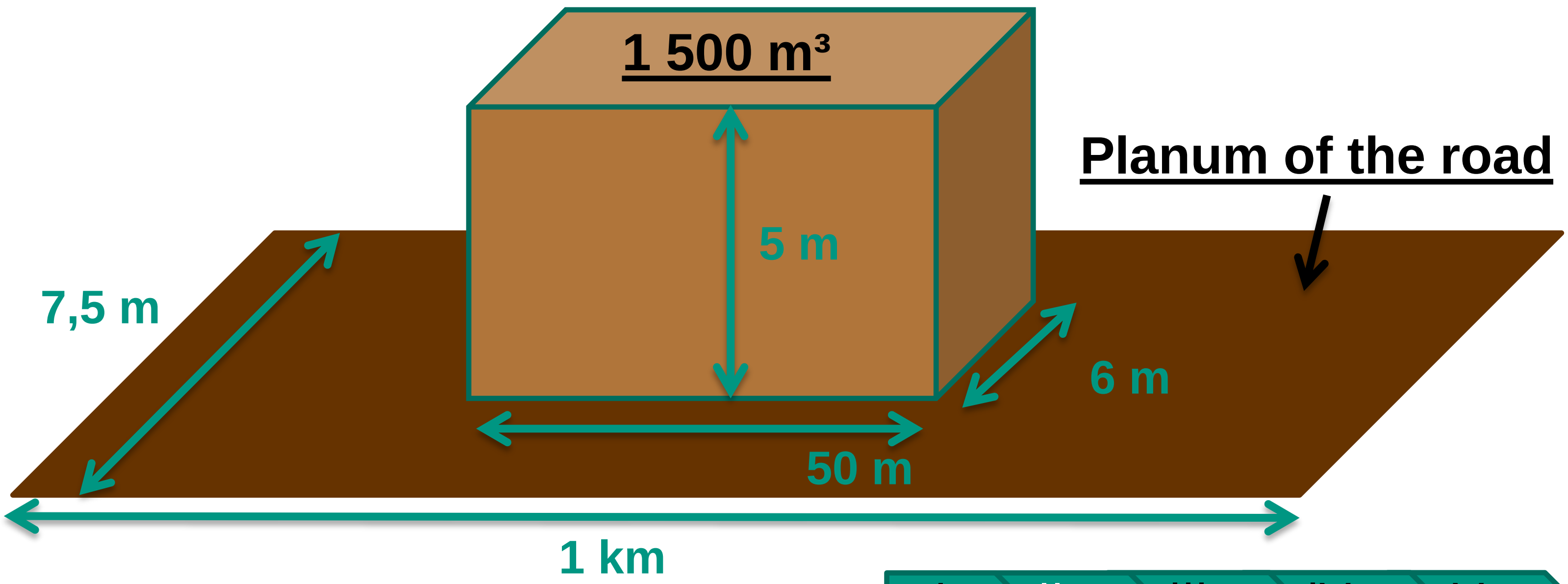
II. Application on the representative example

1. Work tasks & 2. Conditions / Requirements

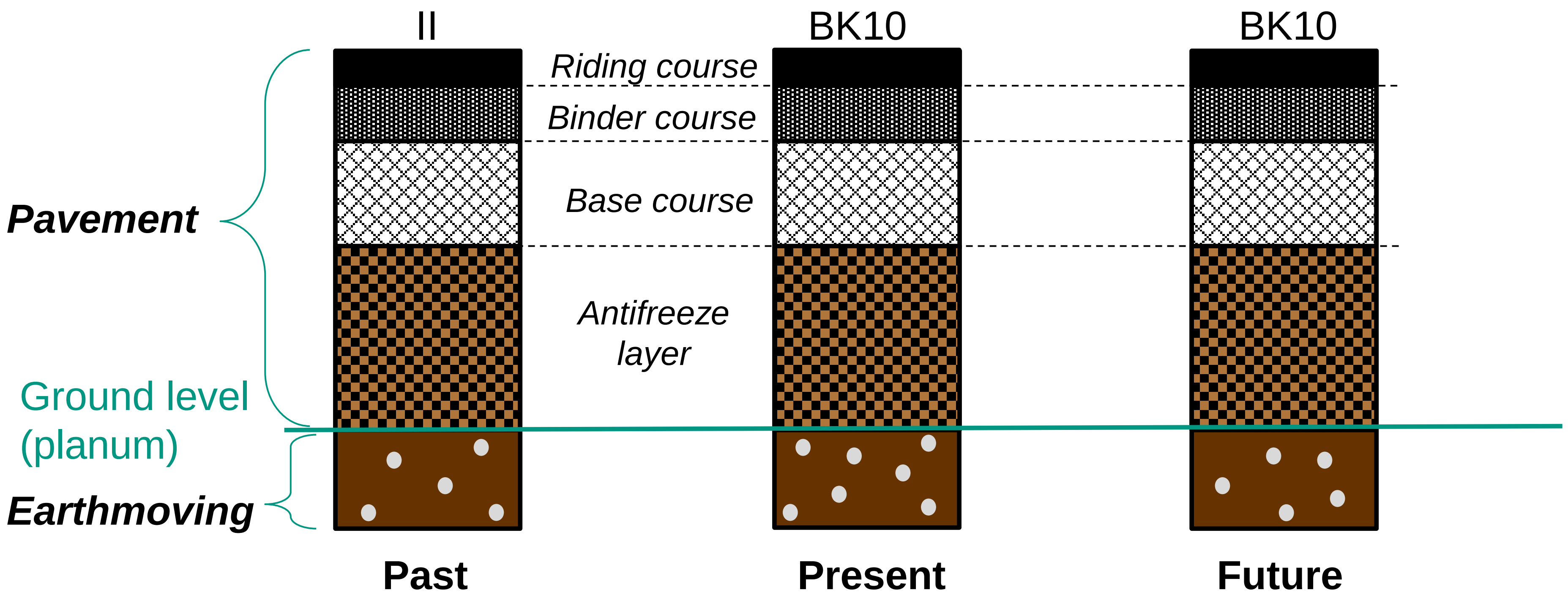
- <u>Adjustment of the representative example</u>
  - Soil: Brown earth & luvisol from wind & terrace sand (in Karlsruhe) (1+2)
    - ➡ No cohesive,
    - ➡ sand, gravel, silt, clay
    - ➡ **Soil class 3** (DIN 18300)



I. II. III. IV. V.

II. Procedure for the construction of a road

1. Determination of the road type



II. Procedure for the construction of a road

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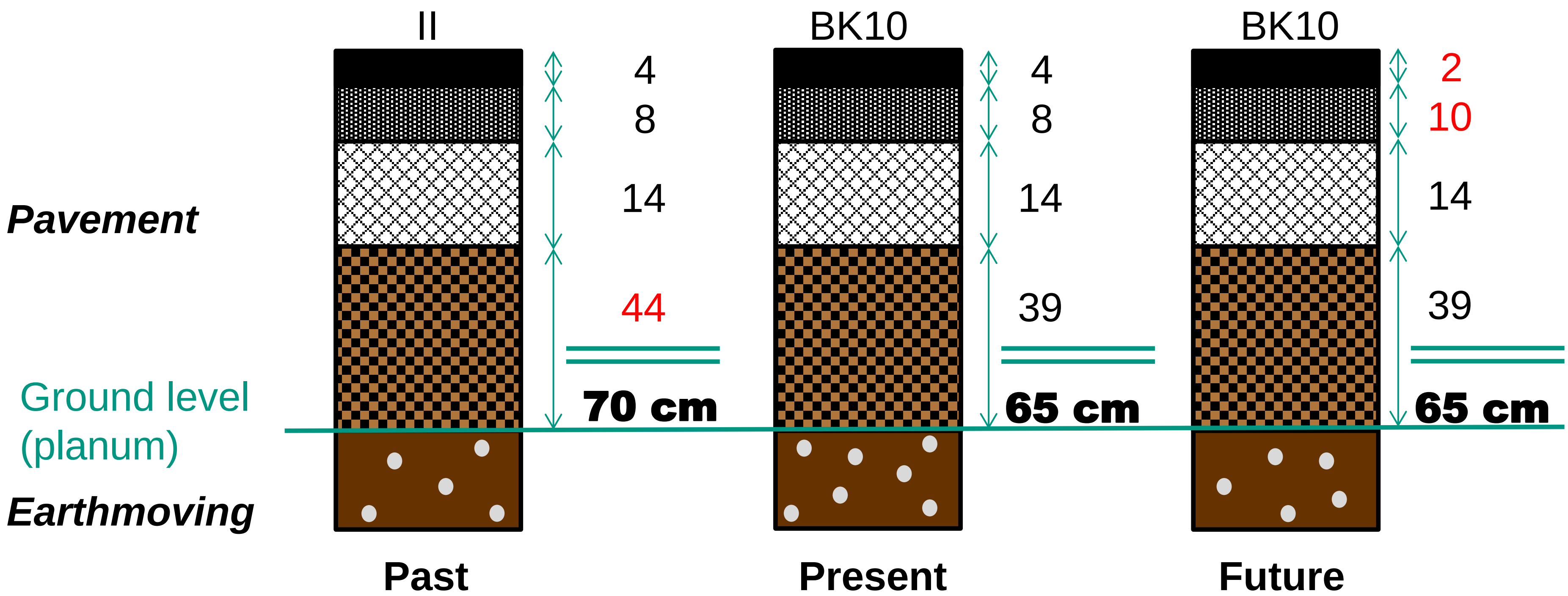
1. Determination of the road type & 2. Thicknesses of the layers



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II. Procedure for the construction of a road

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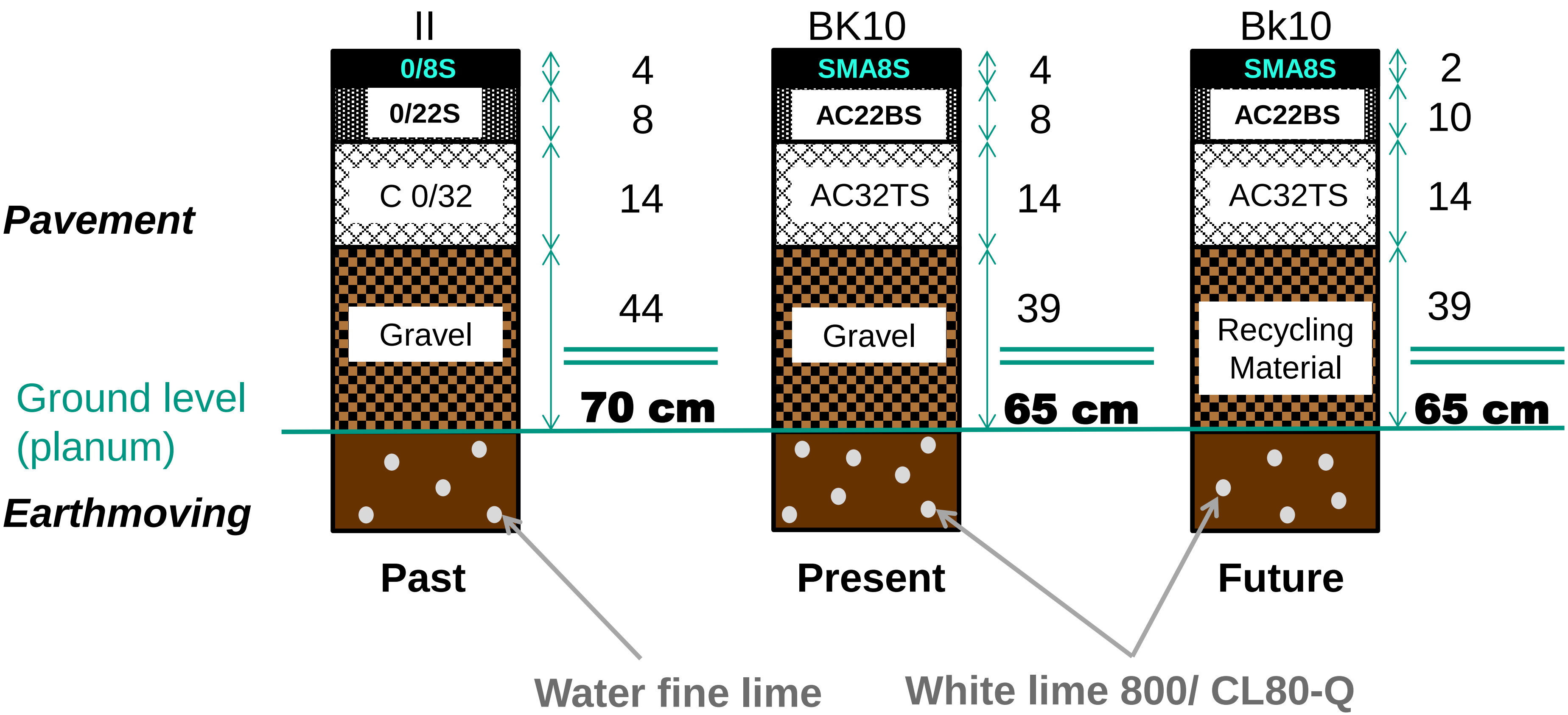
3. Material



I. II. III. IV. V.

II. Procedure for the construction of a road

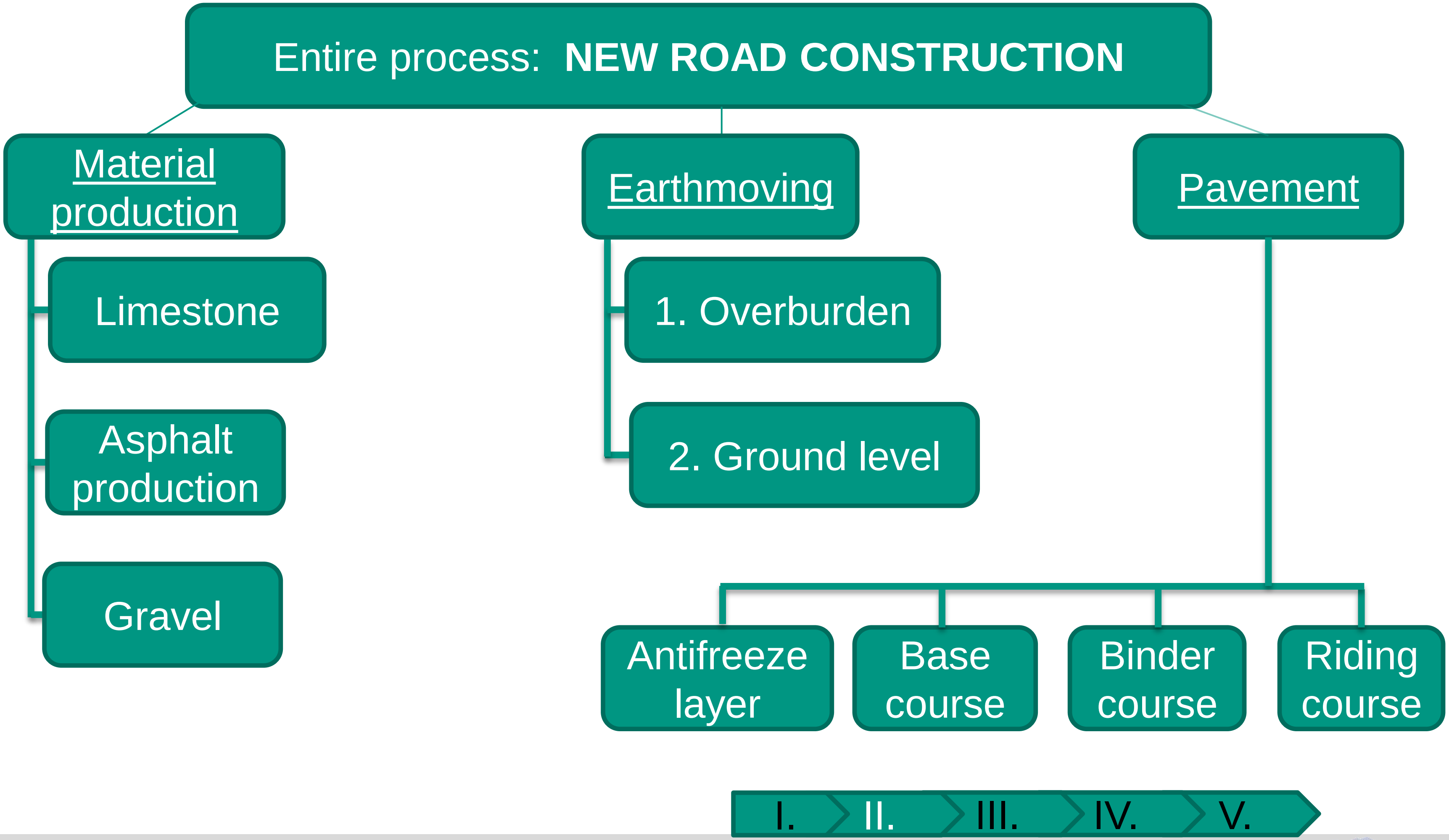
4. Machines

- Hydraulic excavator (25-27t ; 112-140 kW)
- Truck (265 kW)
- Crawler dozer (120 kW)
- Grader (142 kW)
- Vibratory roller (10-11,5 t ; 74 kW for asphalt ; 119 kW for earth)
- Limestone tank truck (41t ; 405 kW)
- Soil stabilizer (315 kW)
- Padfoot compactor (11,5 t ; 115 kW)
- Spreader (300 kW)
- Paver (127 kW)
- Material feeder (160kW)

I. II. III. IV. V.

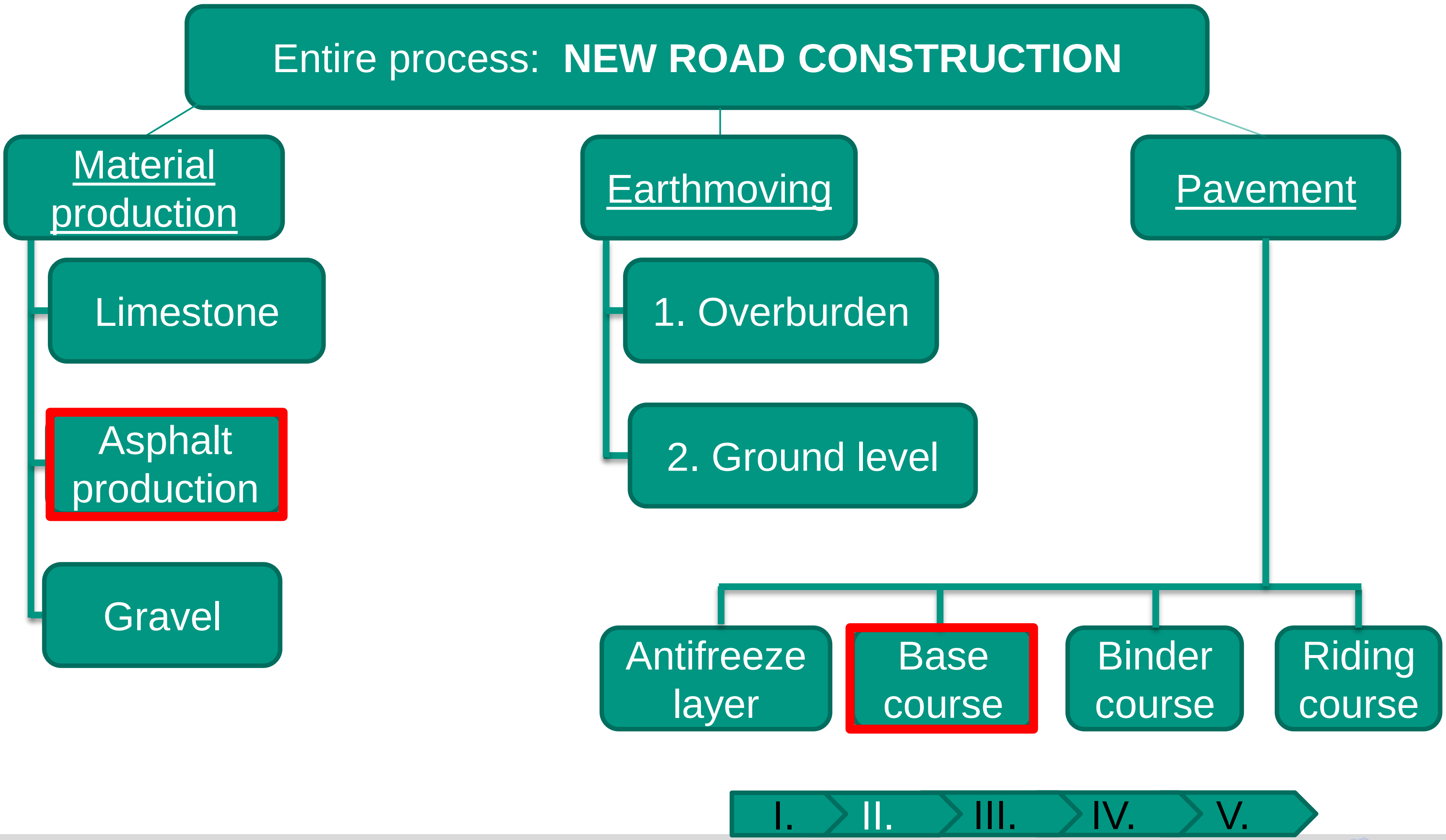
II. Procedure for the construction of a road

5. Process



II. Procedure for the construction of a road

5. Process



III. Sample calculation: Asphalt production

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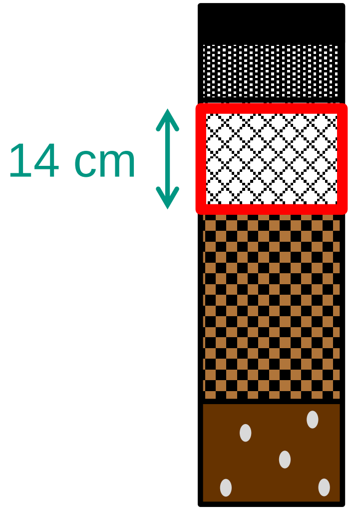
General information AC32TS			
Asphalt production	46	kg CO2/t	
Thickness	0,14	m	
Total quantity	1050	m³	
Density	2312	kg/m³	(4)
Total weight	2427	t	



- Asphalt production:

$$46 \text{ kg } CO_2/\text{t} \times 2427 \text{ t} = \mathbf{111{,}7 \text{ t } CO_2}$$

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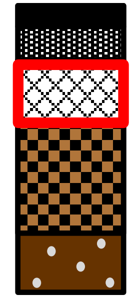
III. Sample calculation: Base course



Pavement

<u>Source:</u> *bauforum24.biz*

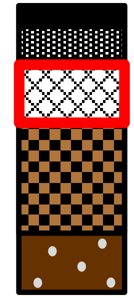
Source: AMMANN

Aim	2. Base course					
Process	**2.1 Pavement**					
Subprocesses	Transport	Unloading	Paving	Precompaction	Compaction	
Machines Type	**Rear-dump truck** 265 kW – 13m³		**Paver** 127 kW – 7,5m width		**Tandem roller static** 74kW 10t-11,5t	**Tandem roller dynamic** 74kW 10t-11,5t

Material
AC32TS

I. II. III. IV. V.

III. Sample calculation: Base course



Pavement

Source: bauforum24.biz

Source: AMMANN

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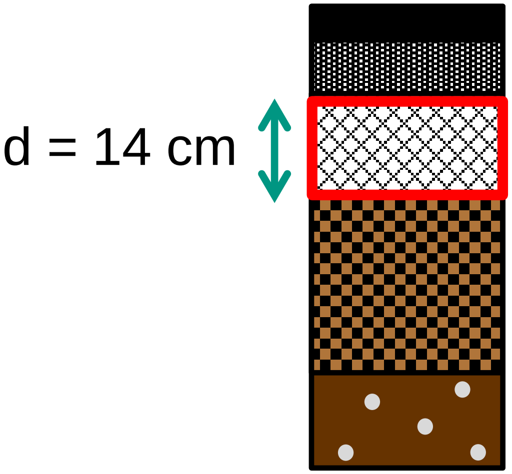
Material
AC32TS

I. II. III. IV. V.

III. Sample calculation: Base course, paver

- **Asphalt quantity:** 1050 m³

- **Paver data :**
  - Working velocity: v_{paver}= 480 m/h
  - Working width: b‘ = 7,5 m
  - Engine performance: P_{max}= 127 kW
  - Consumption: b = 175 g/kWh



Paver data source (3) + Wirtgen group

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III. CO_2 quantification basics for mobile machines

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- CO_2 quantification emitted by mobile machines:

$$CO_2 = B \times (2,6 + 0,4)$$

$$CO_2e = B \times (2,6 + 0,6)$$

Emissions for diesel production (6+7):
0,4 kg CO_2/l_{diesel} or 0,6 kg CO_2e/l_{diesel}

CO_2 emissions for diesel combustion (CO_2~CO_2e) (5):
2,63 kg CO_2/l_{diesel}

- Total consumption for the subprocess : $B = P \times b \times t_i$

b = specific fuel consumption

- Performance: $P = 0,7 \times P_{max}$

P_{max} = maximal engine power

- Working time (3): $t_i = \dfrac{\text{Volume of material}}{Q_E}$

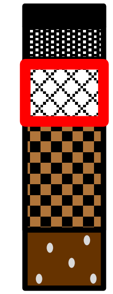
- Effective capacity (3): $Q_E = Q_B \times 0,75 \times 0,9$

Utilisation factor : 0,75

Factor for unforeseeable difficulties: 0,9

- Firm capacity (3): $Q_B = \dfrac{\text{nominal machine volume}}{\text{time}}$

III. Sample calculation: paver



- CO_2 quantification emitted by mobile machines:

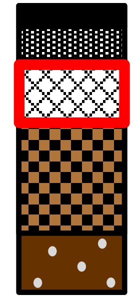
$$CO_2 = B \times (2{,}6 + 0{,}4) = 0{,}177 \text{ t}$$
$$CO_2e = B \times (2{,}6 + 0{,}6) = 0{,}184 \text{ t}$$

- Total consumption for the subprocess: $B = P \times b \times t_i = 57{,}9 \; l$
- Performance: $P = 0{,}7 \times P_{max} = 88{,}9 \text{ kW}$
- Working time: $t_i = \dfrac{\text{Volume of material}}{Q_E} = 3{,}1 \; h$
- Effective capacity: $Q_E = Q_B \times 0{,}75 \times 0{,}9 = 340 \text{ m}^3/\text{h}$
- Firm capacity: $Q_B = b' \times v_{paver} \times d = 504 \text{ m}^3/\text{h}$

III. Sample calculation: Base course

Source: bauforum24.biz

Pavement



Source: AMMANN

Aim	2. Base course					
Process	**2.1 Pavement**					
Subprocesses	Transport	Unloading	Paving	Precompaction	Compaction	
Machines Type	**Rear-dump truck** 265 kW – 13m³ **8,99 t CO_2**		**Paver** 127 kW – 7,5m width **0,177 t CO_2**		**Tandem roller static** 74kW 10t-11,5t **0,093 t CO_2**	**Tandem roller dynamic** 74kW 10t-11,5t **0,291 t CO_2**

Material AC32TS → **111,7 t CO_2**

Total: 121,3 t CO_2

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IV. Results

IV. Results: differences between *earthmoving - pavement - material*

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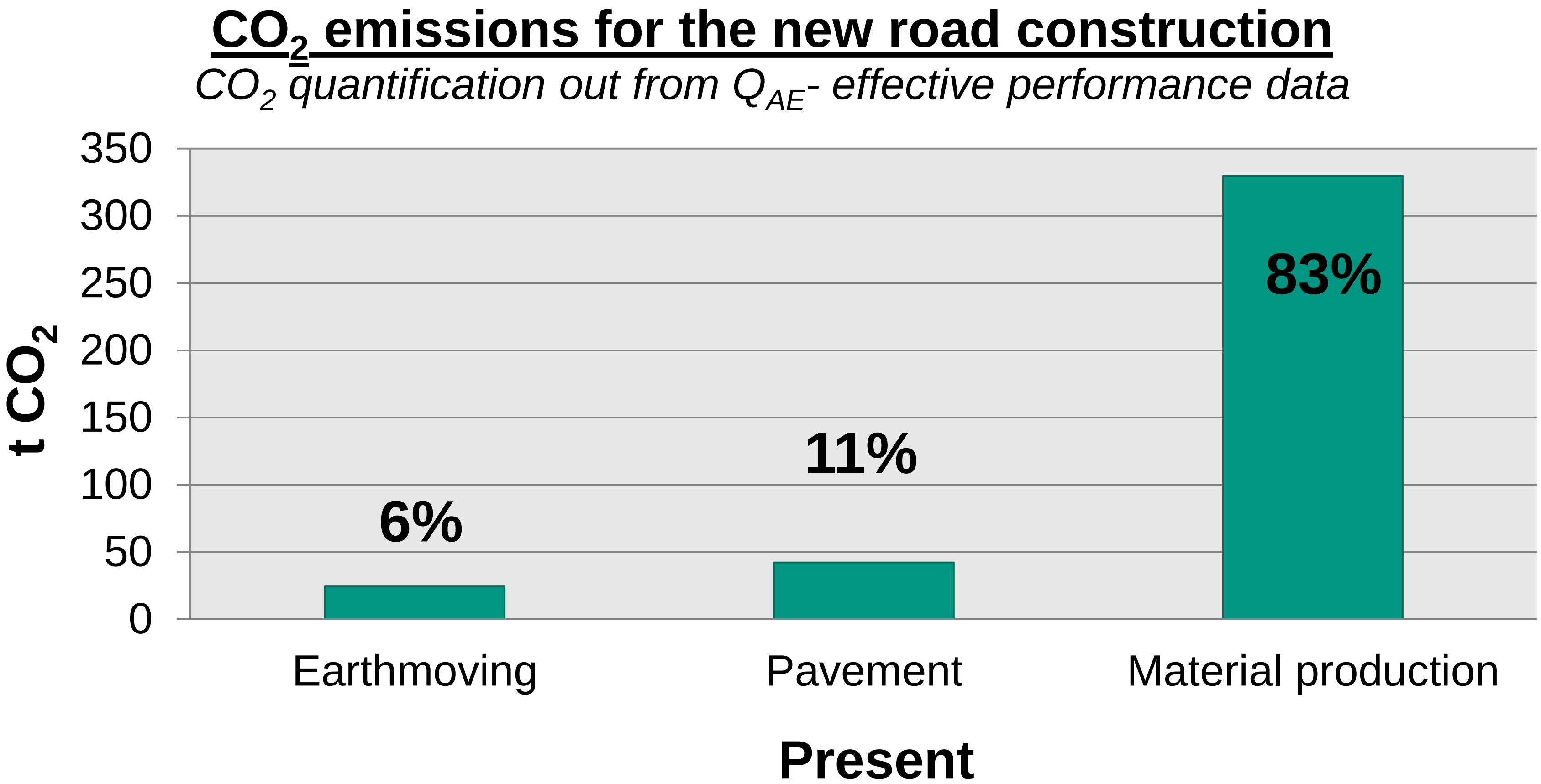
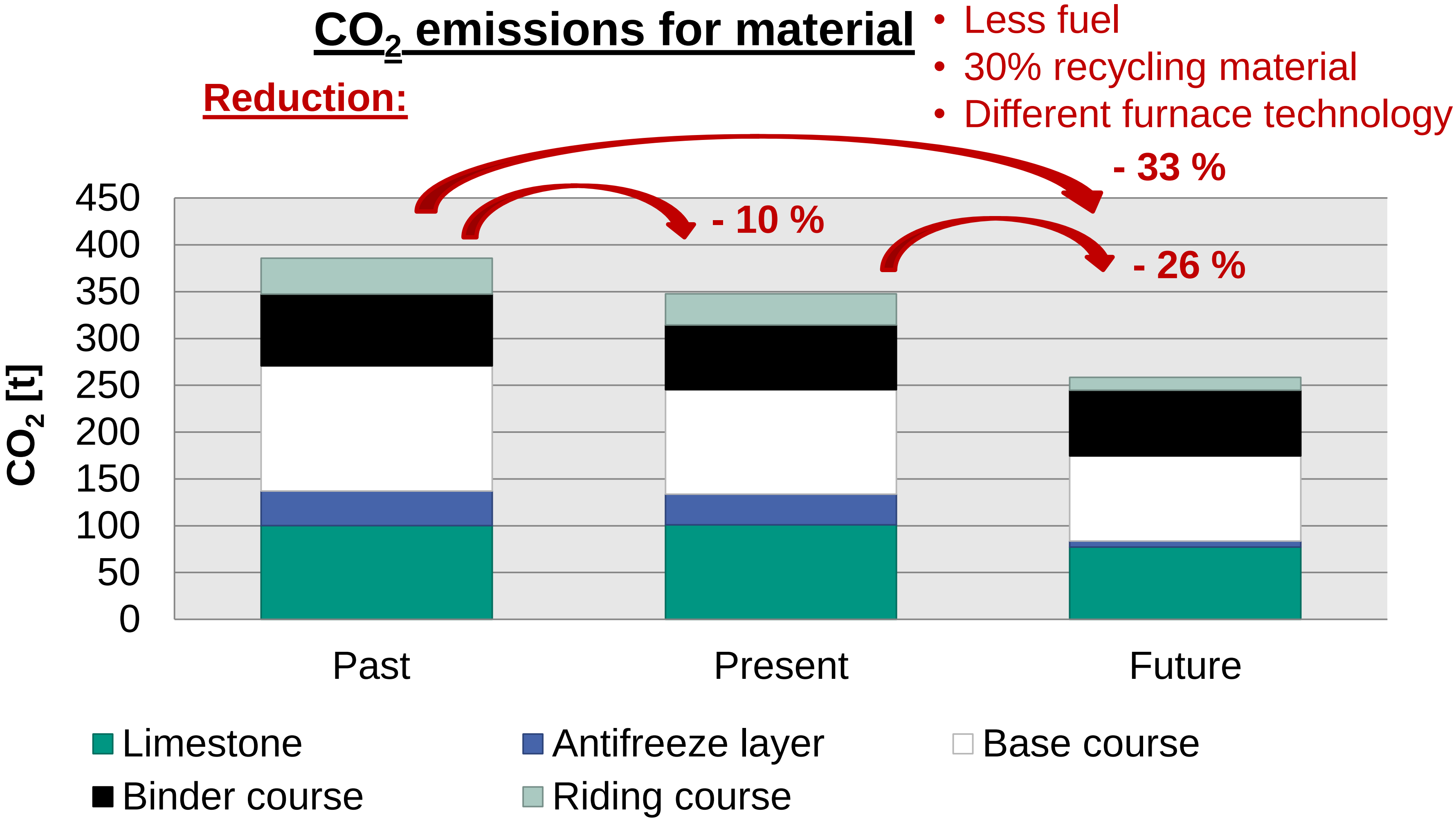


I. II. III. IV. V.

IV. Results: Material production



IV. Results: job-site processes

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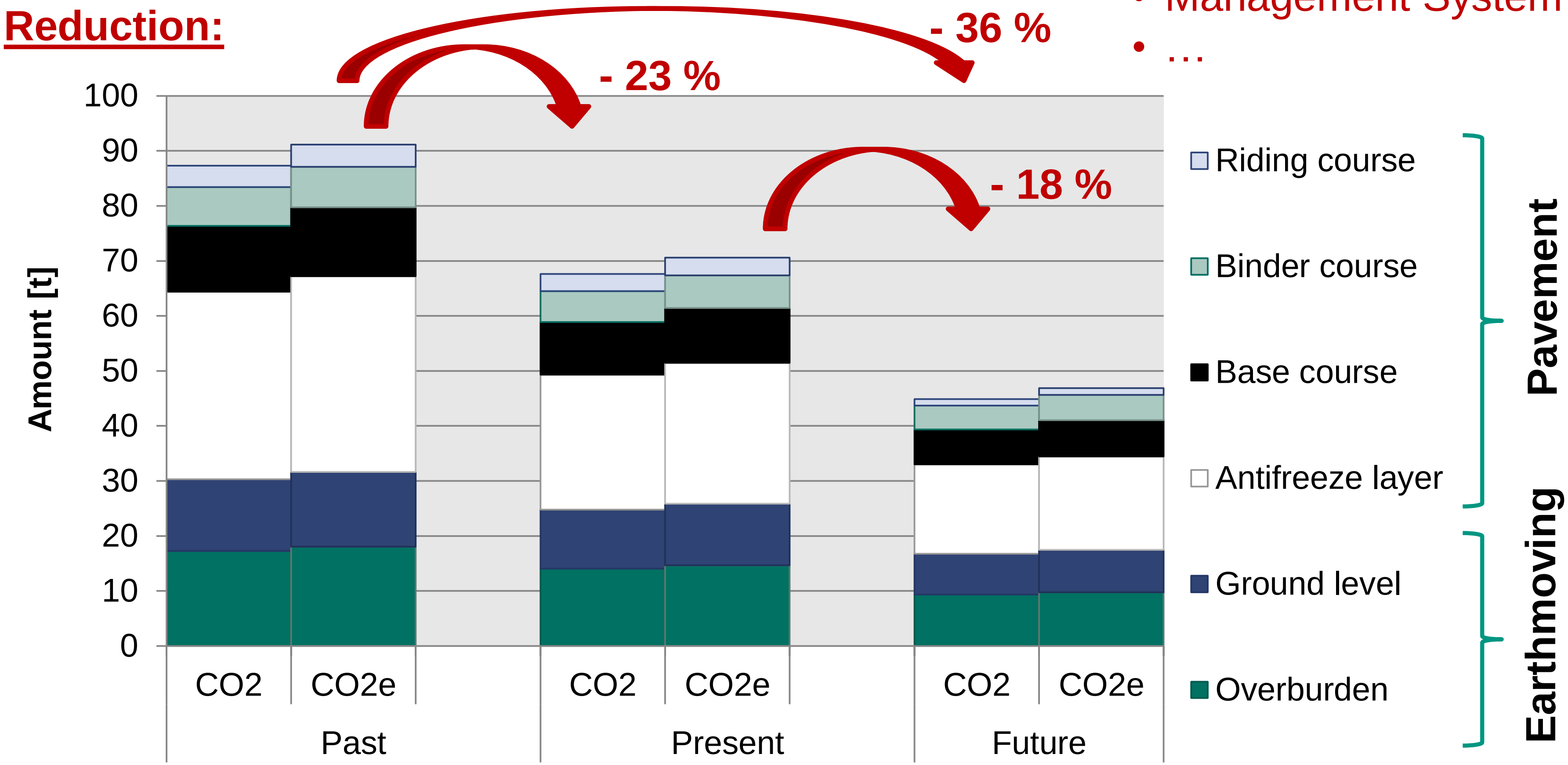
Machine efficiency: lower fuel consumption

- Common rail injection
- Ecomode
- Management System
- …

Reduction:



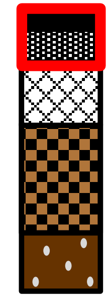
I. II. III. IV. V.

<u>IV. Results:</u> Influences of the 4 pillar approach on a simulation example

IV. Results: Simulation example

- Operation efficiency: 10% better site/working conditions

  ➔ Utilisation factor: 0,75 ⟶ 0,85

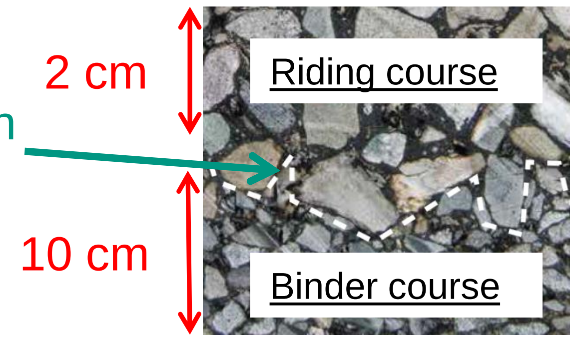


- Process efficiency:
  1. Same truck capacity with 10 % less trucks: e.g. 33 ➔ 30 trucks
  2. **"Hot on Hot"**
     - High interdigitation
     - Different material ratio
     - Different machines:

       "+ 1 paver "

       + 1 material feeder

       - 2 rollers



Source: Vögele (Wirtgen Group)

✓ Machine efficiency: lower fuel consumption

Source: Vögele (Wirtgen Group)

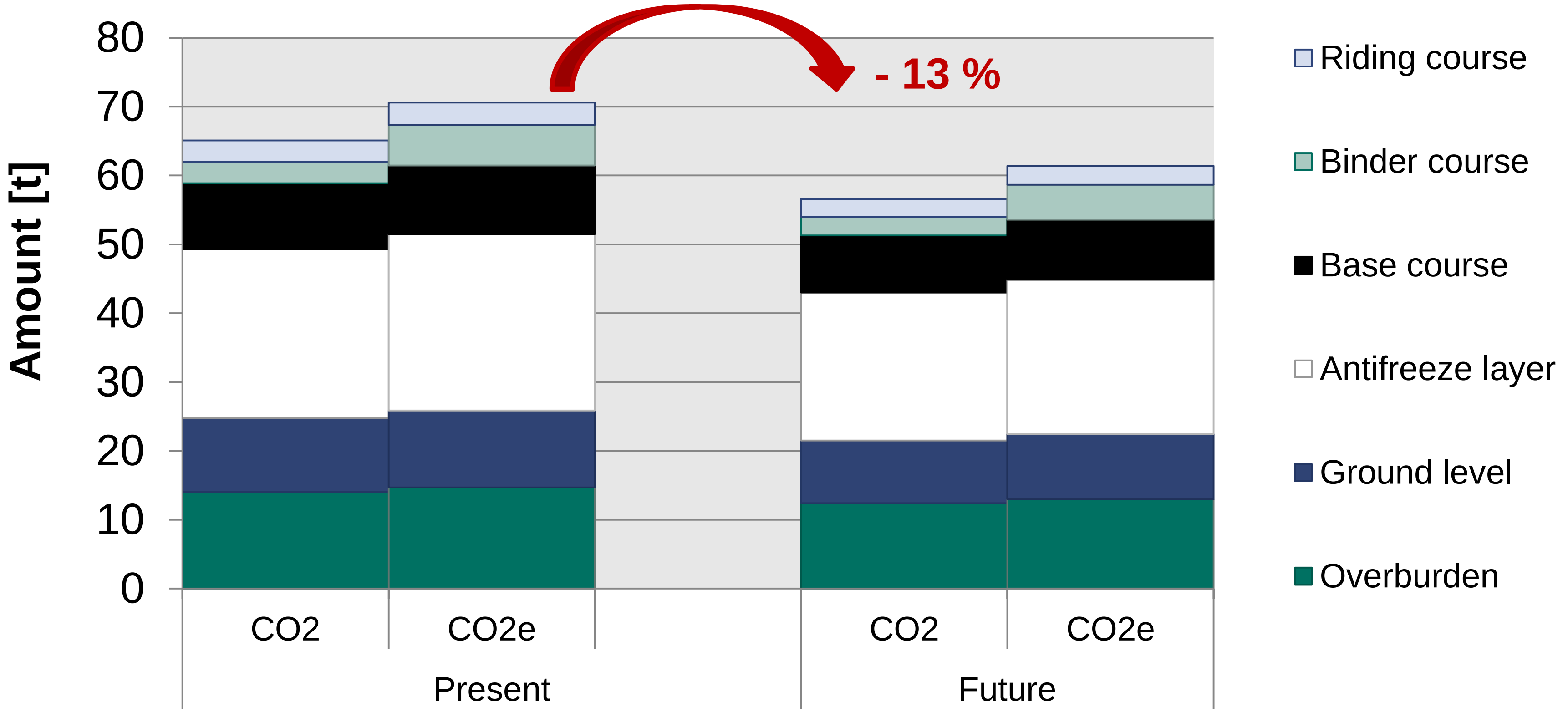
I. II. III. IV. V.

IV. Results: Influences of the 4 pillar approach

- Only operation efficiency

Operation efficiency
Utilisation factor: 0,75 → 0,85

- Tyre pressure control
- Correct settings
- Driving cycle amelioration
- …



I. II. III. IV. V.

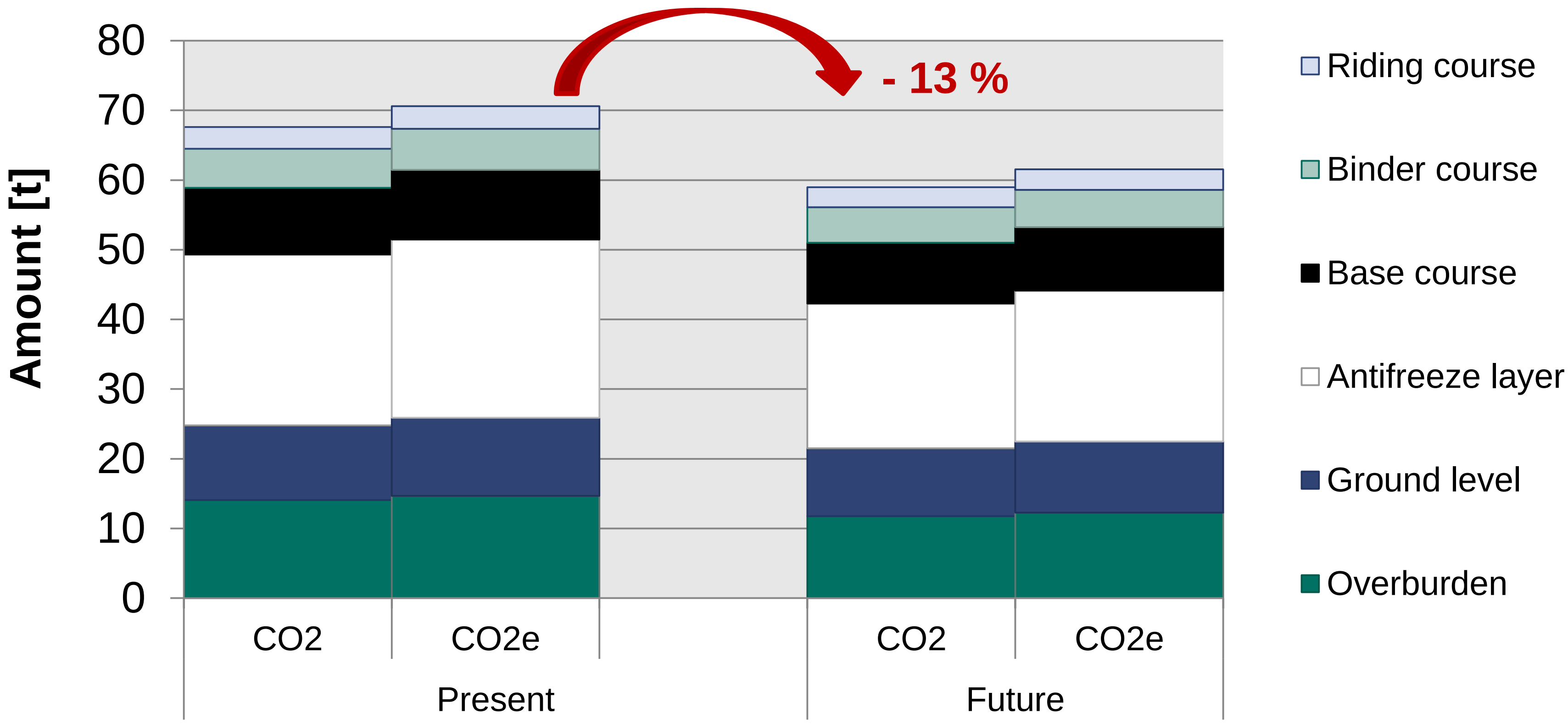
IV. Results: Influences of the 4 pillar approach

- Only process efficiency

Process efficiency:

10 % less trucks: e.g. 33 → 30 trucks

- Lower fuel consumption
- Bigger Volume
- …



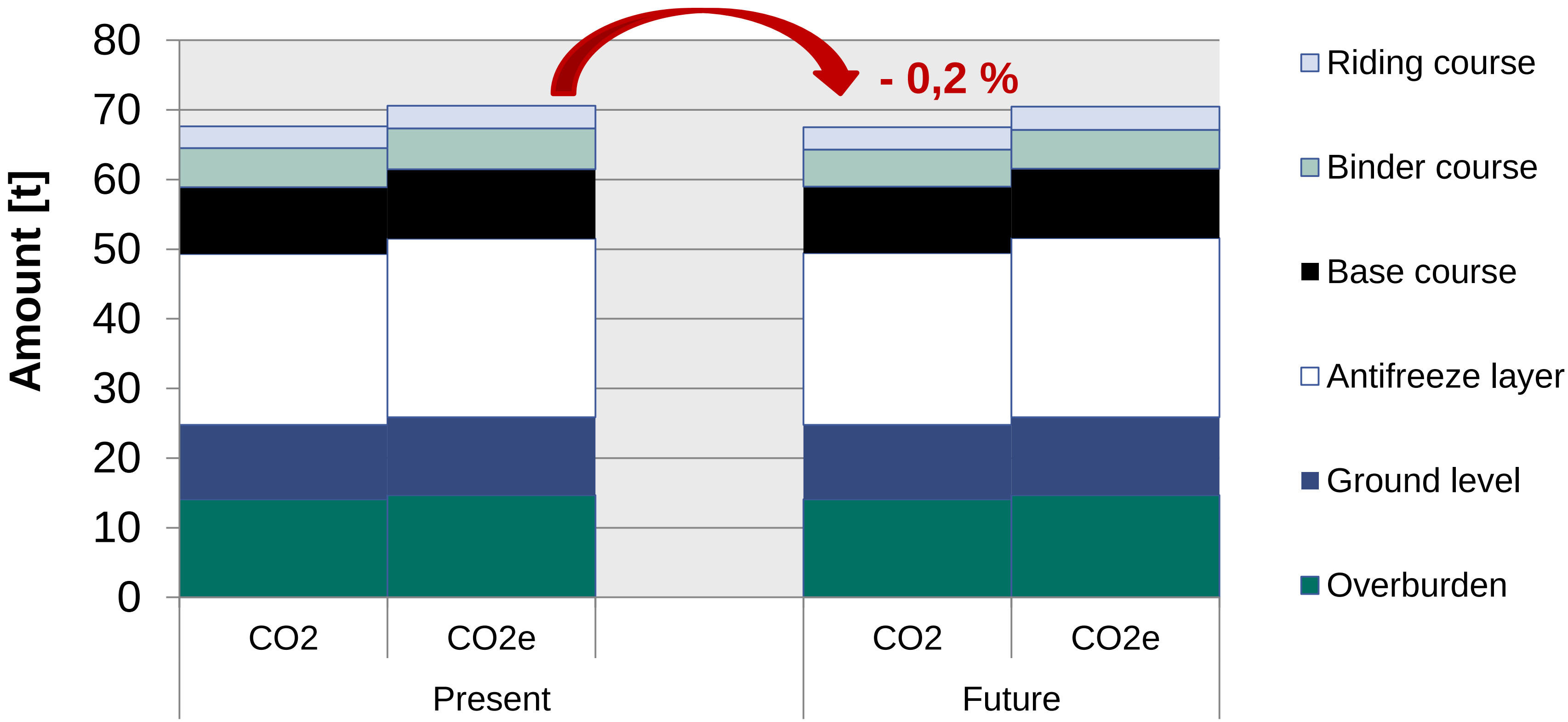
I. II. III. IV. V.

IV. Results: Influences of the 4 pillar approach

- Only process efficiency (not material)

Process efficiency: only "Hot on Hot"

- \+ 1 material feeder
- \- 2 rollers



I. II. III. IV. V.

V. Conclusion

- Summary
  - Elaboration of the method
  - Application on a new road construction of type BK10
  - Identification of the **material** & **processes** & **machines**
  - CO_2 quantification & CO_2 attained and potential reduction

Machine efficiency	**Attained CO_2 reduction 1990-2013**	**Potential CO_2 reduction 1990-2020**
Job-site processes	**23 %**	**36 %**
Material	**10 %**	**26 %**

I. II. III. IV. V.

List of references

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