ORRAP
Optimal recycling of reclaimed asphalt pavement

EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

Recyclage optimal des agrégats de béton bitumineux dans les chaussées à faible trafic

Optimales Recycling von Ausbauasphalt auf verkehrsschwachen Straßen

01/11/2016 - 31/12/2020

FINAL ANNUAL MEETING

02/12/2020

ORRAP
Optimal recycling of reclaimed asphalt pavement

EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

Action 3

Economic and environmental assessment of the deployment of ORRAP at the level of the Upper Rhine region

Action 3

3.1 - Data collection (location and number of asphalt plants, flows, environmental problems) 

3.2 - Technico-economic and environmental study of the proposed technique and risk analysis 

3.3 - Study of the deployment of the proposed technique to the region 

➔ **Action Goal: Compare conventional and ORRAP construction method**

ORRAP
Optimal recycling of reclaimed asphalt pavement

EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

Action 3

3.1 - Data collection (location and number of asphalt plants, flows, environmental problems)

In order to carry out an economic and ecological assessment of the use of this technology, we will first collect data (identification of the low-traffic roads and their sites, as well as recycling-materials companies holding stocks, taking into account the forecasts of 5 years and 10 years of maintenance road infrastructures. A summary report of the collected required data on lightly trafficked roads, location and number of asphalt mixing plants, mass flows and environmental pollution) will be written.

Hochschule Karlsruhe
Technik und Wirtschaft
UNIVERSITY OF APPLIED SCIENCES

ORRAP
Optimal recycling of reclaimed asphalt pavement

EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

Action 3

3.2 - Technico-economic and environmental study of the proposed technique and risk analysis

In this work package a techno-economic and an ecological evaluation of the application of this technology in the Upper Rhine region will be carried out. The aim is to investigate, locate and evaluate the conditions for the introduction of this technology in the region, and to determine on which road constructions it would be most suitable. A summary report on the techno-economic and environmental evaluation of the proposed technique will be written and a comparison with the reference technique with the addition of bituminous binders will be carried out.

Hochschule Karlsruhe
Technik und Wirtschaft
UNIVERSITY OF APPLIED SCIENCES

- Detailed Assessment of ORRAP test sections

Fachhochschule Nordwestschweiz

- Assessment of Swiss construction method
- Risk analysis

ORRAP
Optimal recycling of reclaimed asphalt pavement

EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

Action 3

3.3 - Study of the deployment of the proposed technique to the region

In this third part we will try to simulate the use of AA recycling technology in the Upper Rhine region. This study should make it possible to better define the parameters linking material resources to needs and their changes over time at the level of a region. A summary report of the study on the impact of a regional application of the technique will be written.

Hochschule Karlsruhe
Technik und Wirtschaft
UNIVERSITY OF APPLIED SCIENCES

ORRAP
Optimal recycling of reclaimed asphalt pavement

EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

ORRAP
Optimal recycling of reclaimed asphalt pavement

Recyclage optimal des agrégats de béton bitumineux dans les chaussées à faible trafic

Optimales Recycling von Ausbauasphalt auf verkehrsschwachen Straßen

01/11/2016 - 31/12/2020

FINAL ANNUAL MEETING

02/12/2020

ORRAP
Optimal recycling of reclaimed asphalt pavement

EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

ORRAP
Optimal recycling of reclaimed asphalt pavement

Action 3

Economic and environmental assessment of the deployment of ORRAP at the level of the Upper Rhine region

- Results Hochschule Karlsruhe -

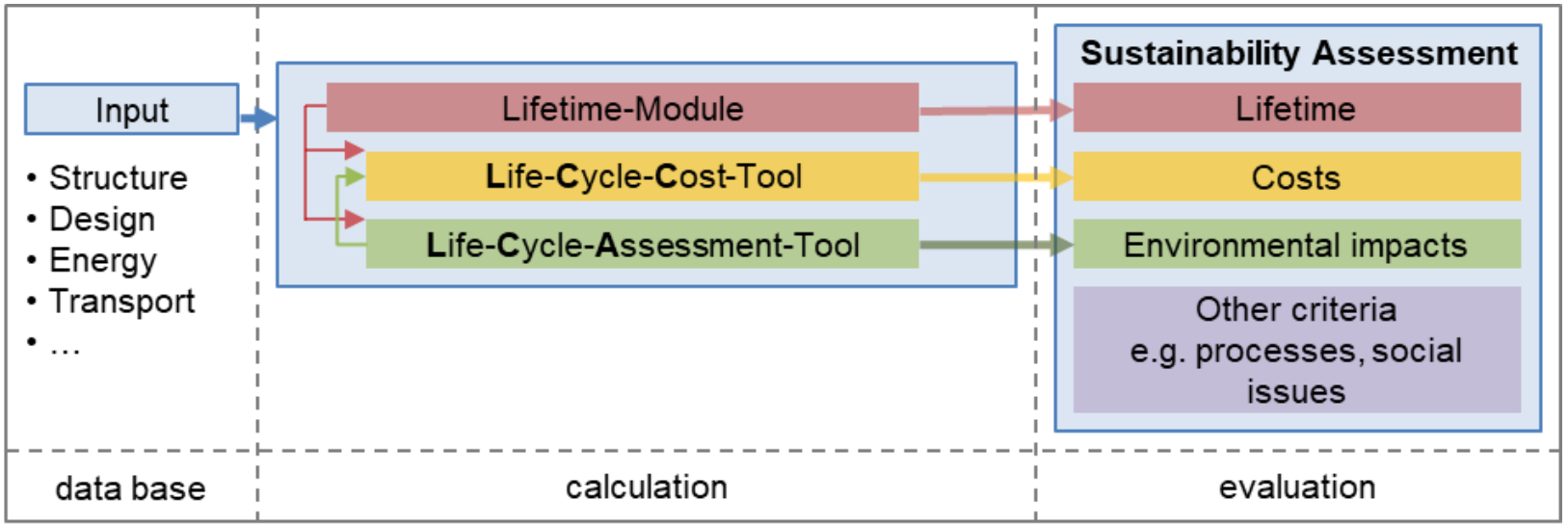
Amina Wachsmann, M.Eng.

Prof. Dr.-Ing. Christian Holldorb

Hochschule Karlsruhe
Technik und Wirtschaft
UNIVERSITY OF APPLIED SCIENCES

IVI Institut für Verkehr und Infrastruktur

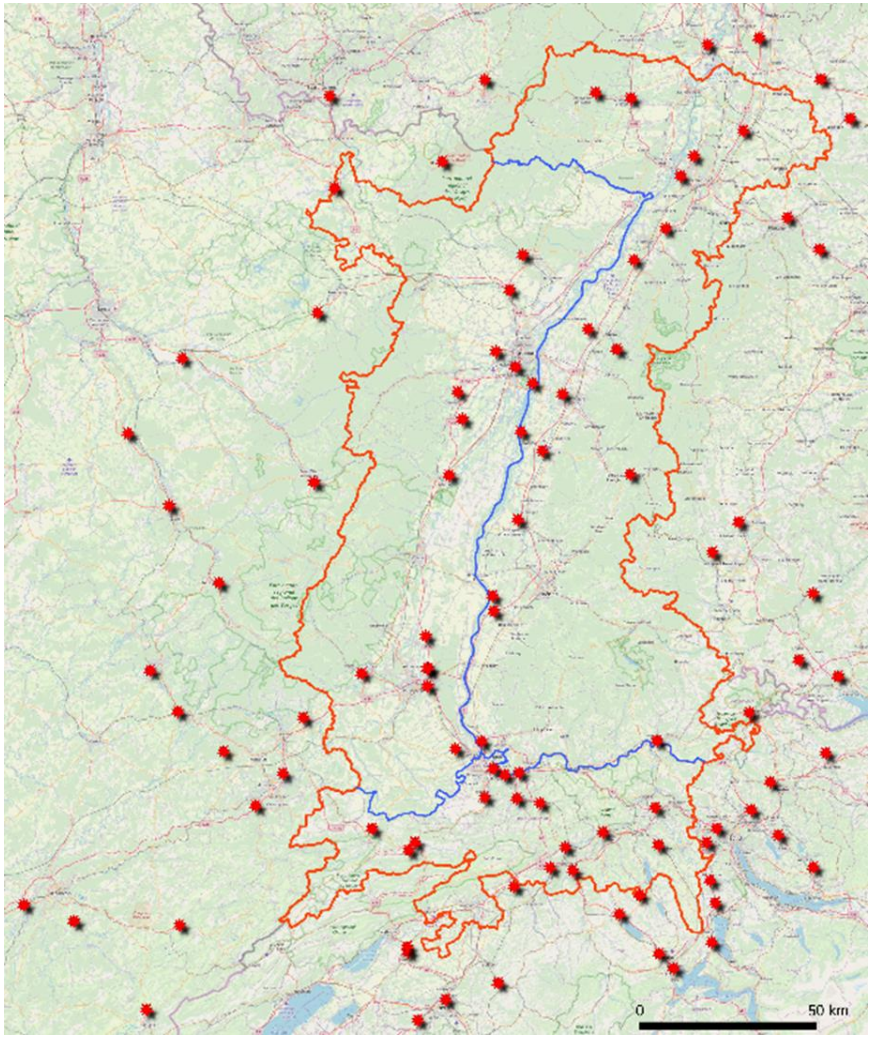
Results Action 3.1: Data collection



→ **Basics for Action 3.2: Techno-economic**

EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

Results Action 3.1: Data collection



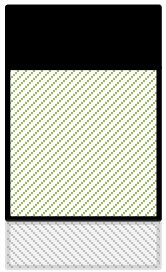
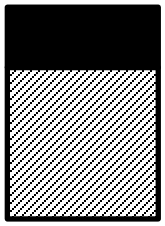
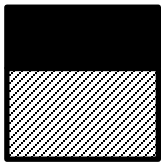
asphalt compounds	transport distance
RAP	20 km
bitumen	100 km
sand, gravel	20 km
crushed gravel	50 km
filler	50 km

EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

Results Action 3.2: Assessment of ORRAP test sections

ORRAP test section in Wahlen (CH)

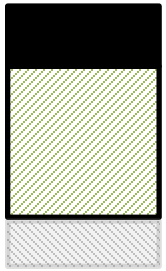
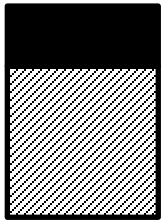
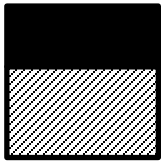
→ **Bounded layers as basis for the assessment – Layer thickness**

ORRAP	**conventional**	
scenario ① + ②	scenario 1	scenario 2
		
4 cm surface course 10 cm ORRAP … existing pavement	4 cm surface course 10 cm base course	4 cm surface course 6 cm base course

EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

ORRAP test section in Wahlen (CH)

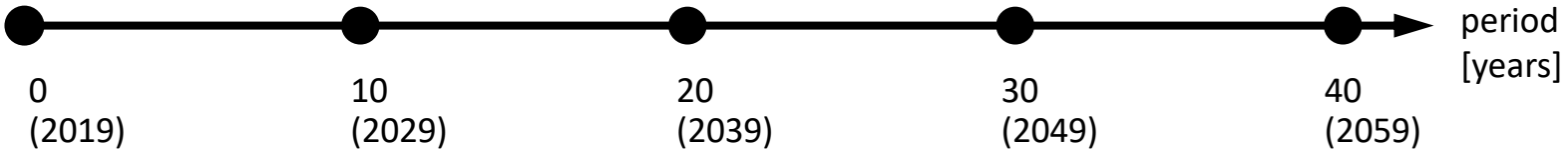
→ **Bounded layers as basis for the assessment – Lifetime assumption**

ORRAP scenario ① + ②	**conventional** scenario 1	**conventional** scenario 2
		
① **10 a** surface course **10 a** ORRAP **-** existing pavement		
② **15 a** surface course **40 a** ORRAP **-** existing pavement	**15 a** surface course **40 a** base course	**15 a** surface course **40 a** base course

ORRAP test section in Wahlen (CH)

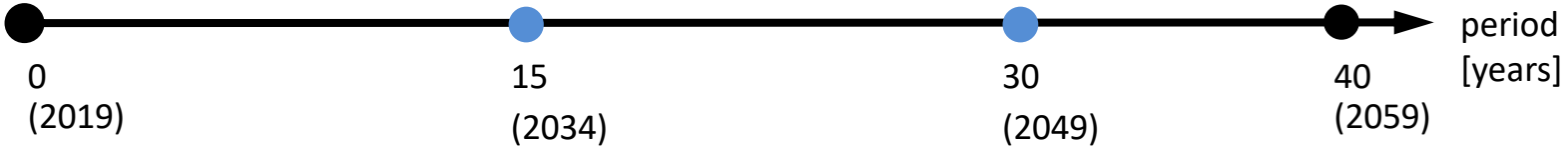
→ **Considered renewal measures based on the life cycle consideration**

ORRAP scenario 1: 5 times renewel of asphalt surface and ORRAP course



● renewal of surface and ORRAP course

ORRAP scenario 2 and conventional scen. 1 & 2: 2 times renewel of asphalt surface and ORRAP/base course; 2 times renewal of asphalt surface course



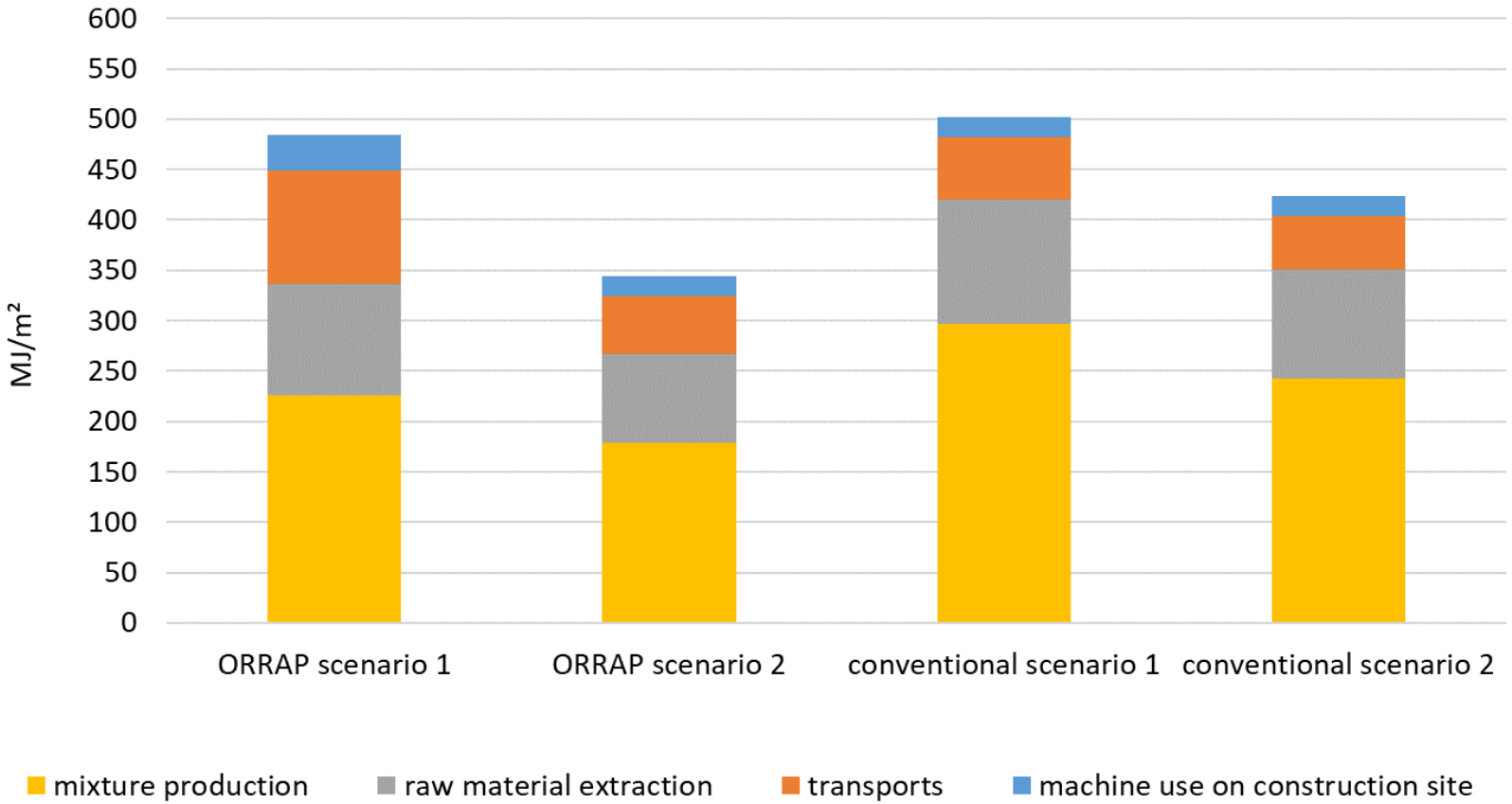
● renewal asphalt surface

● renewal asphalt surface and ORRAP/base course

EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

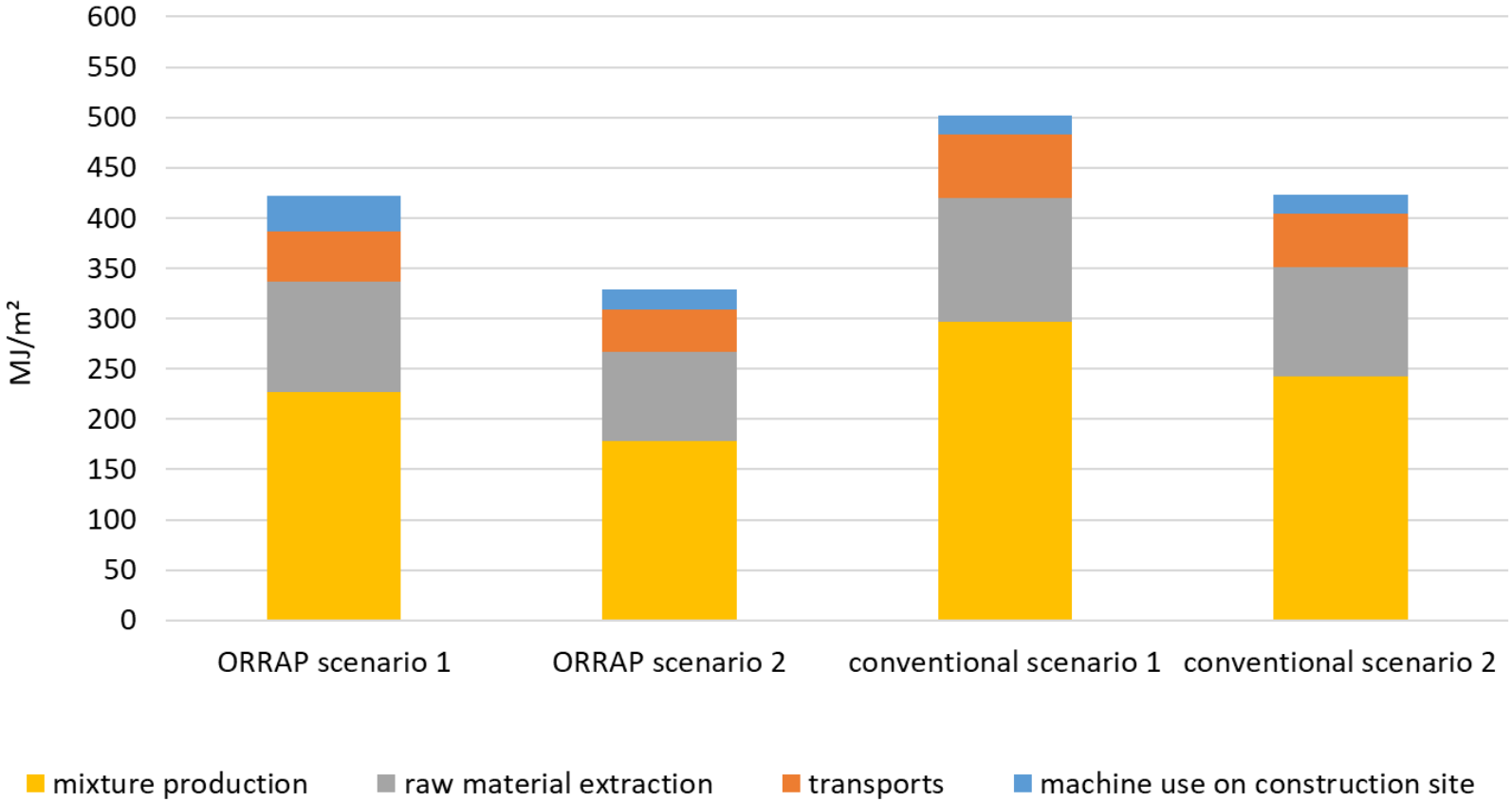
ORRAP test section in Wahlen (CH)

→ **Primary energy demand over 40 years**



ORRAP test section in Wahlen (CH)

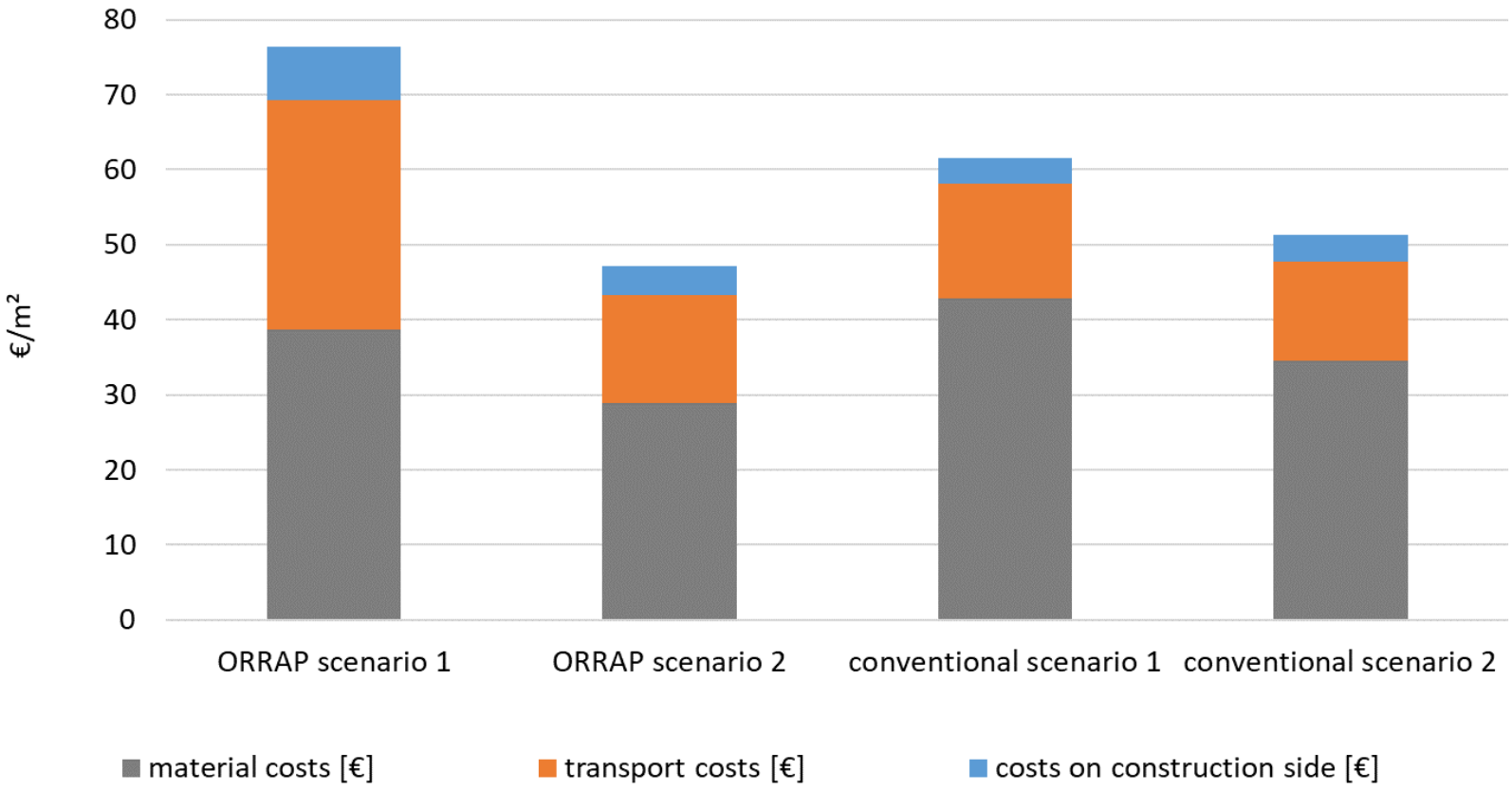
→ **Primary energy demand over 40 years; transport of the ORRAP material only before the first paving**



EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

ORRAP test section in Wahlen (CH)

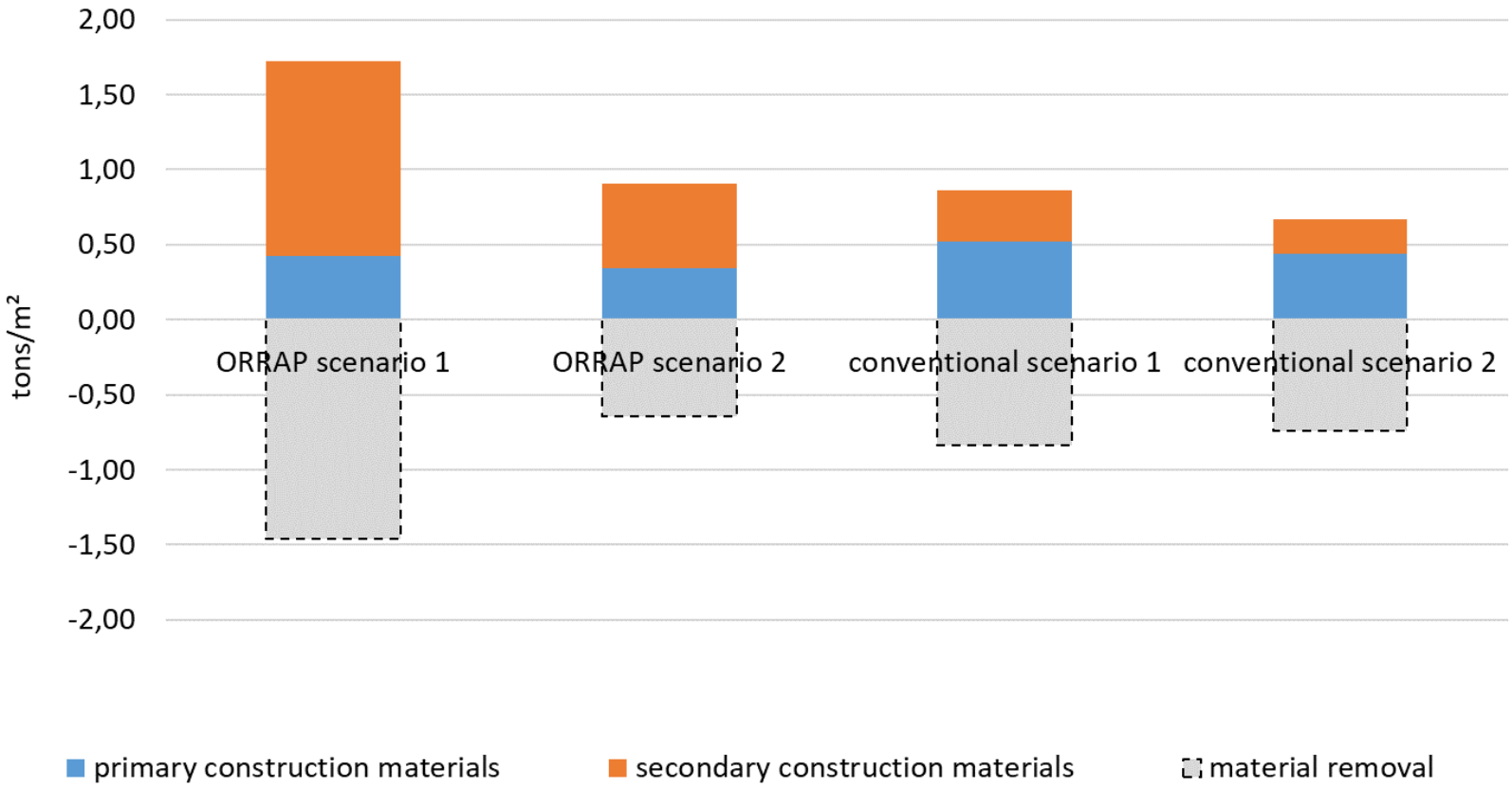
→ Costs over 40 years (based on year 2019 incl. a discount factor of 3 percent)



EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

ORRAP test section in Wahlen (CH)

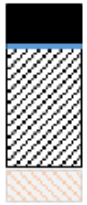
→ **Construction materials over 40 years**



EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

ORRAP test section in Semersheim (F)

→ Bounded layers as basis for the assessment – Layer thickness

Layer thickness / Lifetime assumption in years	ORRAP method				Conventional method		Unbound Granular Material			
	OM1	OM2	OM3	OM4	CM1	CM2	UGM 1	UGM 2	UGM 3	UGM 4
										
- asphalt surface course	-		4 cm		4 cm	4 cm	-		4 cm	
- ORRAP course	12 cm		12 cm		-	-	-		-	
- asphalt base course	-		-		8 cm	11 cm	-		-	
- unbound granular layer	-		-		-	-	12 cm		12 cm	
- existing pavement	…		…		-	-	-		-	
- unbound layers	…		…		…	…	-		-	
- sealer	yes		yes		-	-	yes		yes	
- bitumen emulsion	-		-		yes	yes	-		-	

EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

ORRAP test section in Semersheim (F)

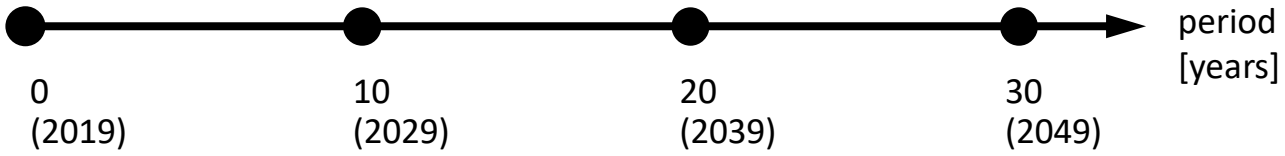
→ Bounded layers as basis for the assessment – Lifetime assumption

Layer thickness / Lifetime assumption in years	ORRAP method				Conventional method		Unbound Granular Material			
	OM1	OM2	OM3	OM4	CM1	CM2	UGM 1	UGM 2	UGM 3	UGM 4
										
- asphalt surface course	-	-	10 a	15 a	15 a	15 a	-	-	10 a	15 a
- ORRAP course	10 a	30 a	10 a	30 a	-	-	-	-	-	-
- asphalt base course	-	-	-	-	30 a	30 a	-	-	-	-
- unbound granular layer	-	-	-	-	-	-	10 a	30a	10 a	30 a
- existing pavement										
- unbound layers										
- sealer										
- bitumen emulsion										

ORRAP test section in Semersheim (F)

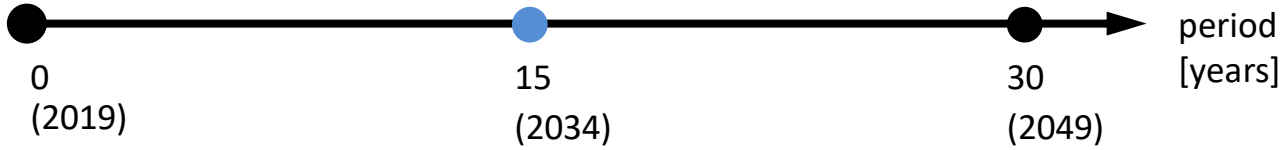
→ **Considered renewal measures based on the life cycle consideration**

ORRAP scenario 1 & 3 and UGM scenario 1 & 3:
4 times renewal of surface and ORRAP/UGM layer **or** 4 times renewal of ORRAP/UGM layer



- renewal of surface and ORRAP/UGM layer **or** only ORRAP/UGM layer

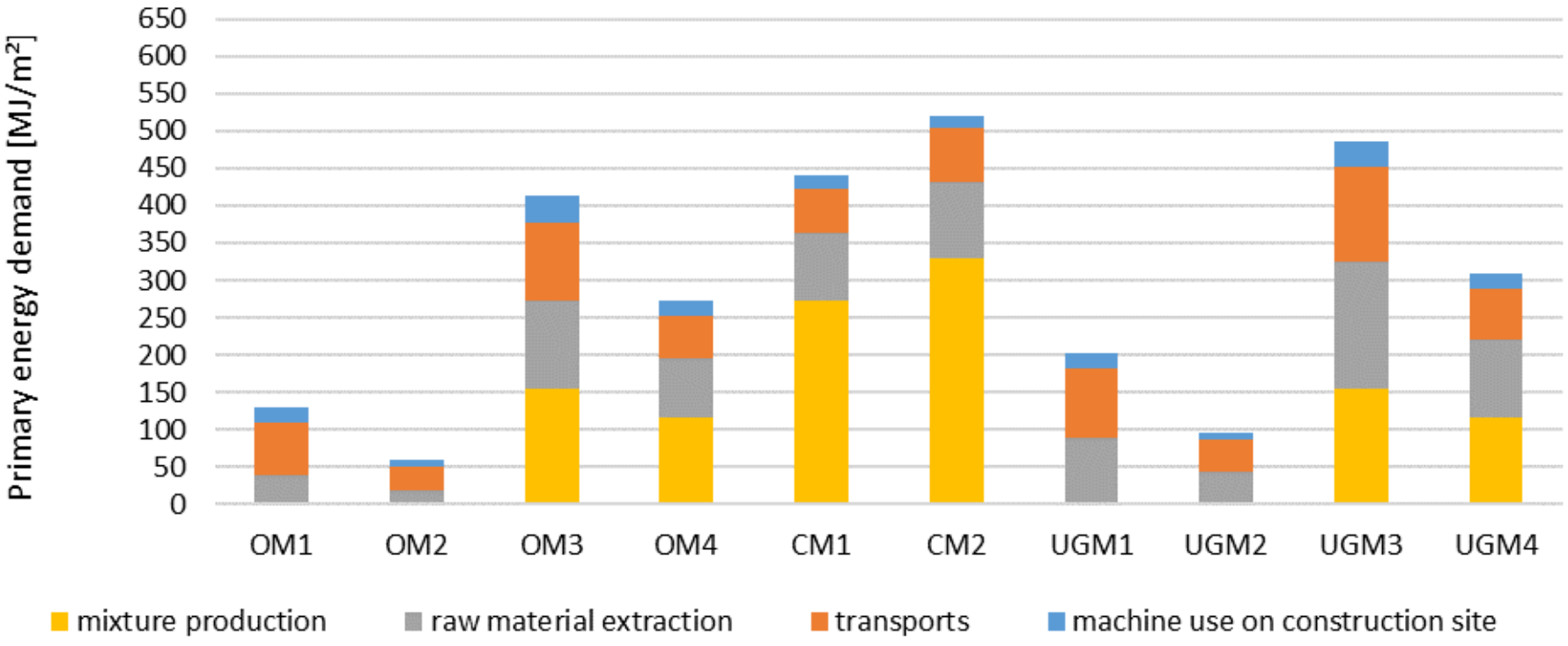
ORRAP scenario 2 & 4; conventional scenario 1 & 2; UGM scenario 2 & 4:
2 times renewel of asphalt surface and ORRAP/UGM/base course, 1 time renewal of asphalt surface course **or** 2 times renewal of ORRAP/UGM layer



- renewal surface
- renewal surface and ORRAP/UGM/base course

ORRAP test section in Semersheim (F)

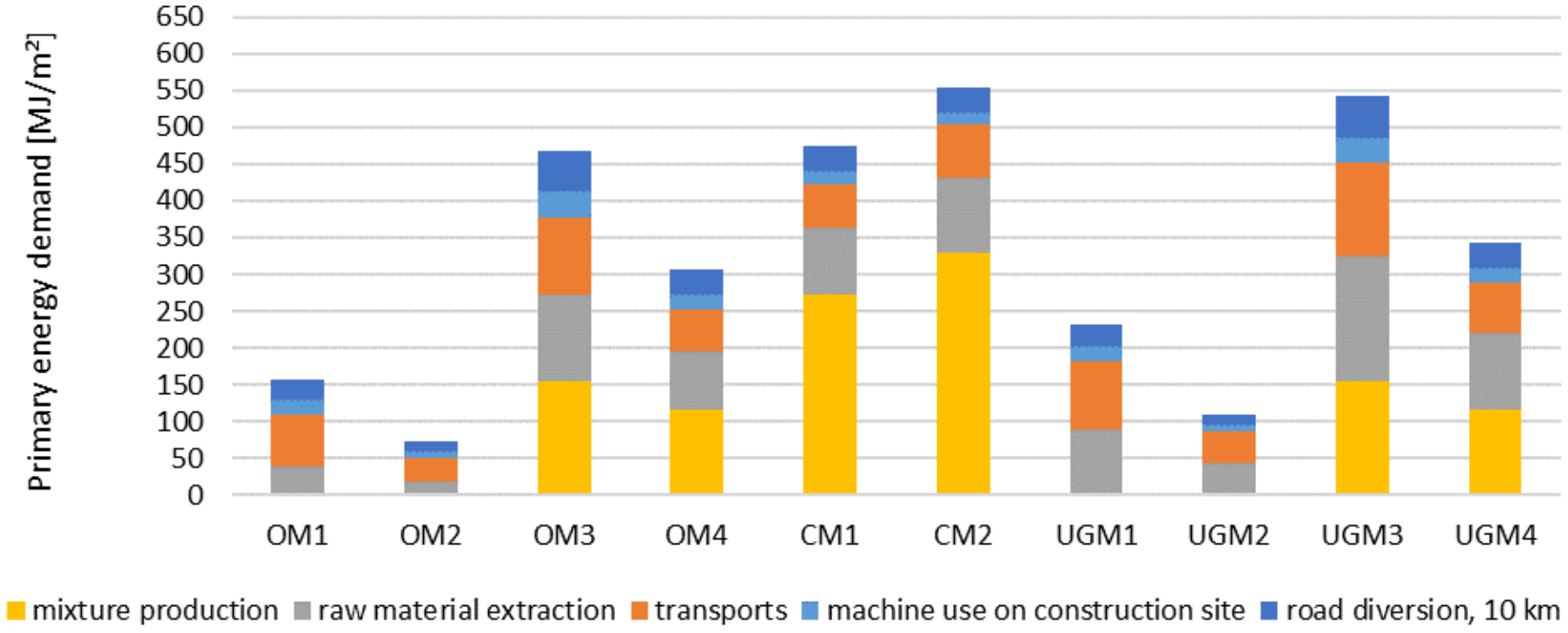
→ Primary energy demand over 30 years



EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

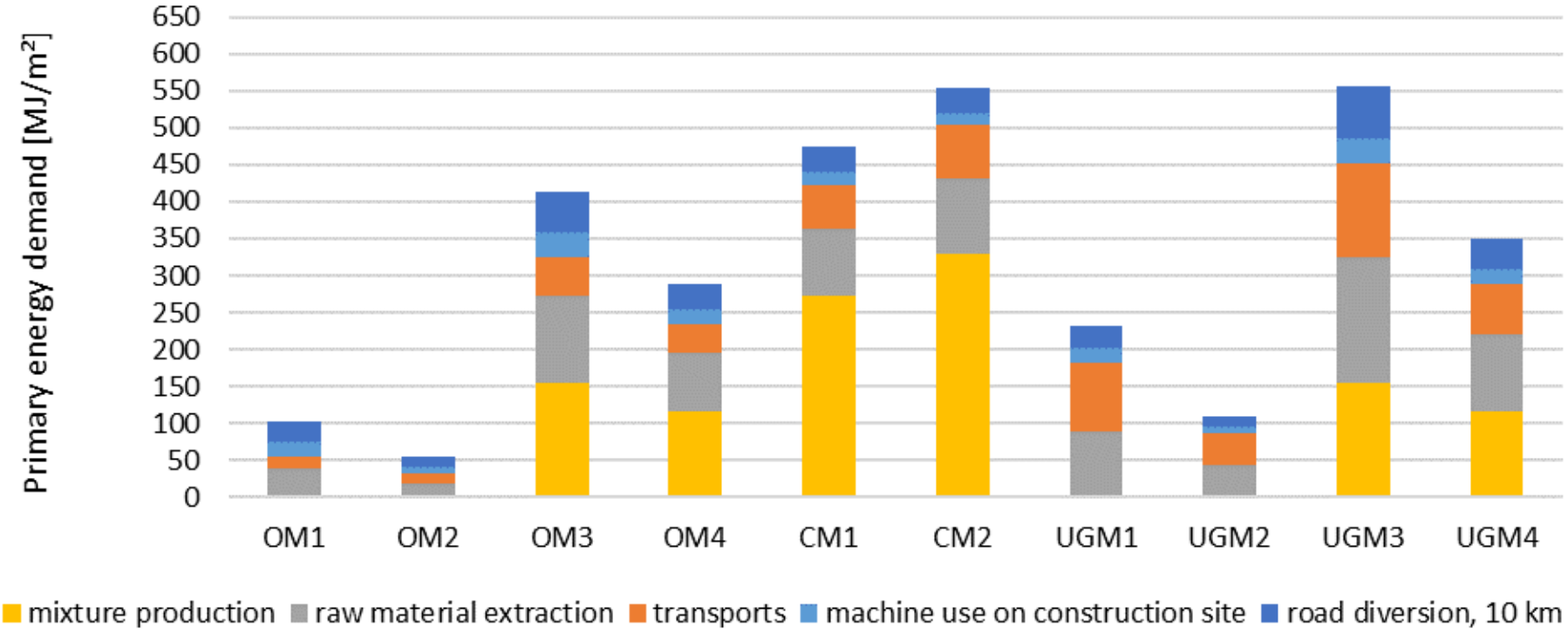
ORRAP test section in Semersheim (F)

→ **Primary energy demand over 30 years, incl. 10 km road diversion for 400 cars and 40 trucks per day**



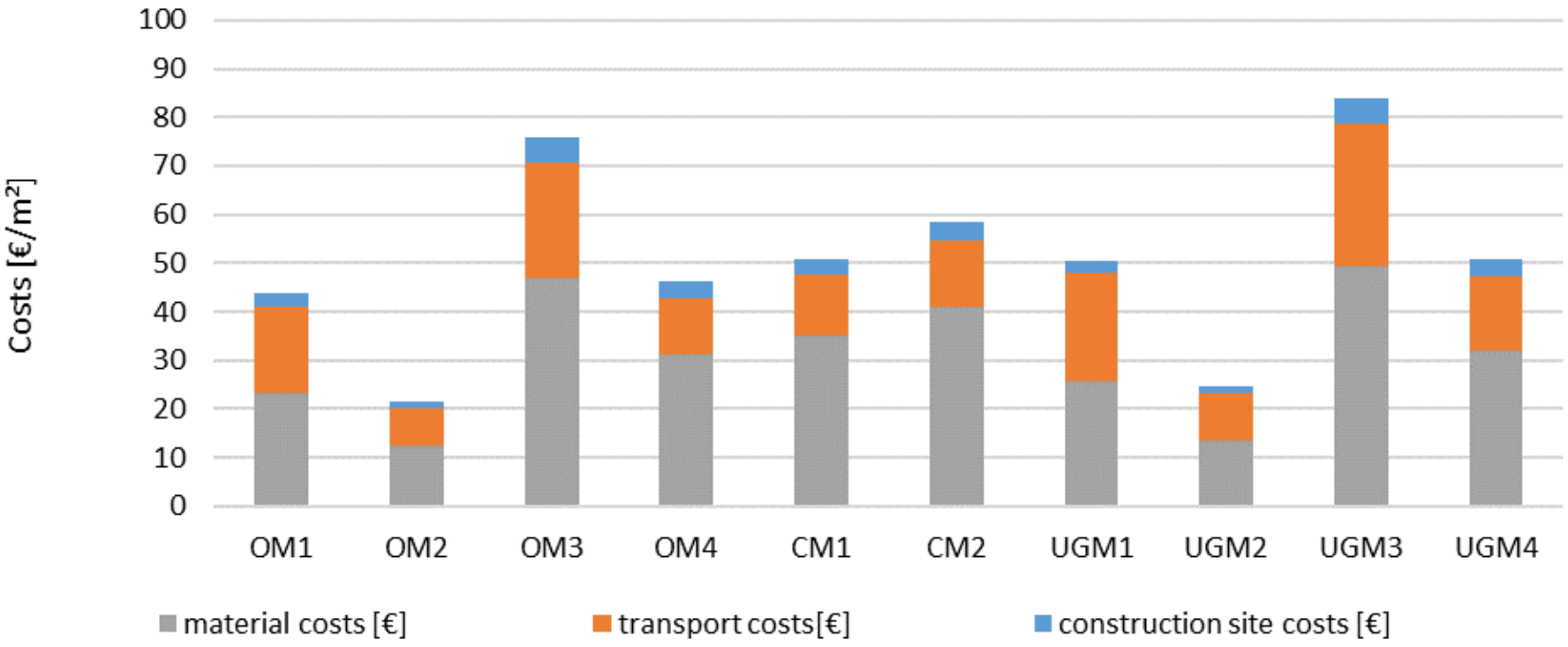
ORRAP test section in Semersheim (F)

→ **Primary energy demand over 30 years, incl. 10 km road diversion for 400 cars and 40 trucks per day; transport of the ORRAP material only before the first paving**



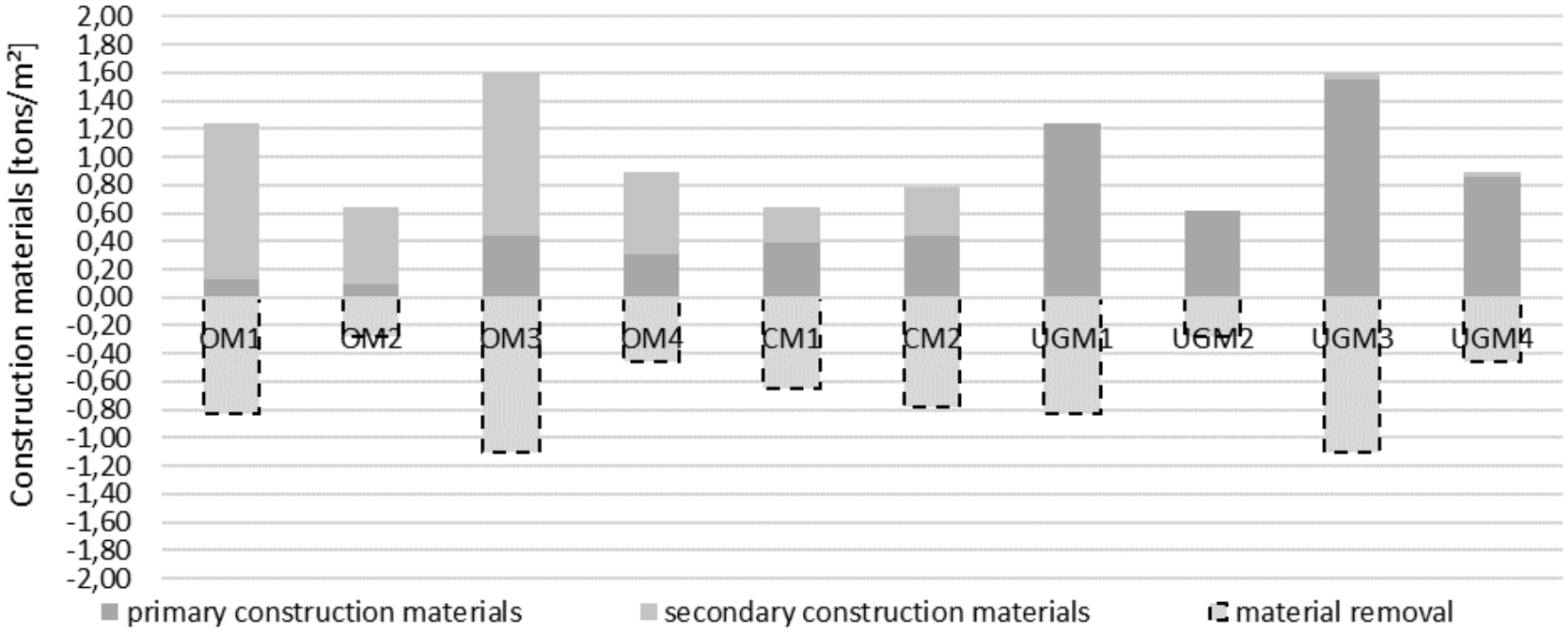
ORRAP test section in Semersheim (F)

→ Costs over 30 years (based on year 2019 incl. a discount factor of 3 percent)



ORRAP test section in Semersheim (F)

→ **Construction materials over 30 years**



Results Action 3.3: Study of the deployment of the proposed technique to the region

EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

Low traffic pavements

Rough estimation of the potential for application on the basis of low-traffic roads outside towns and cities in the Upper Rhine region

France	Germany	Switzerland
5,514 kilometre	2,212 kilometre	2,563 kilometre

→ Actual practicability may also depend on material-specific and political factors in particular

→ Additional potential is to be expected inside towns and cities

Estimation of future stockpiles

On the example of of the German Upper Rhine region

Assumptions for the forecasts

- Reclaimed asphalt only occurs during road renewal in deep installation
- A certain proportion of all roads will be renewed within 10 years
- The material from the renewal inside of towns and cities is disregarded
- The ORRAP-method with a thickness of 15 cm will be used on district roads
- A certain proportion of the removed asphalt cannot be reused, e.g. due to PAH or material properties
- A certain proportion of the reclaimed asphalt will be reused for conventional asphalt pavements

Estimation of future stockpiles

On the example of of the German Upper Rhine region

Further assumptions for the forecasts

	Federal trunk roads and state roads	District roads
Scenario 1	100 % conventional asphalt;	20 % conventional asphalt; 80 % ORRAP-material;
Scenario 2	80 % conventional asphalt; 20 % conventional asphalt;	20 % conventional asphalt; 80 % ORRAP-material;

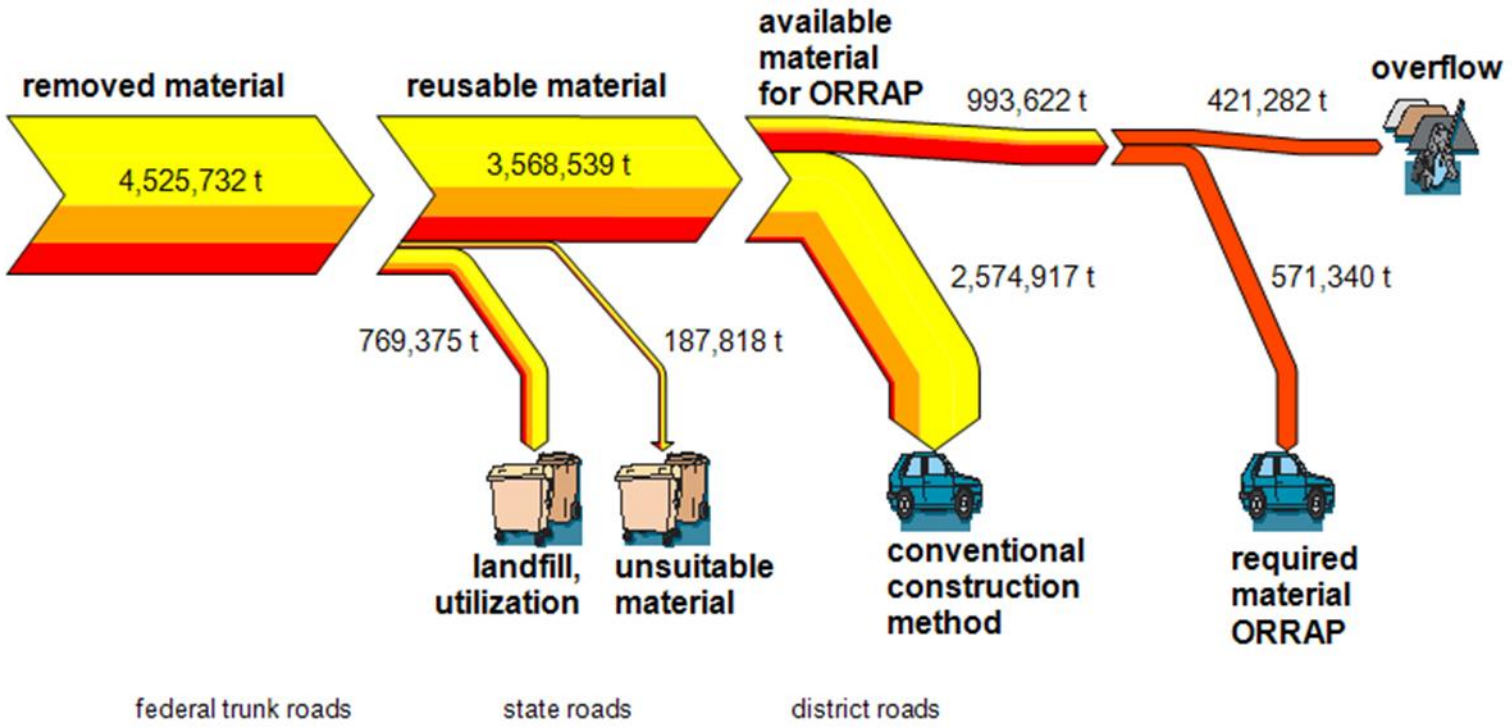
— Complete replacement of the bounded layers

····· Apply on the existing pavements

Estimation of future stockpiles

On the example of of the German Upper Rhine region

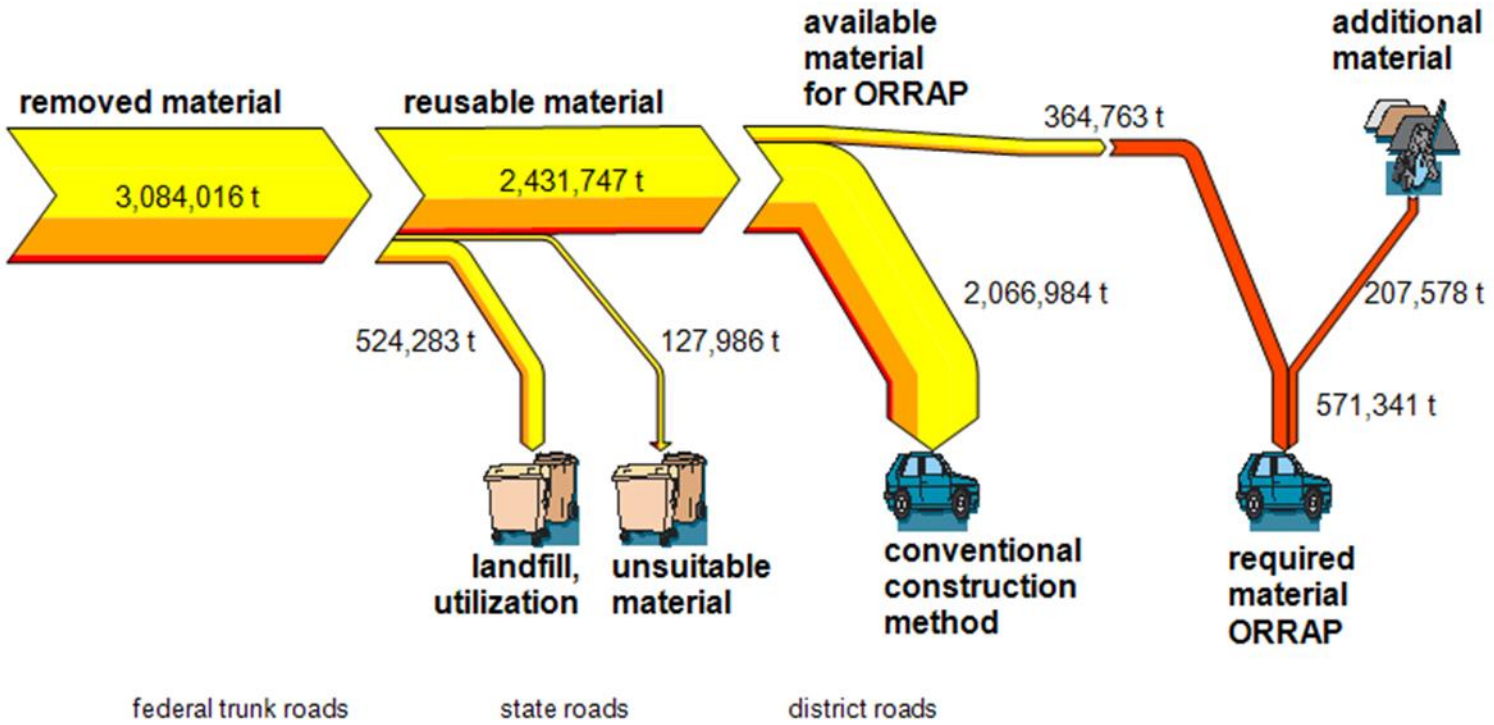
→ Results scenario 1



Estimation of future stockpiles

On the example of of the German Upper Rhine region

→ Results scenario 2



ORRAP
Optimal recycling of reclaimed asphalt pavement

EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

ACKNOWLEDGMENTS

- The ORRAP **project is supported by the INTERREG Upper Rhine program** from the ERDF **(European Regional Development Fund)** to the tune of **622 553€** and by the **Swiss Confederation, Canton Basel-Landschaft Canton Aargau.**
- ORRAP started in November 2016 with a total budget of 1.48 M€. Due to ongoing experimental requirements, its duration has been extended until December 2020.


ORRAP
Optimal recycling of reclaimed asphalt pavement
interreg
Oberrhein
Rhin Supérieur
EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"
Thank you for you attention

ORRAP
Optimal recycling of reclaimed asphalt pavement

EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

Environmental and cost assessment with Swiss boundary conditions
Risk analysis

Anders Nättorp, Simon Keller, Raphael Krieg, Armin Zenker, Alex King
University of Applied Sciences and Arts Northwestern Switzerland
School of Life Sciences

01/11/2016 - 31/12/2020

FINAL ANNUAL MEETING

02/12/2020

EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

Outline

- Environmental assessment with Swiss boundary conditions
- Swiss cost assessment
- Risk analysis method
- Risk analysis uncertainties and main results

University of Applied Sciences and Arts Northwestern Switzerland
School of Life Sciences

EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

Swiss boundary conditions

The Swiss environmental assessment based on

- Swiss experience with road layer composition
- Swiss inventory of national roads in Ecoinvent
- Layers for Swiss test route (status summer 2018)
- Energy data from the Swiss PLANET research project

University of Applied Sciences and Arts Northwestern Switzerland
School of Life Sciences

EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

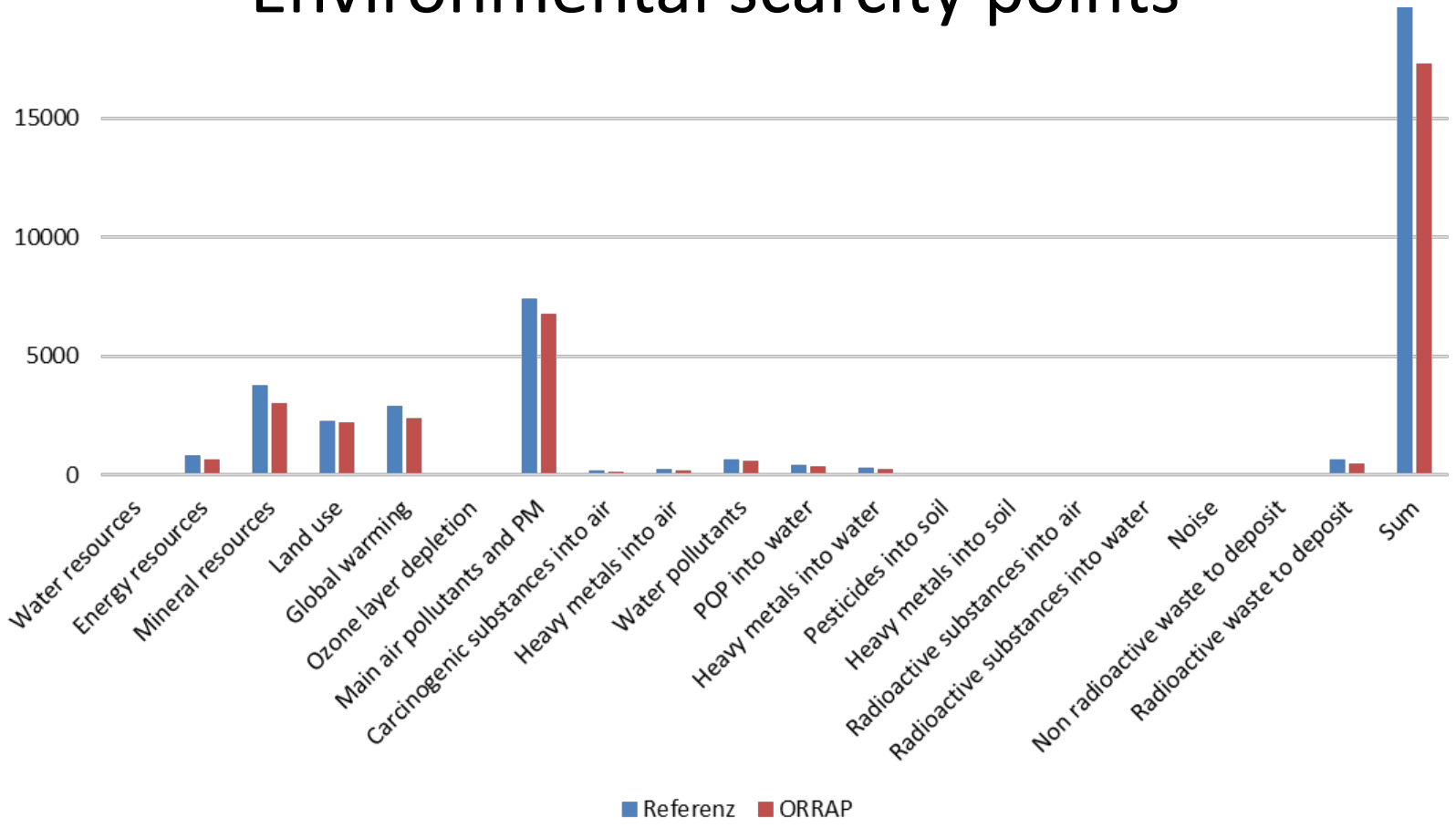
Swiss boundary conditions
Layers

	Switzerland		Germany	
	ORRAP	Reference	OM4	CM1
Layers considered (cm)	Surface course 4, ORRAP course 10, subbase 35	Surface course 4, base course 6, subbase 45	Surface course 4, ORRAP course 12, NO subbase considered	Surface course 4, base course 8, NO subbase considered
Life cycle (years)	SC 15, BC 40, SB 100	SC 15, BC 40, SB 100	SC 15, BC 30	SC 15, BC 30

University of Applied Sciences and Arts Northwestern Switzerland
School of Life Sciences

EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

Swiss environmental assessment
Environmental scarcity points



Swiss environmental assessment Overall results and discussion

ORRAP 12% less environmental scarcity points than reference

Methodology

- Significant differences in absolute results compared to HsKa
- HsKa results more comparable to the Swiss PLANET study

University of Applied Sciences and Arts Northwestern Switzerland
School of Life Sciences

EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

Swiss cost assessment

Method

- Average cost of Swiss test route ORRAP layers compared to reference layers

Results

- Cost slightly higher (20%) due to increased thickness of base course

University of Applied Sciences and Arts Northwestern Switzerland
School of Life Sciences

EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

Risk analysis
What was studied?

Compounds

- 26 PAHs

Risk

- Human impact
- Environmental impact

Scenarios

- ORRAP pavement
- Reference pavement
- Whole life cycle
- Maximum legal content in CH, D, F

Exposure route

- Fume
- Dust
- Freshwater

University of Applied Sciences and Arts Northwestern Switzerland
School of Life Sciences

Usetox Method
Example: dust in urban air

Mass fraction of PAH in dust from literature data

Mass of PAH as dust emission

Standard values

V Volume air

fr Dust fraction

ρ Density of dust

$$M_{urban\text{-}air} = C_{dust} \times V_{urban\text{-}air} \times fr_{dust} \times \rho_{dust}$$

Usetox Method

$$M_{urban\text{-}air} = C_{dust} \times V_{urban\text{-}air} \times fr_{dust} \times \rho_{dust}$$

$$\sum_{i=0}^{n} M \times CF = IS$$

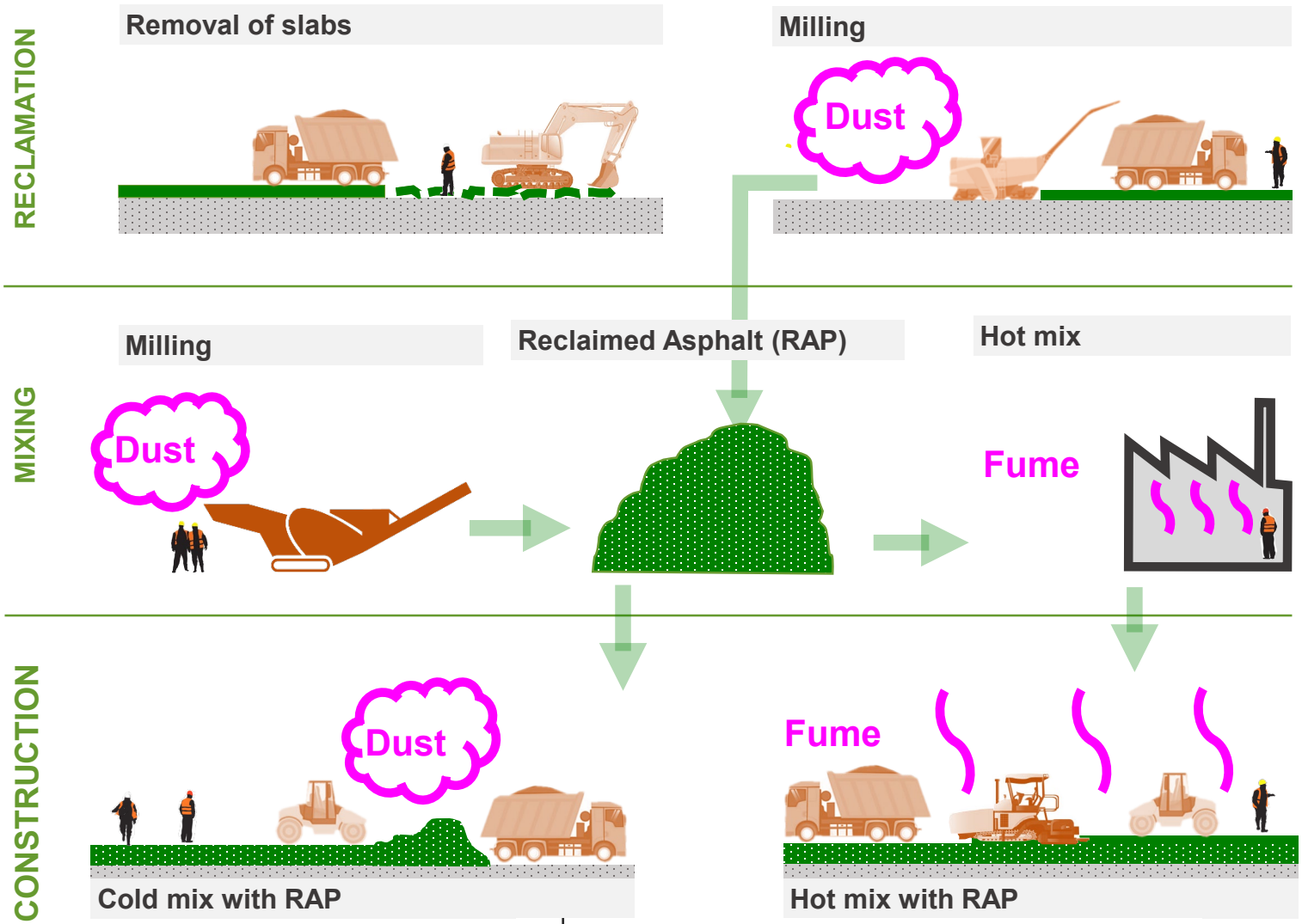
Impact score [DALY or PDF]

PAH considered

Characterisation factor Human. [Human: DALY(Disability-adjusted life year)/kg emitted

Environment: PDF (Potentially disappeared fraction of species) /kg emitted]

Routes of exposure to PAH



interreg Oberrhein Rhin Supérieur
EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

Exposure proportional to amount of RAP

	Fume- proportional to RAP amount in hot mix		Dust- proportional to total RAP amount	
	Reference kg/m*a	ORRAP kg/m*a	Reference kg/m*a	ORRAP kg/m*a
CH	0.57	0.00	0.57	1.72
F	0.00	0.00	0.00	2.07

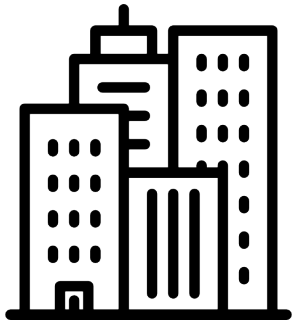
EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

Uncertainties Usetox Method
Representative Concentration?

Mass fraction of PAH in dust from literature data

?

V Volume urban
fr Dust fraction
ρ Density of dust

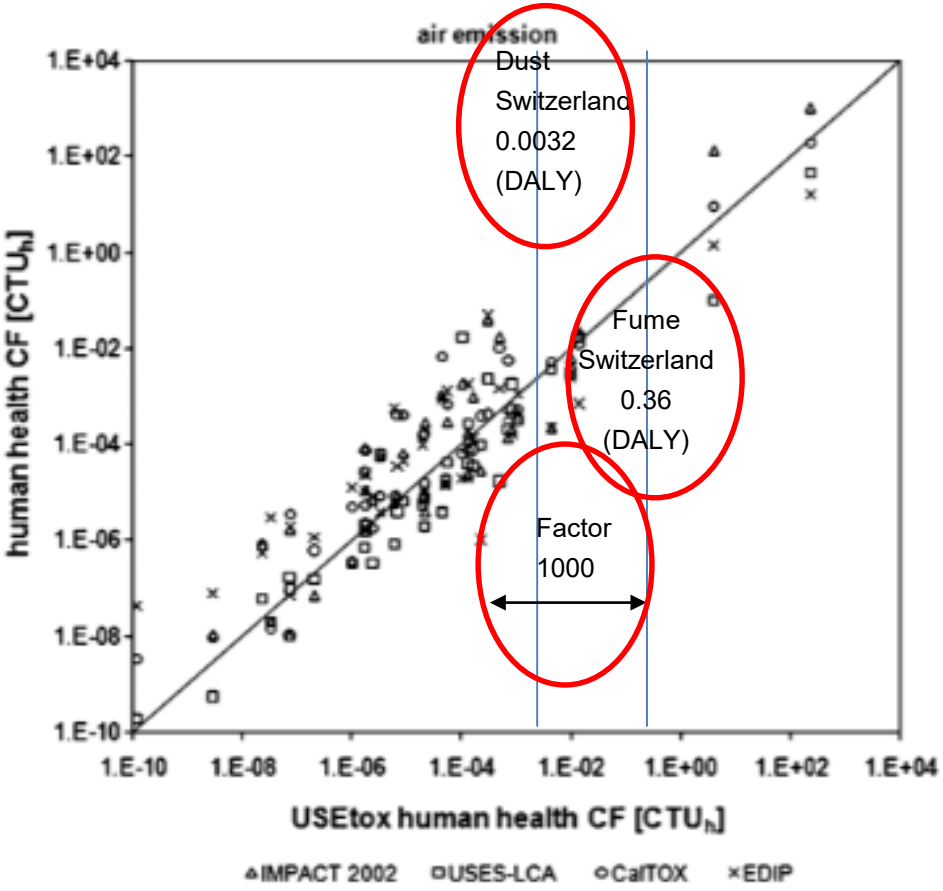


Mass of PAH as dust emission

$$M_{urban\text{-}air} = C_{dust} \times V_{urban\text{-}air} \times fr_{dust} \times \rho_{dust}$$

➔ Exposure overestimated, how much is not known

Exposure harmless?
Comparison with rural air



Rosenbaum et al. 2008

➔ Exposure to fume not sure to be harmless

EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

Main results risk assesment

Human exposure and environmental exposure are proportional

Literature data

- Impact fume route 100x higher than dust route, water route not relevant
- BUT: uncertain du to Usetox method

Comparison ORRAP with reference

- Method
  - legal limits in D, F, CH, amount in reference pavements
  - PAH composition and fume/dust-ratio of Thalheim
- Strong incluence of layers, e.g. presence of hot mix
  - ORRAP method can reduce exposure to fume considerably, in the Swiss case
  - French case no difference
- ORRAP method always leads to higher dust exposure

University of Applied Sciences and Arts Northwestern Switzerland
School of Life Sciences

EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

Conclusions

- ORRAP method in Swiss context can slightly reduce environmental impact
- ORRAP method in Swiss test road slightly more costly

- USETOX method use of a typical concentration for a huge compartment is difficult and leads to important overestimation of impacts in risk assessment
- Therefore it could neither be shown that the risks from PAH are relevant nor that they are irrelevant compared to other risks
- Risk through fume route and dust route are likely more important than freshwater route
- Assuming dust proportional to total RAP use and fume exposure proportional to hot mix RAP use it was shown that
  - ORRAP method sometimes leads to lower risk from fume exposure than the reference
  - ORRAP method always leads to higher risk from dust exposure than the reference

University of Applied Sciences and Arts Northwestern Switzerland
School of Life Sciences

ORRAP
Optimal recycling of reclaimed asphalt pavement

EFRE – Europäischer Fonds für regionale Entwicklung
FEDER – Fonds européen de développement économique et régional
„Der Oberrhein wächst zusammen, mit jedem Projekt."
„Dépasser les frontières : projet après projet"

ACKNOWLEDGMENTS

- The ORRAP **project is supported by the INTERREG Upper Rhine program** from the ERDF **(European Regional Development Fund)** to the tune of **622 553€** and by the **Swiss Confederation, Canton Basel-Landschaft Canton Aargau.**
- ORRAP started in November 2016 with a total budget of 1.48 M€. Due to ongoing experimental requirements, its duration has been extended until December 2020.