Recycling Asphalt Pavements:

Past, Present and Future

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Recycling Asphalt Pavements

- Presentation will provide brief overview of the Recycled Materials Resource Center
- Where have we been, where are we now and where are we going?
- Present a life-cycle costing and impact assessment tool developed specifically for highways
  - Asphalt paving example

RMRC Overview

- The Recycled Materials Resource Center is a National Center in Partnership with FHWA
- Established in TEA-21 in 1998

MISSION

To reduce barriers to the appropriate use of recycled materials in the highway environment

- ➢ Research
- ➢ Outreach

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RMRC RAP-Asphalt Projects

- Project 9 - Properties of Asphalt Mixtures Containing RAP
- Project 15 - Determination of N_{design} for CIR Mixture Design Using the SGC
- Project 16 - Laboratory Foamed Asphalt Producing Plant
- Project 17 - Development of a Rational and Practical Mix Design System for Full Depth Reclamation (FDR)

RMRC RAP-Asphalt Projects Cont.

- Project 22 - Overcoming the Barriers to Asphalt Shingle Recycling (Phase Three)
- Project 26 - Determination of Structural Layer Coefficient for Roadway Recycling Using Foamed Asphalt
- Other projects in progress on RMRC website

RAP: Where have we been?

Asphalt Pavement Recycling

- Began as early as the 1900's
- Oil embargo increased recycling in the 1970's
- Began with hot mix
- Became the most recycled material in the United States

Categories of Recycling

- Hot In-place Recycling (HIP)
  - Surface recycling
  - Remixing
  - Repaving
- Cold Recycling
  - Cold In-place Recycling (CIR)
  - Cold Central Plant Recycling (CCPR)
- Full Depth Reclamation
  - Pulverization
  - Mechanical stabilization
  - Bituminous stabilization
  - Chemical stabilization

RAP: Where are we now?

Project 37 - RAP Mixtures and the Mechanistic-Empirical Pavement Design Guide

Principal Investigator: Dr. Jo Sias Daniel, UNH

Approach:

- RMRC Project 9 results showed RAP affects volumetrics, which offsets increased stiffness due to RAP binder in dynamic modulus measurements - effect on field performance not well defined
- AASHTO Design Guide predicts pavement performance, Level 3 uses binder properties – what are the appropriate binder properties to input for RAP mixtures?
- Perform Level 3 analysis using combinations of virgin & RAP binder properties – dovetails with NETC 04-4:Determining effective PG grade of RAP mixtures
- Products include recommendation on how to handle RAP mixtures within the framework of the M-E Pavement Design Guide

Project 41 - Determination of Moisture Damage (Stripping) Potential of HMA With Recycled Materials Using Accelerated Loading Equipment

Principal Investigator: Dr. Jo Sias Daniel, UNH

Approach:

- There is potential for stripping in recycled mixes (water in RAP, poor blending, etc.)
- Use Model Mobile Load Simulator (MMLS3) for APT of RAP mixtures
- Test control (no RAP), 2-3 RAP percentages & sources for field density, rut depth vs # load applications, ITS before & after wet loading
- Provide method of identifying recycled mixtures that are susceptible to moisture damage, applicable to materials other than RAP as well as a better method for simulation of field conditions

Project 41 - Determination of Moisture Damage (Stripping) Potential of HMA With Recycled Materials Using Accelerated Loading Equipment

Recycled Materials Use Survey

RMRC is currently conducting a national survey of state use of recycled materials.

RAP: Where are we going?

Green Highways and Sustainability –
“buzz words”

How can sustainability be applied to road construction?

- Roads can be constructed in a more sustainable manner
- Roads can be sustainable (materials can be recovered and reused/recycled)
- Tools are available to evaluate environmental burdens and trade-offs of various options
- Present a life-cycle costing and impact assessment tool developed specifically for highways
  - Asphalt paving example

Pavement Life-cycle Assessment Tool for Environmental and Economic Effects (PaLATE)

Developed by Arpad Horvath (UC Berkeley) for the Recycled Materials Resource Center

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Questions that can be answered:

- For a particular roadway, which material is better environmentally, economically: e.g., recycled or virgin?
- Will changing the recycled material content in a particular pavement affect its environmental performance?
- Does sending demolished portions of a road to a processing plant or to a landfill make more environmental and economic sense?
- Which maintenance options will minimize environmental and economic effects? For example, should full depth reclamation be performed instead of more frequent, smaller maintenance procedures?

Factors that are considered:

- Design of the roadway
- Construction materials, material transportation distances and modes
- Technology choices – e.g., on-site construction and maintenance equipment (e.g., asphalt paver), and off-site processing equipment (e.g., rock crusher)
- Life-cycle economic costs

		Material	Density [tons/cy]	New Asphalt Pavement	New Concrete Pavement	New Subbase & Embankment Construction	Transportation	
				Vol [cy]	Vol [cy]	Volume [cy]	One-way trans dist [mi]	Transp mode
WC1	Materials	Virgin Aggregate	1.25	1123	0		100	
		Bitumen	0.84	50			50	
		Cement	1.27		0		0	
		Concrete Additives	0.84		0		0	
		RAP transportation	1.85	0	0		0	
		RCM transportation	1.88	0	0		0	
		Coal Fly Ash	2.2	0	0		0	
		Coal Bottom Ash	2	0	0		0	
		Blast Furnace Slag	1	0	0		0	
		Foundry Sand	1.5	0	0		0	
		Recycled Tires/ Crumb Rubber	1.92	0	0		0	
		Glass Cullet	1.93	0	0		0	
		Water	0.84		0			
		Steel Reinforcing Bars	0.24		0			
		Total: Asphalt mix to site	1.23	1173			20	dump truck
		Total: Ready-mix concrete mix to site	2.03		0		0	mixing truck
	Waste mat to LF	RAP from site to LF	1.85	0			0	
		RCM from site to LF	1.88		0		0	

Equipment Data

ACTIVITY	Equipment	Brand/Model		Eng Cap	Productivity	Fuel Consumption	Fuel Type
Concrete Paving	Slipform paver		1	106 hp	564 tons/h	19.7 l/h	diesel
	Texture curing machine		1	70 hp	187 tons/h	20.2 l/h	diesel
Asphalt Paving	Paver		4	196 hp	2,400 tons/h	49.1 l/h	diesel
	Pneumatic roller		1	100 hp	668 tons/h	26.1 l/h	diesel
	Tandem roller		2	125 hp	285 tons/h	32.7 l/h	diesel

- Equipment type utilized for each activity: Concrete & asphalt paving, CIR & HIPR, FDR, rubblization, milling, concrete demolition, excavation, placing, compaction, tire & glass recycling, HMA production

Case Study

- NH DOT Construction Project in central NH
- Portion of project will utilize rubblization of an existing concrete roadway
- Investigate alternative materials and compare life-cycle costs and life cycle impacts (environmental effects)
- Data from DOT engineers put into PaLATE – small investment in time

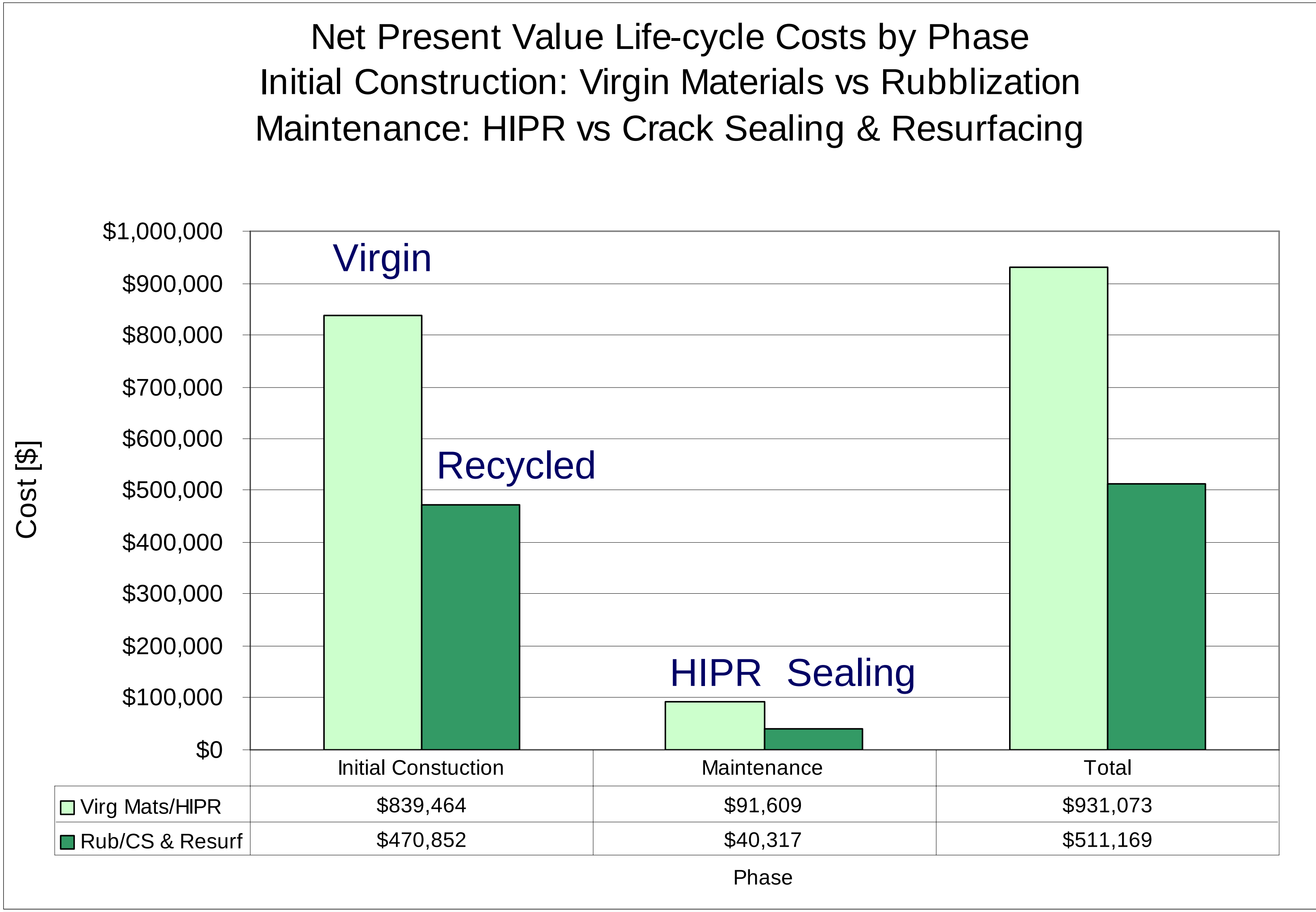
NH DOT Case Study

- *Initial Construction*
  - Option 1
    - Mill off the existing Pavement
    - Rubblize **(Recycle)** Concrete / Cover with (**Recycled**) Pavement Millings
    - Widen with **Virgin** Materials
    - Pave with 3.5” on New Hot Mix Asphalt
  - Option 2
    - Remove Concrete Slab and **landfill**
    - Construct 12” of Gravel & Crushed Gravel full width
    - Pave with 5.5” of New Hot Mix Asphalt

NH DOT Case Study (cont)

- *Maintenance Option 1*
  - Years 4 & 8: Crack Seal
  - Year 12: Resurface – 1” Wearing Course
  - Years 16 & 20: Crack Seal
  - Year 24: Resurface – 1” Wearing Course
- *Maintenance Option 2*
  - Year 1-11: nothing
  - Year 12: **Hot In-Place Recycling (HIPR)**
  - Year 13-23: nothing
  - Year 24: **HIPR**

Case Study Results: Total Cost

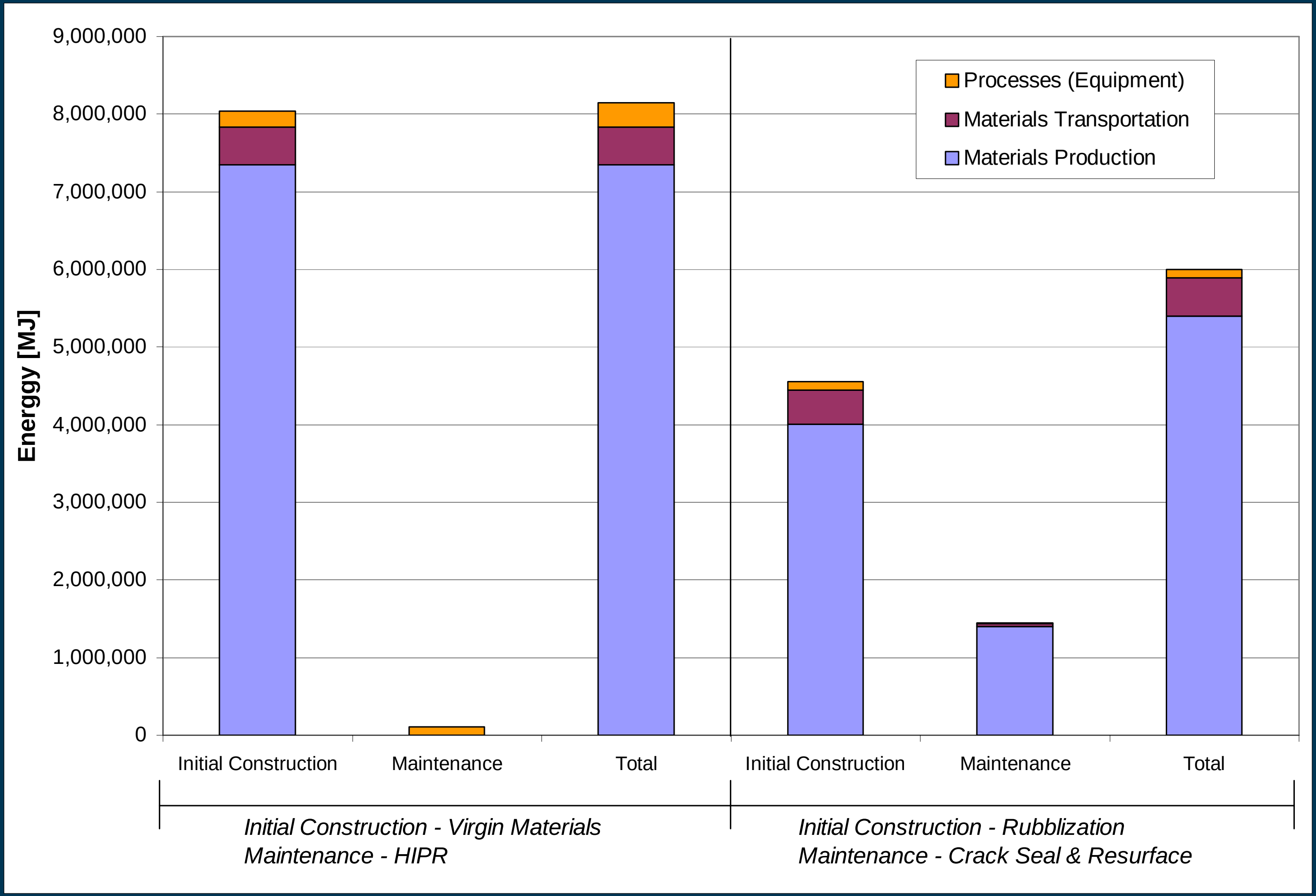


	Initial Constuction	Maintenance	Total
Virg Mats/HIPR	$839,464	$91,609	$931,073
Rub/CS & Resurf	$470,852	$40,317	$511,169

Initial Construction cost for rubblization is about half that of using virgin materials

Maintenance cost of crack sealing & resurfacing is about half that of HIPR

Case Study Results: Energy Consumption (MJ)



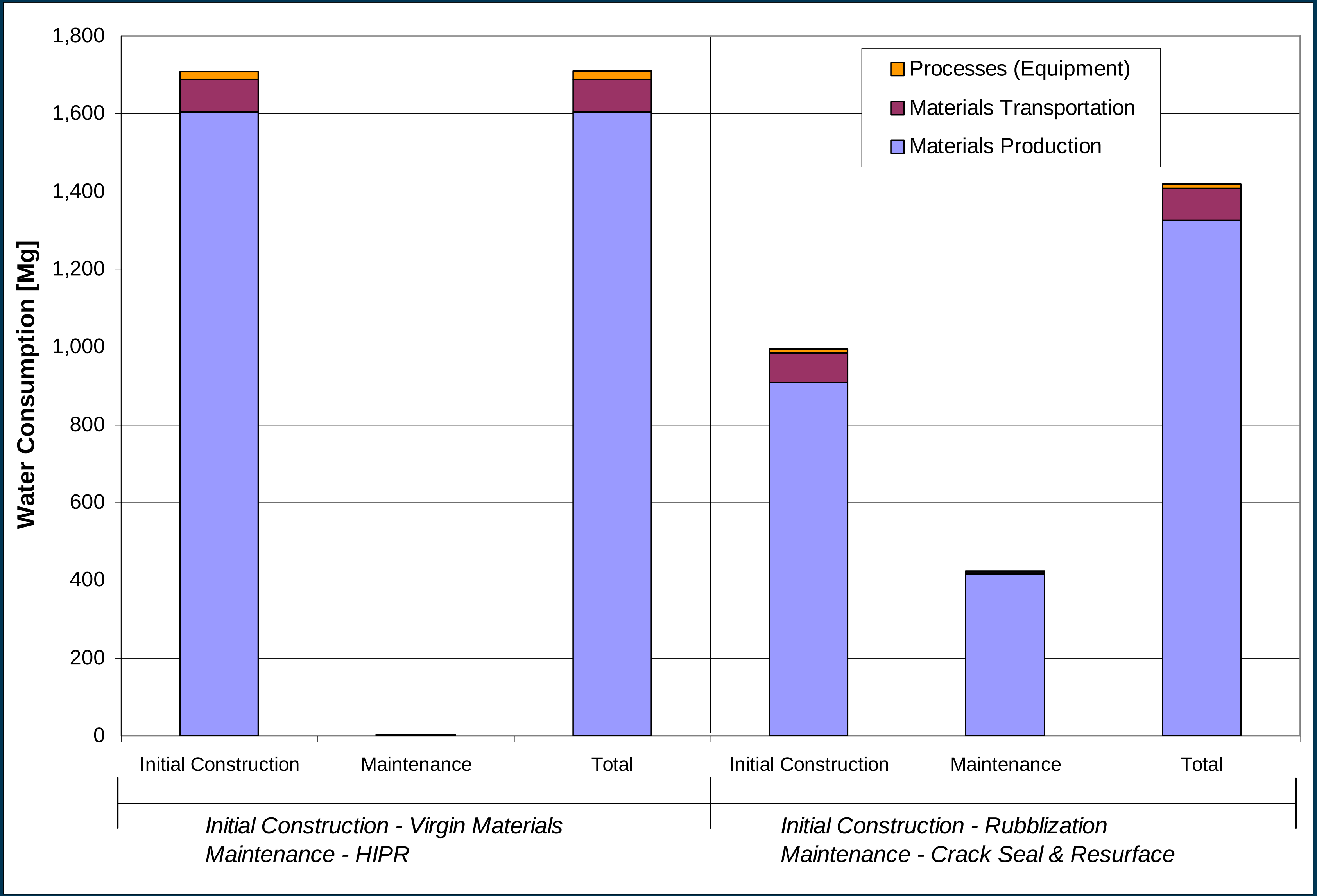
Initial Construction: Recycling uses 3.5M MJ less energy than use of virgin materials (reduced materials production)

Maintenance: HIPR uses 1.5M MJ less than crack sealing & resurfacing.

HIPR - equipment processes

Crack seal & resurfacing - materials production

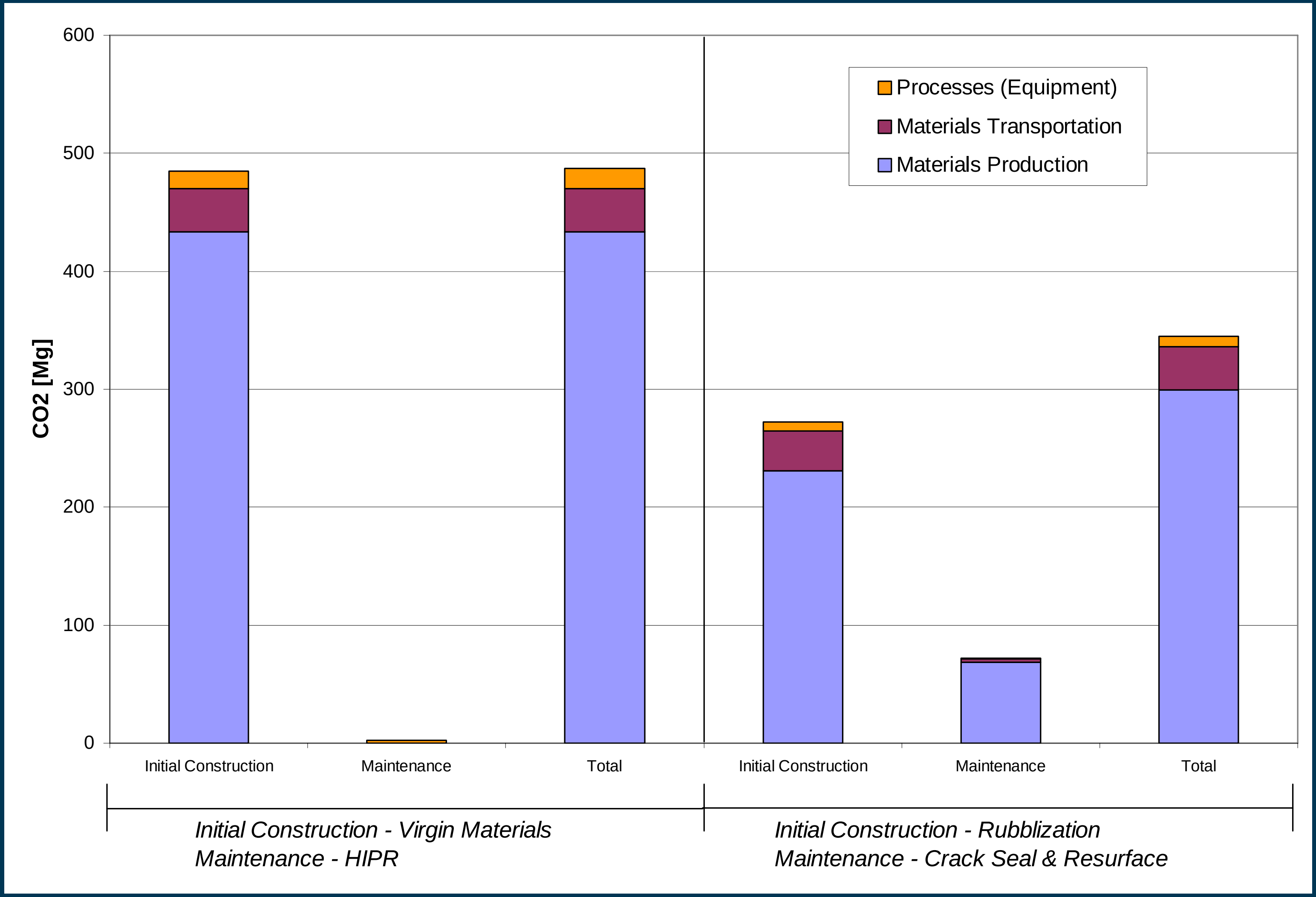
Case Study Results: Water Consumption (Mg)



Initial Construction: Rubblization uses 700 Mg less (reduced materials production)

Maintenance: HIPR uses 400+ Mg less (reduced materials production)

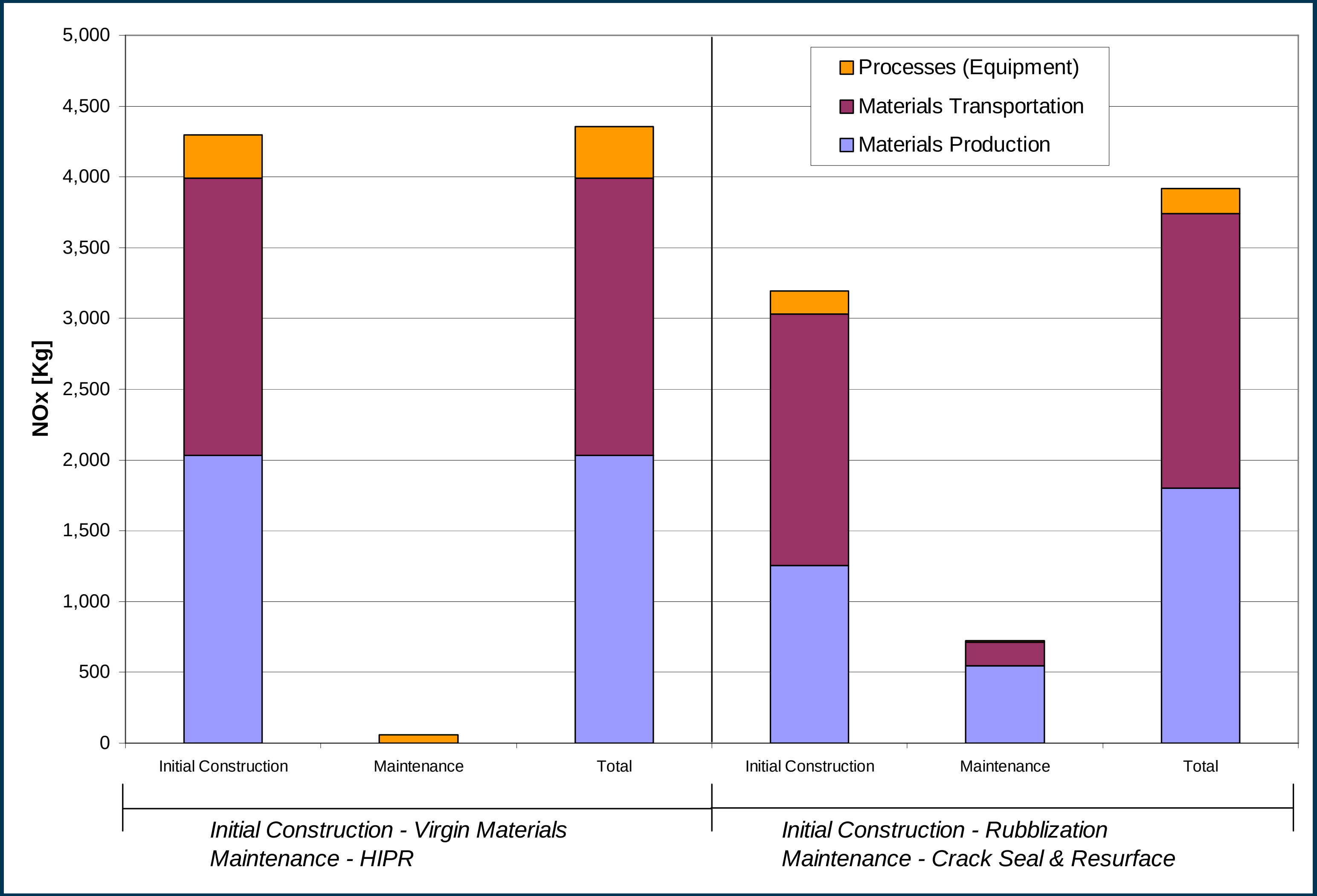
Case Study Results: CO_2 / GWP (Mg)



Initial Construction: Rubblization generates ~200 Mg less of CO_2 emissions (reduced materials production)

Maintenance: HIPR generates ~75Mg less of CO_2 emissions (reduced materials production)

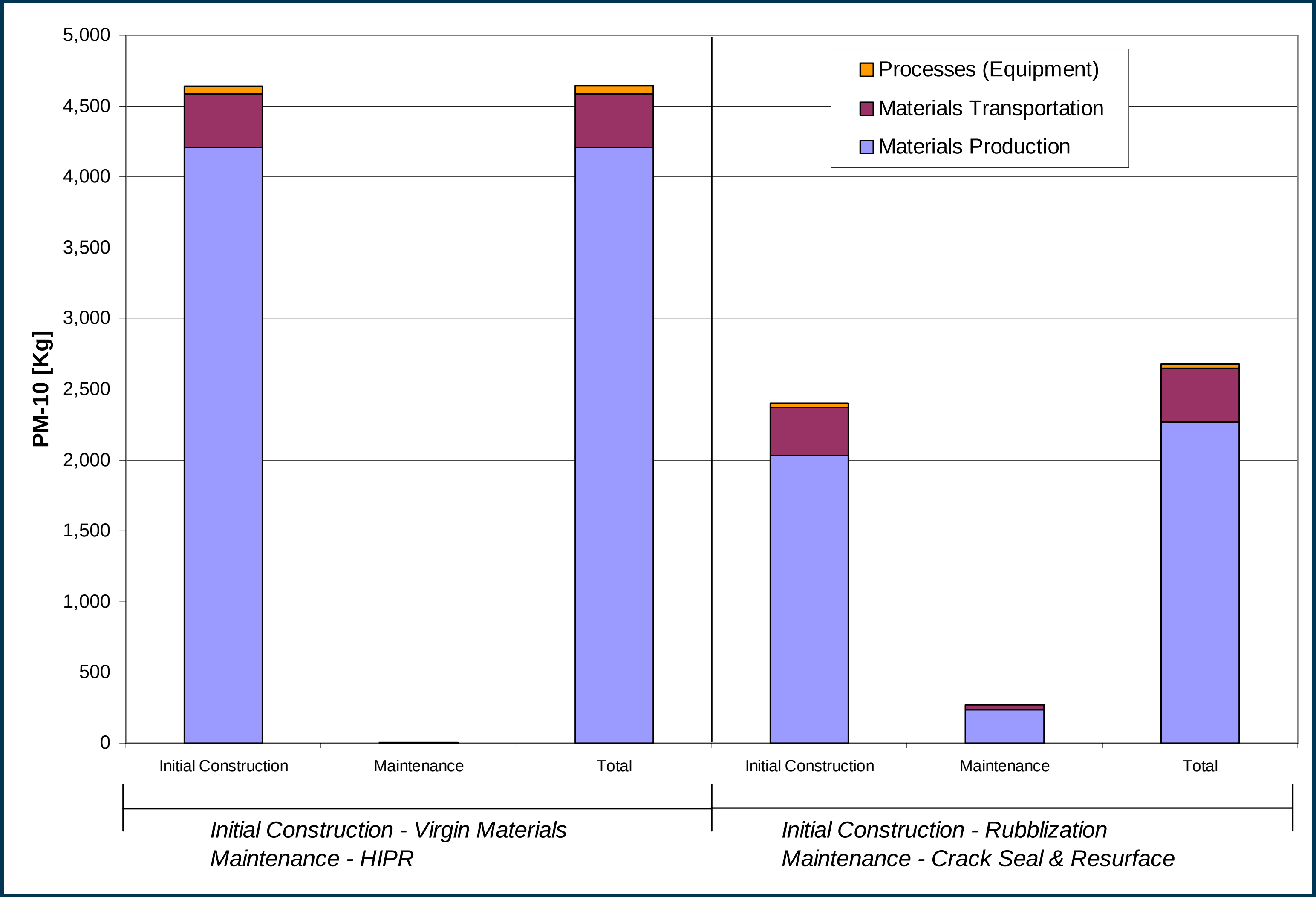
Case Study Results: NO_x Emissions (kg)



Initial Construction: Rubblization generates ~1000kg less NOx emissions (reduced emissions from all sections)

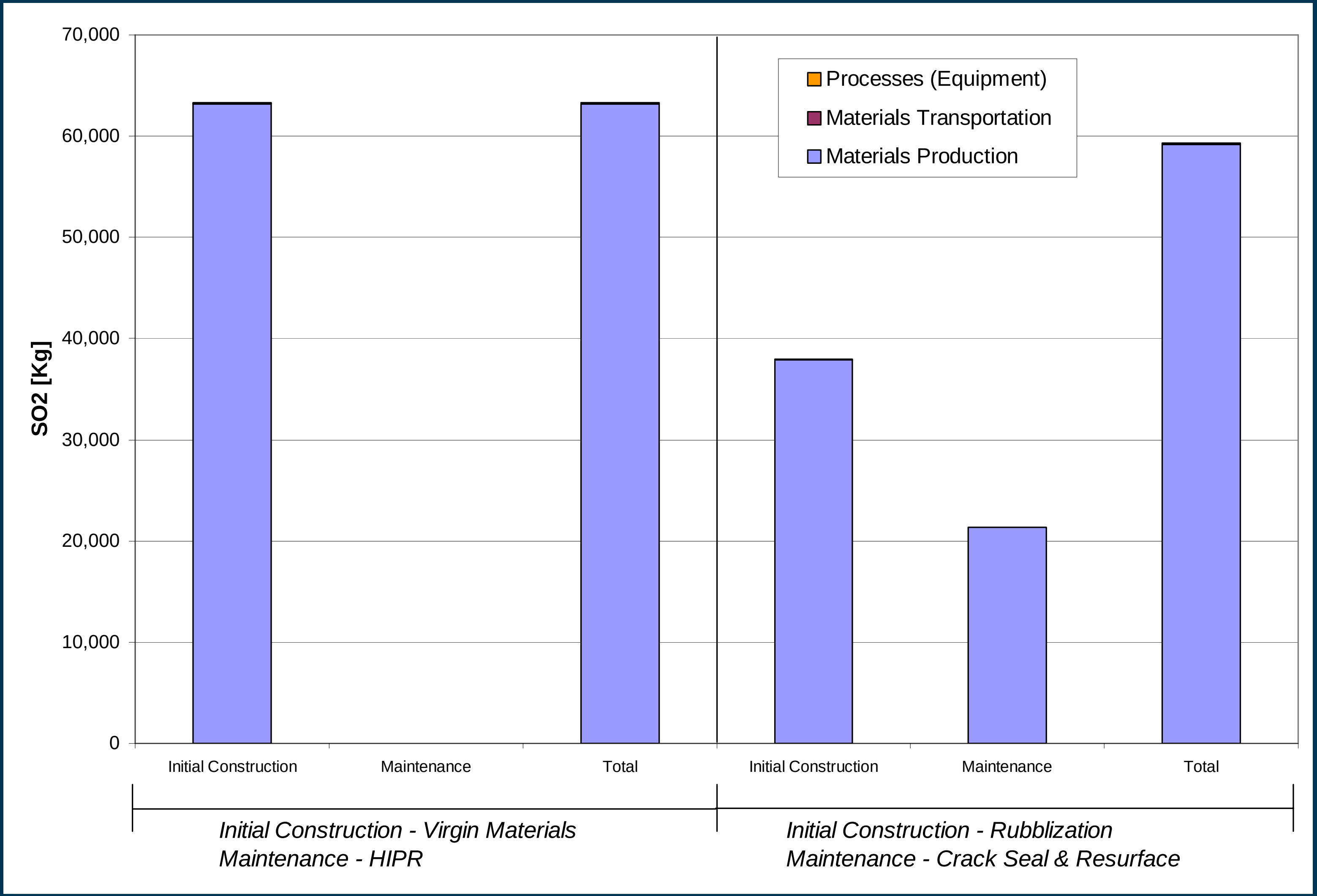
Maintenance: HIPR generates ~700kg less NOx emissions (no material production or transportation)

Case Study Results: PM_{10} Emissions (kg)



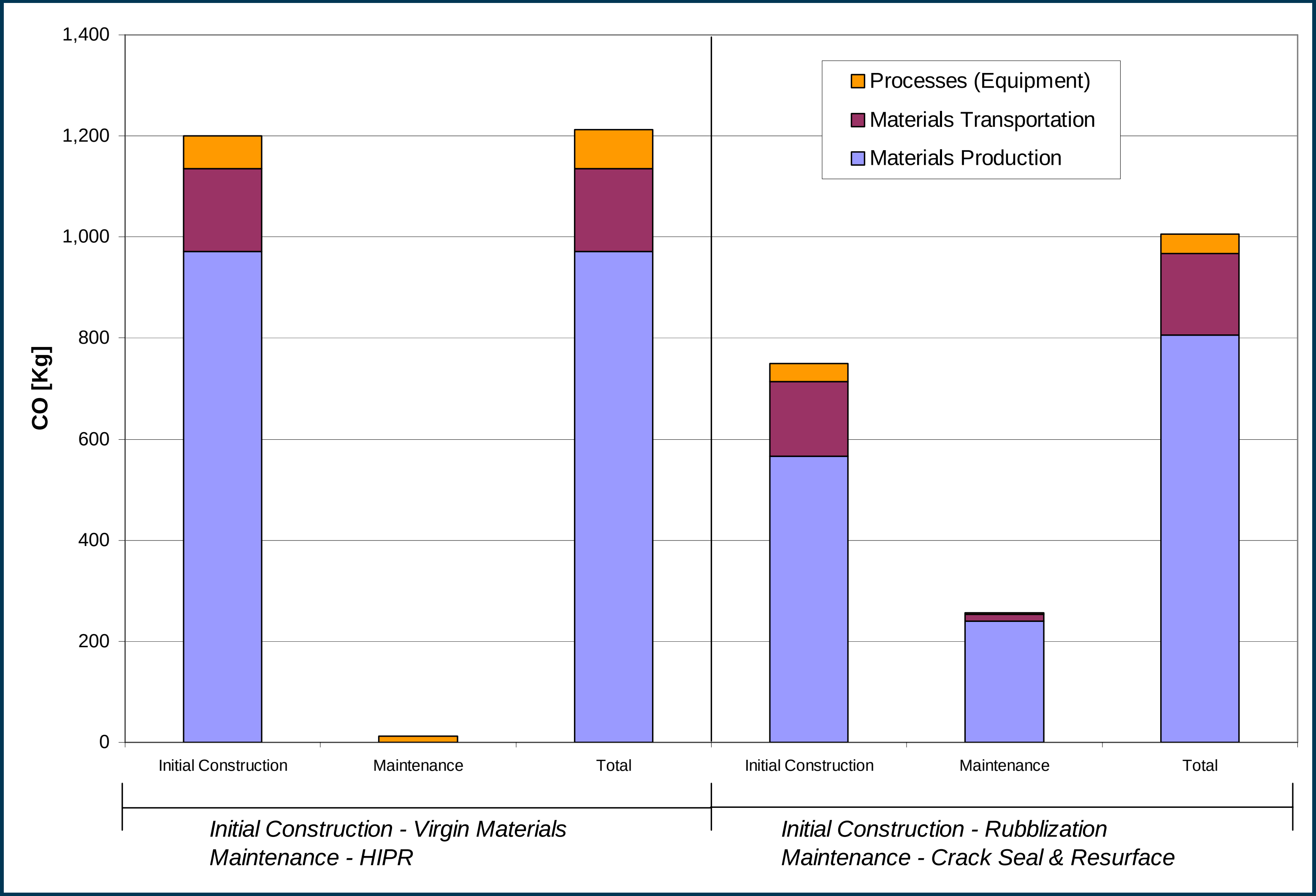
- Initial Construction: Rubblization generates ~2000kg less PM_{10} emissions (reduced materials production)
- Maintenance: HIPR generates ~300kg less PM_{10} emissions (no material production or transportation)

Case Study Results: SO_2 Emissions (kg)



- Initial Construction: Rubblization generates ~25K kg less SO_2 emissions (reduced materials production)
- Maintenance: HIPR generates ~20K kg less SO_2 emissions (no materials production)

Case Study Results: CO Emissions (kg)



- Initial Construction: Rubblization generates ~500kg less CO emissions (reduced materials production)
- Maintenance: HIPR generates ~250kg less CO emissions (no materials production or transportation)

Decision-making

- So how does one make a decision with so many performance metrics?
- It’s not trivial, but it needs to be done transparently and rigorously to defend the sustainability of a highway design

Conclusions

- The future of utilizing recycled materials, including RAP, may include an assessment of sustainability and life cycle impacts
- There are tools available to specifically address the life cycle impacts of roadway construction, and recycling
- Recycling and recycled materials use are two important components of sustainability in highways
- The RMRC has
    - conducted some 43 research projects nationwide
    - conducted training for DOT/EPA personnel in 39 states
    - developed specifications and recommended practices adopted by AASHTO
    - developed important tools for evaluating the sustainability and life cycle impacts of highway construction and maintenance

Caveats

- Use of recycled materials is VERY site specific. Just because it worked at one site does not mean it will work at your site, and vice versa.
- Recycled materials must be considered at the very beginning of the project, not in middle of the project.
- Include all stake holders (including public) at the beginning of the project to avoid surprises at the end.

Acknowledgements

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Questions?

Further information available on RMRC website:

www.rmrc.unh.edu