Recycling paint sludge in asphalt pavements: cost-benefit and life cycle assessment

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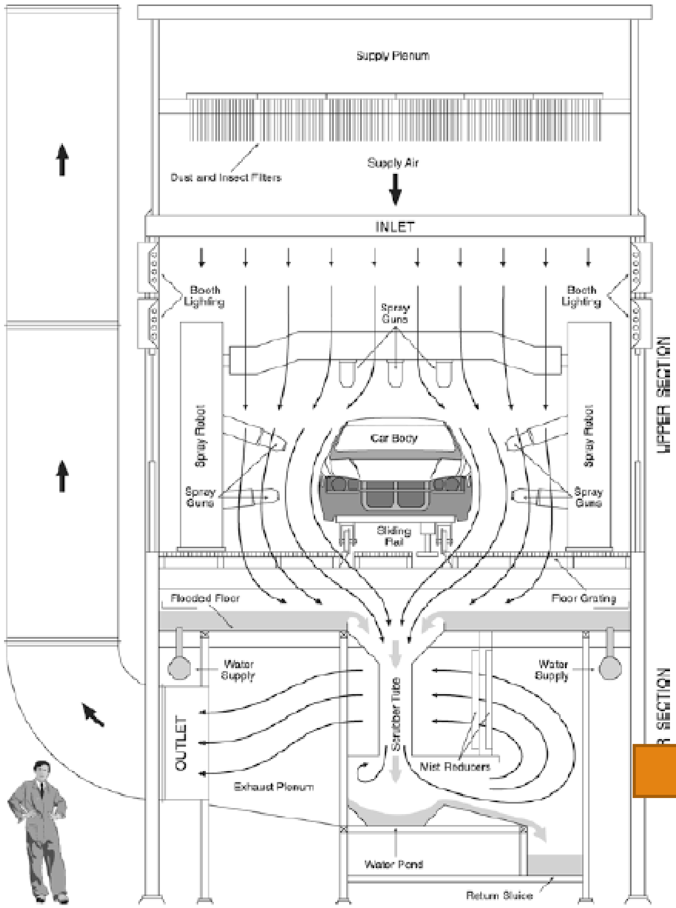
Paint sludge

Waste product generated during automotive painting, when the overspray is captured by air flows and collected with water.



Sample	TS (%)	VS (%)	C (%)	H (%)	N (%)	Fe (%)	Al (%)	Ti (%)
Primer (3)	57±22	61±7	ND	ND	ND	0.9 ±1.4	0.5 ±0.2	8.3 ±3.6
Basecoat (6)	40±9	73±8	48±6	6.4 ±0.8	3.0 ±1.4	0.5 ±0.2	2.1 ±0.9	7.4 ±3.1
Clearcoat (3)	35±11	95±1	60±2	8.1 ±0.1	7.5 ±0.8	0.2 ±0.2	1.0 ±0.6	< 0.05

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Recycling of Paint Sludge in Asphalt Pavements

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ORIGINAL ARTICLE

Rheological characterization and performance-related evaluation of paint sludge modified binders

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Abstract Application of paints by spraying, extensively used in the automotive industry, generates a solid waste, known as paint sludge, which, if improperly managed, may lead to significant environmental and economic burdens. In the research work described in this paper, use of paint sludge for the production of modified bituminous binders for paving applications was investigated. In particular, expected field performance of paint sludge modified binders (PSMBs) was assessed and compared to that of neat bitumen and polymer-modified binders. PSMBs considered in the study were prepared in the laboratory by employing variable dosages of sludge coming from different painting plants and derived either from basecoat or clearcoat application. PSMB characteristics were evaluated by means of rheological tests which led to construction of master curves, determination of performance grade (PG) according to the SUPERPAVE scheme, detailed evaluation of resistance to permanent deformation by means of multiple stress creep recovery tests, and analysis of resistance to fatigue damage by making use of time sweep and linear amplitude sweep tests. Obtained results showed that use of automotive paint sludge for the production of PSMBs is a feasible, cost-effective and environmentally compatible alternative to currently adopted management solutions which consist either in incineration or in energy production in cement kilns. Although fluxing and stiffening effects were observed in the case of basecoat and clearcoat sludge, respectively, only minor variations were recorded in terms of PG, elastic response, stress sensitivity, fatigue resistance and fatigue ductility of neat bitumen.

Keywords Paint sludge · Modified bituminous binders · Rheology · Performance grading · Permanent deformation · Fatigue

Demonstration at a lab scale of the feasibility of using paint sludge in mixtures for asphalt pavements

1 Introduction

Automotive paints are multilayer systems constituted by three main coatings: a primer, which improves resistance to corrosion, a basecoat, which gives colour to the vehicle body, and a clearcoat, which provides shiny appearance and protection from UV damage [1]. During painting operations, approximately 40 % paint becomes overspray and is subsequently transformed into sludge by means of a process in which residual paint particles are collected by a water stream [2]. Because of the high calorific power of this waste material, regulations of the European Commission demand its incineration or its recycling in other production activities. However incineration, the most

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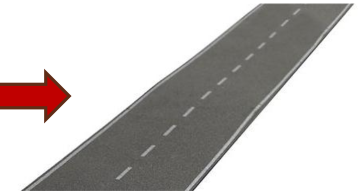
Field test, November 2016

- Traditional binder
- Paint sludge modified binder (1)
- Paint sludge modified binder (2)

Cost Benefit Assessment

DEWATERING & MILLING → MIXING WITH BITUMEN → ASPHALT CONCRETE PREPARATION →



A focus on the cost-benefit assessment procedure

INPUT DATA

M = 3,000 t/y

TS = 35-40%

t = 250 d/y, 24 h/d

TPDC: Total Plant Direct Costs

Purchase costs:

- Pieces of equipment/machines
- Other instrumentations
- Electrical facilities

Installation

TPIC: Total Plant Indirect Costs

Design Engineering

Construction

TFC: Total Fixed Costs ⇒ Mortgage system (interest rate, useful life) ⇒ **Annual installment**

+ Utilities
+ Maintenance
+ Labor
+ Raw Materials

↓

Annual Operating Cost

$$\frac{\text{Annual Operating Cost}}{\text{Annual Amount of waste to be treated}} = \text{Unit Cost of Treatment}$$

Adapted from Ruffino et al., 2014 – Waste Manage 34 (2014), 148-155

Cost Benefit Assessment

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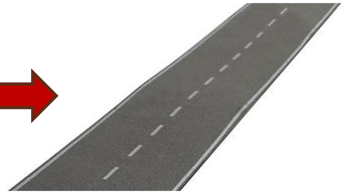


95 €/t   49 €/t

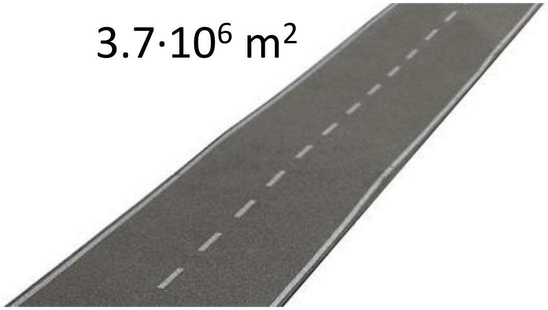
144 €/t treatment cost

↕

450 €/t neat bitumen cost

Amount of sludge in bitumen	10%
Amount of binder in HMC	5.5%
Hot mix concrete density	2.3 kg/dm^3
Thickness of the wearing course	3 cm
Road wideness	6 m

$3.7 \cdot 10^6$ m^2



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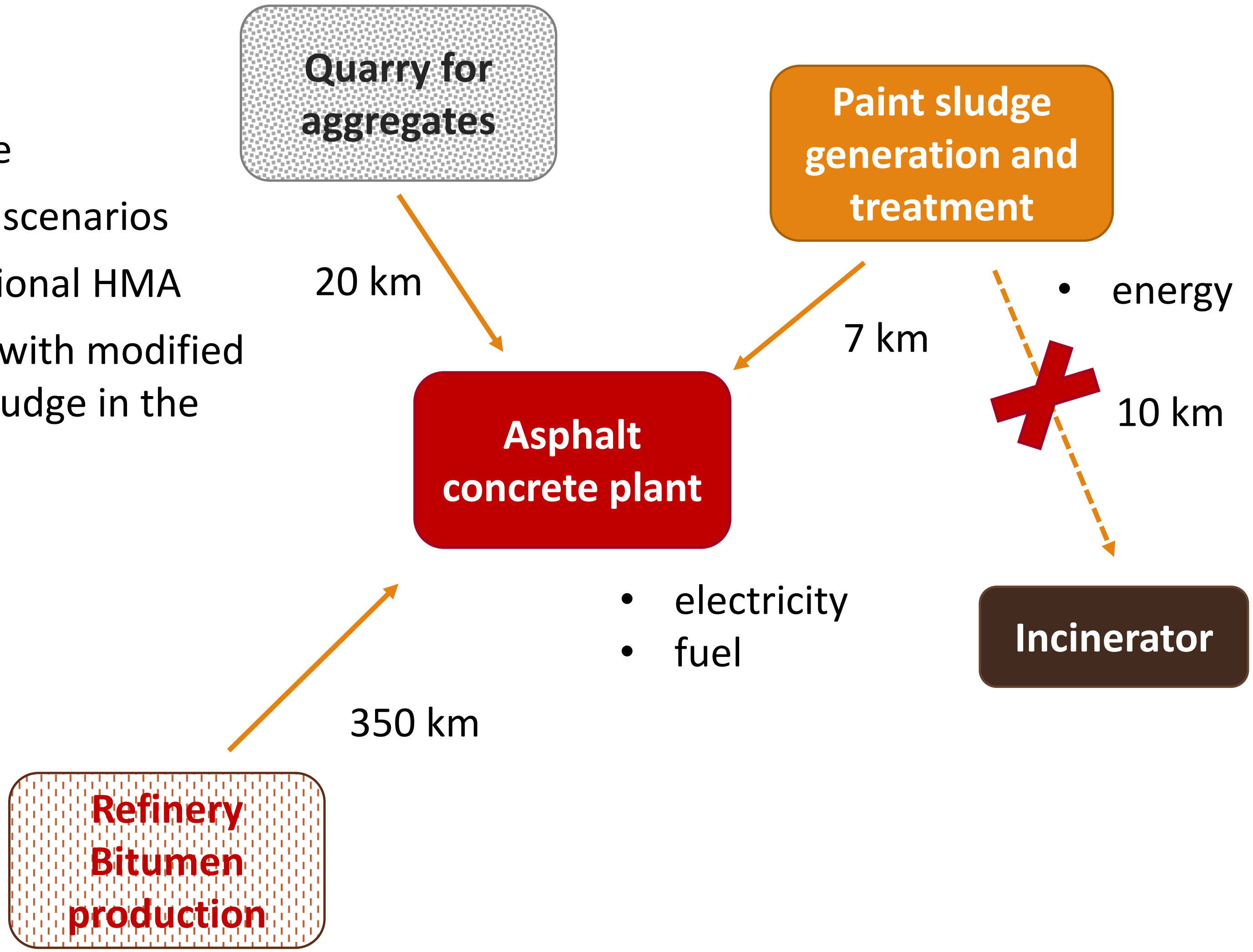
Life Cycle Assessment
«from cradle to gate»

- SimaPro software
- Comparison of 2 scenarios

Production of traditional HMA

Production of HMA with modified binder (20% paint sludge in the binder)



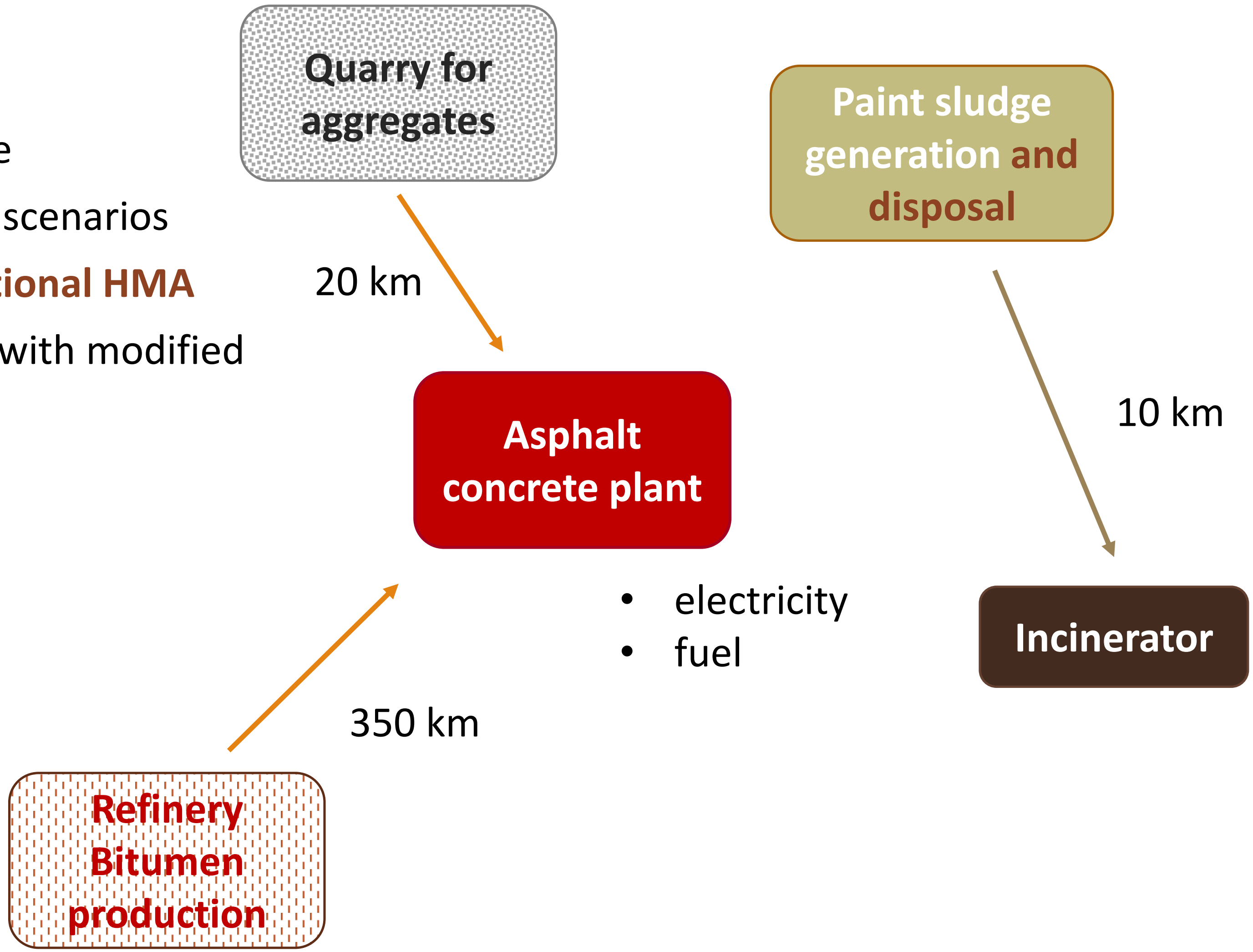
Life Cycle Assessment

«from cradle to gate, scenario 1»

- SimaPro software
- Comparison of 2 scenarios

Production of traditional HMA

Production of HMA with modified binder

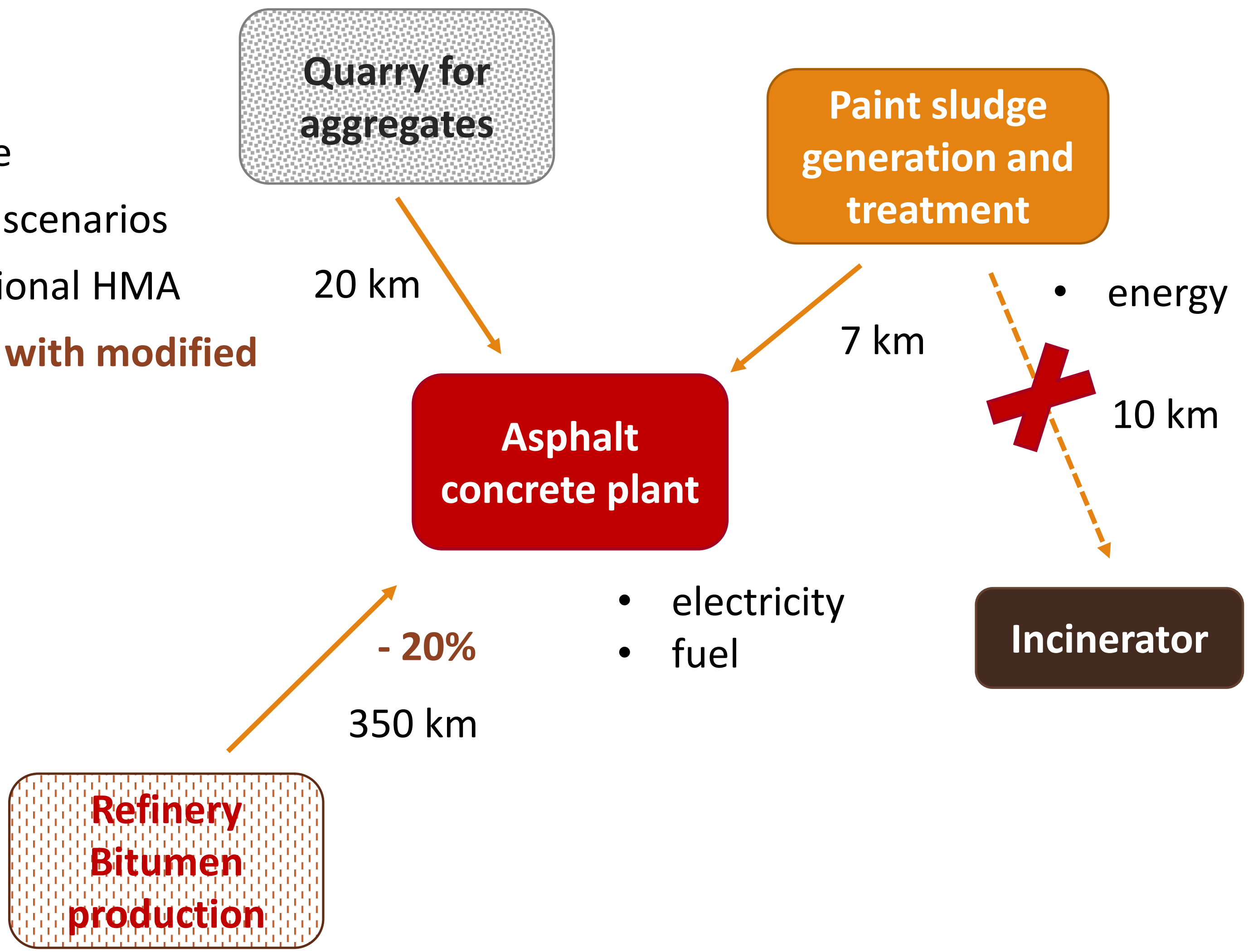


Life Cycle Assessment
«from cradle to gate, scenario 2»

- SimaPro software
- Comparison of 2 scenarios

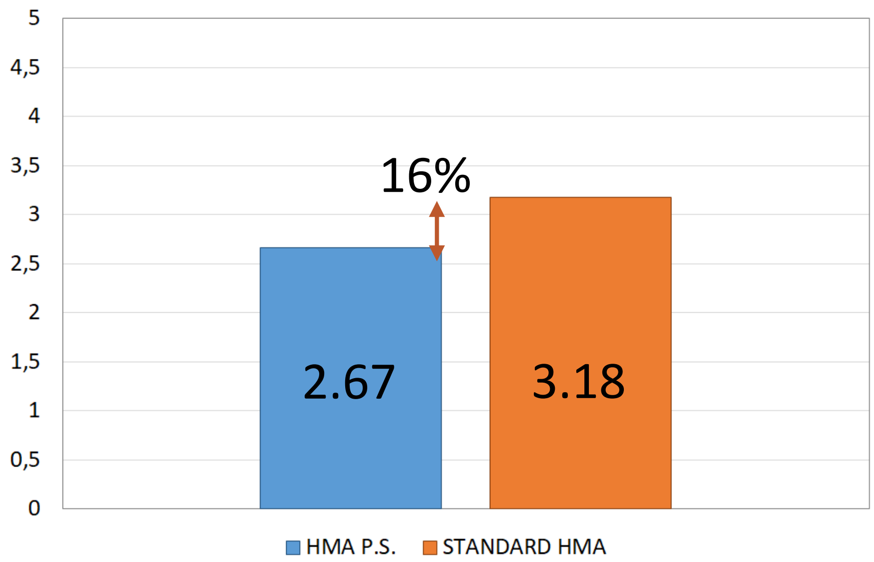
Production of traditional HMA

Production of HMA with modified binder

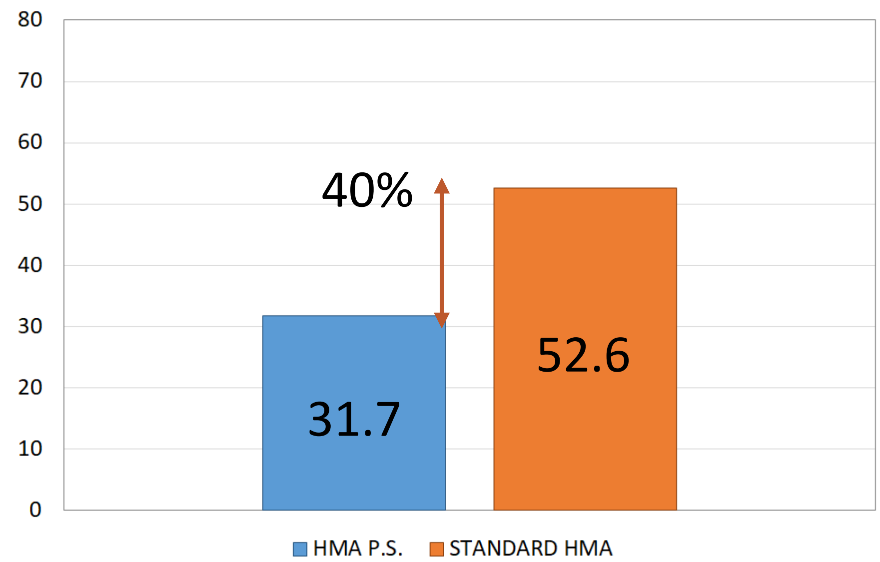


Life Cycle Assessment

GER, Gross Energy Requirement (MJ/kg)



GWP, Global Warming Potential (gCO_2eq/kg)



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Conclusions

- The generation of paint sludge (PS) in Italian plants is in the order of 3 kg/car on a wet basis (FCA, 2016).
- Reuse of paint sludge as a substitute of a part of the conventional binder for the production of concrete for asphalt pavements was proposed and the technical feasibility of the process was successfully demonstrated (Dalmazzo et al., 2017).
- The unit cost of treatment, that includes the operations of dewatering and milling and mixing PS with neat bitumen, was of 144 €/t.
- The economic balance was positive, because a PS treated at a cost of 144 €/t could substitute up to 20% of neat bitumen (at a cost of 450 €/t) in a binder used for asphalt concrete production without worsening the performances of the pavement.
- The LCA analysis revealed that the production of a hot mix asphalt by employing a bitumen with the addition of 20% (w/w) PS, reduced the Gross Energy Requirement (GER) by approximately 16% respect to the traditional process.
- The Global Warming Potential (GWP) index decreased from 52.6 to 31.7 g CO_2eq/kg asphalt mixture.

Thanks for your kind attention!

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