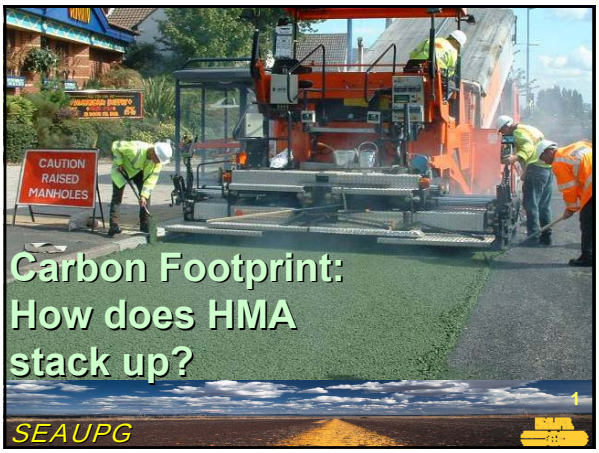
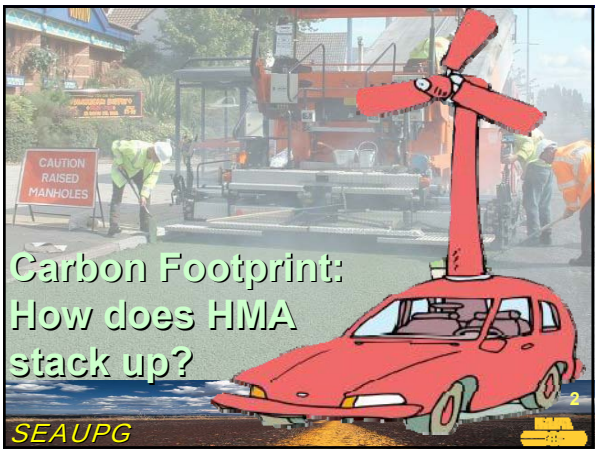
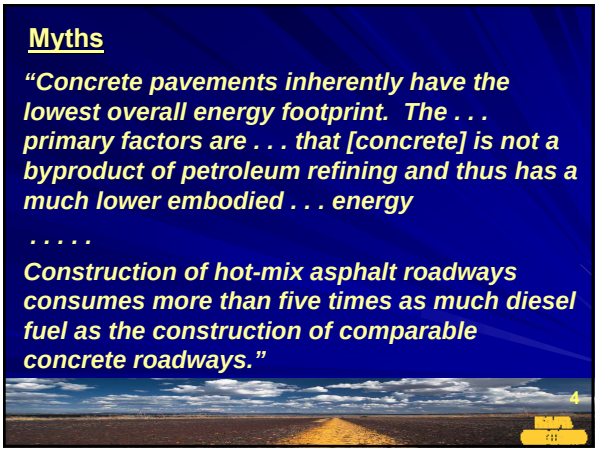
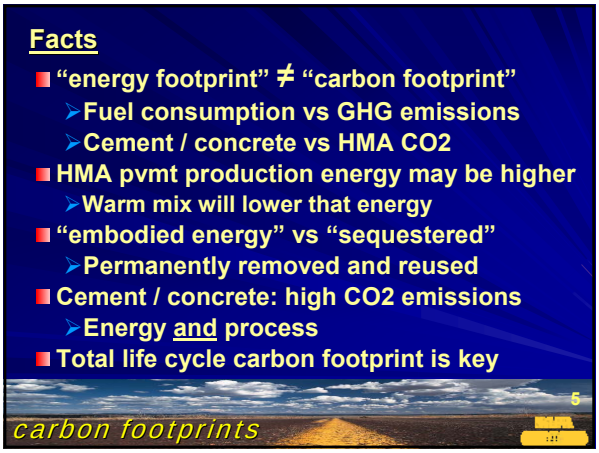

CAUTION
RAISED
MANHOLES
Carbon Footprint:
How does HMA
stack up?
SEAUPG
1


CAUTION
RAISED
MANHOLES
Carbon Footprint:
How does HMA
stack up?
SEAUPG
2


what's a carbon footprint ??
3


Myths
"Concrete pavements inherently have the lowest overall energy footprint. The . . . primary factors are . . . that [concrete] is not a byproduct of petroleum refining and thus has a much lower embodied . . . energy
. . . . .
Construction of hot-mix asphalt roadways consumes more than five times as much diesel fuel as the construction of comparable concrete roadways."
4


Facts
"energy footprint" ≠ "carbon footprint"
Fuel consumption vs GHG emissions
Cement / concrete vs HMA CO2
HMA pvmt production energy may be higher
Warm mix will lower that energy
"embodied energy" vs "sequestered"
Permanently removed and reused
Cement / concrete: high CO2 emissions
Energy and process
Total life cycle carbon footprint is key
carbon footprints
5


what's a carbon footprint ??
6

"The total amount of greenhouse gas emissions caused directly and indirectly by a . . . product [or material]." Usually expressed in carbon dioxide "equivalents" (CO_2e).

7

what's a carbon footprint ??

Assumptions

10 Hour job

12.5 miles from the plant

250 Truck trips = ~ 1,000 gal fuel

- Producing HMA Generates 40 tons of CO_2
- Delivering HMA Generates 11 tons of CO_2
- Placing HMA Generates 3 tons of CO_2
- Total "emissions" = 54 tons of CO_2

8

carbon footprint: simple example

- Materials extraction
- Materials processing
- Materials transport
- HMA production
- HMA transport
- HMA prep
- HMA placement
- Interim maintenance

Do it all over again!

9

pavement production lifecycle

Assumptions

10 Hour job

12.5 miles from the plant

250 Truck trips

- Producing HMA Generates 40 tons of CO_2
- Delivering HMA Generates 11 tons of CO_2
- Placing HMA Generates 3 tons of CO_2
- Total "emissions" = 54 tons of CO_2
  - Doesn't include raw material acquisition

10

carbon footprint: simple example

- Avg. HMA plant emits ~ 2,500 tons CO_2
- Avg. automobile emits ~ 6 tons CO_2 annually
- 2,500 tons = ~ 0.0023 Tg (MMTons)
- Cement industry emits ~ 77 Tg CO_2
  - Over 300 times more CO_2 emission per plant
- So, where is HMA industry vs. all GHG emissions

11

comparing CO_2 emissions

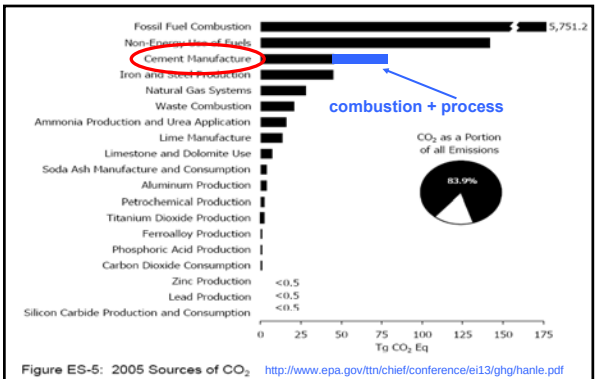


Figure ES-5: 2005 Sources of CO_2 http://www.epa.gov/ttn/chief/conference/ei13/ghg/hanle.pdf

12

carbon footprint: US sources

13

what's a carbon footprint ??

- "carbon footprint" = total set of GHG emissions caused directly / indirectly by . . . product / process
- Raw materials extraction and processing
- Pavement manufacturing
- Pavement placement / transportation
- Pavement maintenance
- Numerous studies look at different components
  - Generally, values embedded as LCA inputs
- A number of entities have attempted to calculate pavement's carbon footprint – why?
  - mass of materials; potential GHG emissions
  - Municipalities "going green"

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the basics: carbon footprint

- First Question: are there any "criteria"
  - Not really, more like recommended methodologies
- ISO 14000 series on Env Mgmt "standards"
  - 14040 series: LCA/I framework/guidelines
  - 14064 series: GHG quantification / reporting
  - ISO is basic: provides no "hands-on" methodology
- GHG "Registries" (state, regional, national, now federal)
  - Facility reporting vs LCA
- SimPro and other "software"
- Inputs are database intensive: much information
  - Energy, fuel, emissions, etc
- Details of 4 or 5 international pavement LCA studies

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LCI / LCA Standards

16

BEES: econ. & env. impacts

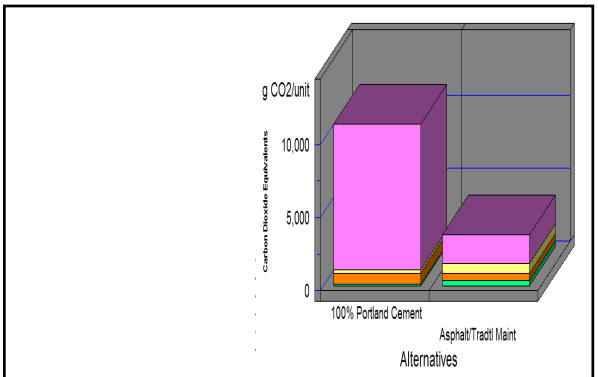
- Typical parking lot
- 50-year life span
- "unit" = 1 sq. ft, typical construction practices

- Similar aggregate bed mass ~ 7- inch
- 3 - inch initial asphalt pavement
  - 3 x 1.5 - inch "mill-and-fill" maintenance regimes
  - 15% RAP
- 6 - inch concrete pavement
  - No maintenance / no rebar
  - Separate iteration substitutes cement with 20% fly ash

- Total mass of asphalt/HMA "unit" = 59.3 lbs
- Total mass of concrete "unit" = 72.5 lbs

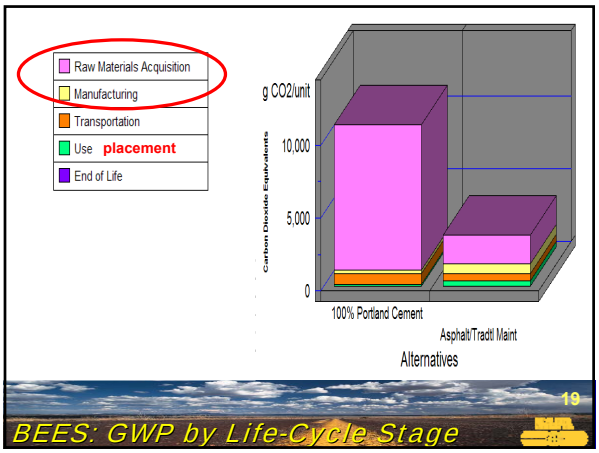
17

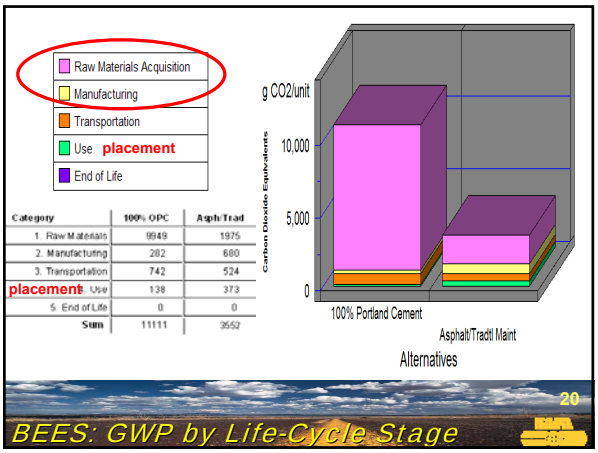
BEES: design characteristics

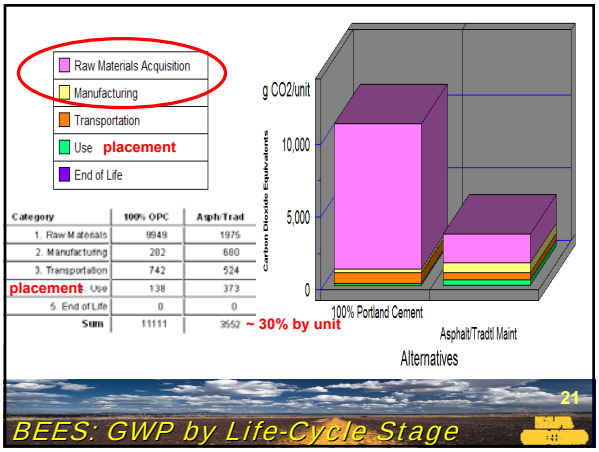


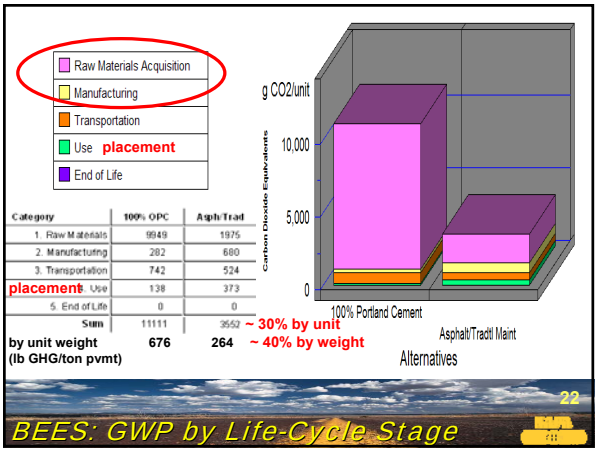
18

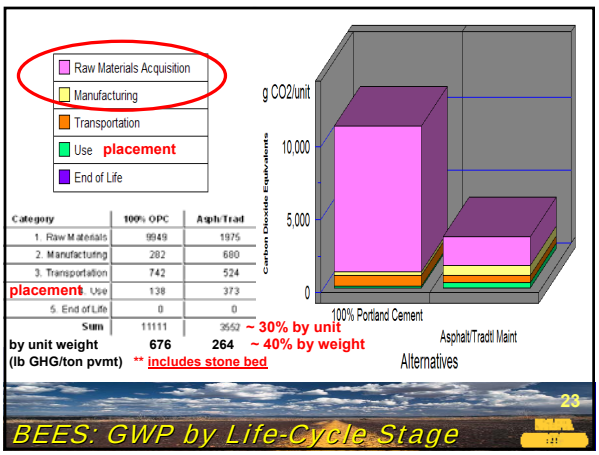
BEES: GWP by Life-Cycle Stage

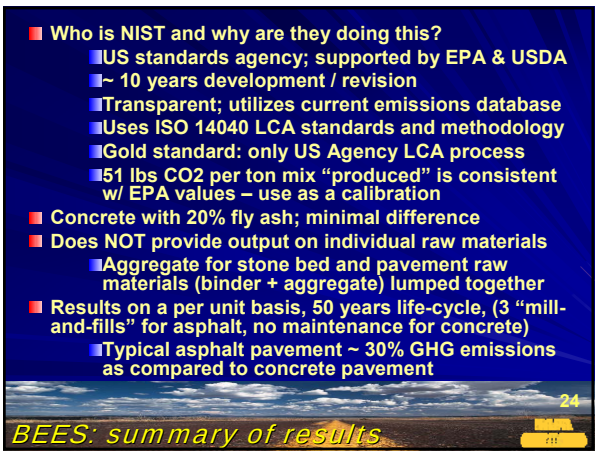

Raw Materials Acquisition
Manufacturing
Transportation
Use placement
End of Life
g CO2/unit
10,000
5,000
0
Carbon Dioxide Equivalents
100% Portland Cement
Asphalt/Tradtl Maint
Alternatives
19
BEES: GWP by Life-Cycle Stage

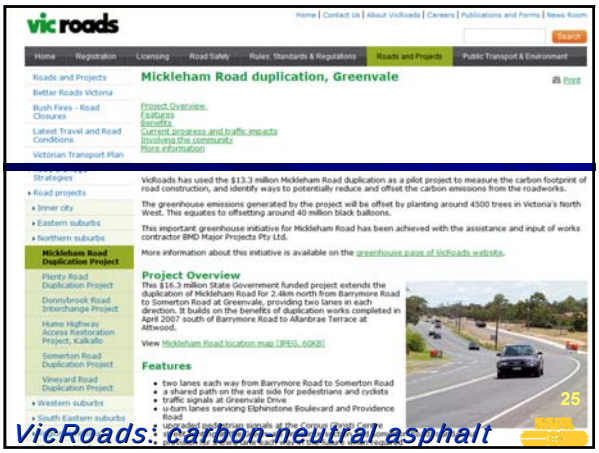

Raw Materials Acquisition
Manufacturing
Transportation
Use placement
End of Life
Category 100% OPC Asph/Trad
1. Raw Materials 9949 1975
2. Manufacturing 282 680
3. Transportation 742 524
placement. Use 138 373
5. End of Life 0 0
Sum 11111 3552
g CO2/unit
10,000
5,000
0
Carbon Dioxide Equivalents
100% Portland Cement
Asphalt/Tradtl Maint
Alternatives
20
BEES: GWP by Life-Cycle Stage

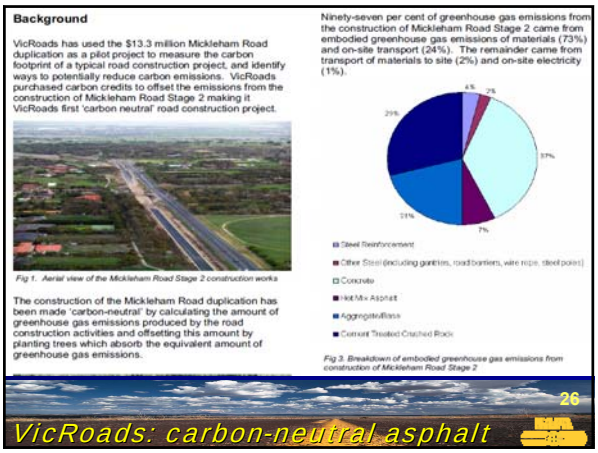

Raw Materials Acquisition
Manufacturing
Transportation
Use placement
End of Life
Category 100% OPC Asph/Trad
1. Raw Materials 9949 1975
2. Manufacturing 282 680
3. Transportation 742 524
placement. Use 138 373
5. End of Life 0 0
Sum 11111 3552
~ 30% by unit
g CO2/unit
10,000
5,000
0
Carbon Dioxide Equivalents
100% Portland Cement
Asphalt/Tradtl Maint
Alternatives
21
BEES: GWP by Life-Cycle Stage


Raw Materials Acquisition
Manufacturing
Transportation
Use placement
End of Life
Category 100% OPC Asph/Trad
1. Raw Materials 9949 1975
2. Manufacturing 282 680
3. Transportation 742 524
placement. Use 138 373
5. End of Life 0 0
Sum 11111 3552
~ 30% by unit
by unit weight 676 264 ~ 40% by weight
(lb GHG/ton pvmt)
g CO2/unit
10,000
5,000
0
Carbon Dioxide Equivalents
100% Portland Cement
Asphalt/Tradtl Maint
Alternatives
22
BEES: GWP by Life-Cycle Stage


Raw Materials Acquisition
Manufacturing
Transportation
Use placement
End of Life
Category 100% OPC Asph/Trad
1. Raw Materials 9949 1975
2. Manufacturing 282 680
3. Transportation 742 524
placement. Use 138 373
5. End of Life 0 0
Sum 11111 3552
~ 30% by unit
by unit weight 676 264 ~ 40% by weight
(lb GHG/ton pvmt) ** includes stone bed
g CO2/unit
10,000
5,000
0
Carbon Dioxide Equivalents
100% Portland Cement
Asphalt/Tradtl Maint
Alternatives
23
BEES: GWP by Life-Cycle Stage

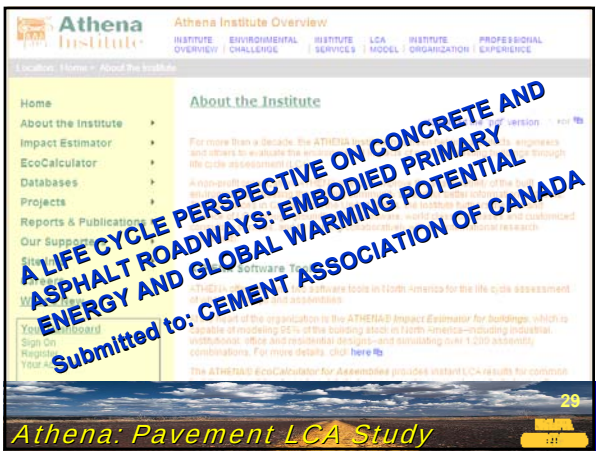

Who is NIST and why are they doing this?
US standards agency; supported by EPA & USDA
~ 10 years development / revision
Transparent; utilizes current emissions database
Uses ISO 14040 LCA standards and methodology
Gold standard: only US Agency LCA process
51 lbs CO2 per ton mix "produced" is consistent w/ EPA values – use as a calibration
Concrete with 20% fly ash; minimal difference
Does NOT provide output on individual raw materials
Aggregate for stone bed and pavement raw materials (binder + aggregate) lumped together
Results on a per unit basis, 50 years life-cycle, (3 "mill-and-fills" for asphalt, no maintenance for concrete)
Typical asphalt pavement ~ 30% GHG emissions as compared to concrete pavement
24
BEES: summary of results





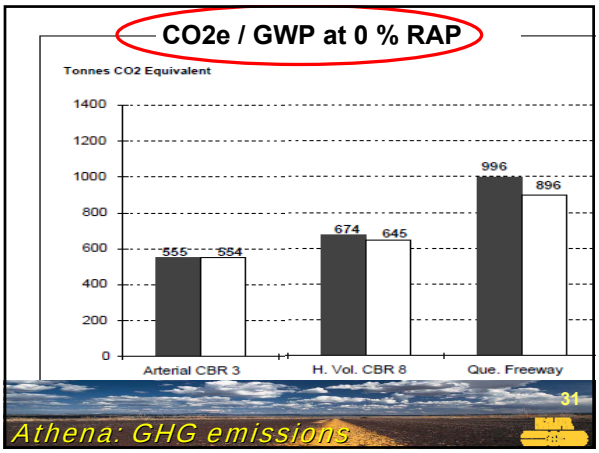
- Open / transparent process
  - publically available
- At first glance, difficult to understand design characteristics and maintenance activities
- Emphasis on carbon "offsets" using trees
  - accurately calculate pavement carbon
- Used embodied energy / GHG emissions
  - Also accounted for cement process CO_2
- Appears to be initial construction carbon only
- Bottom line:
  - asphalt ~ 10% GHG emissions vs concrete

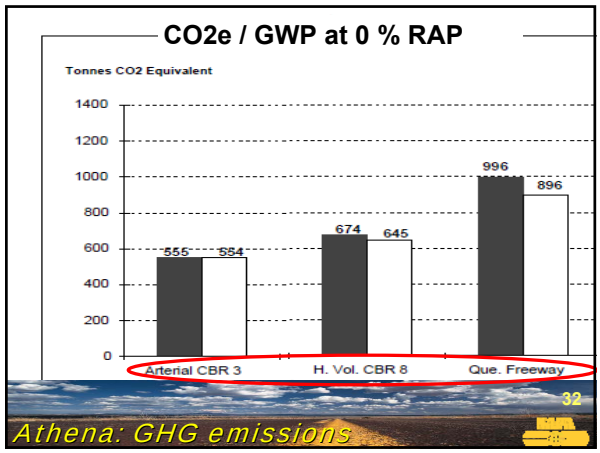
27
VicRoads: general findings

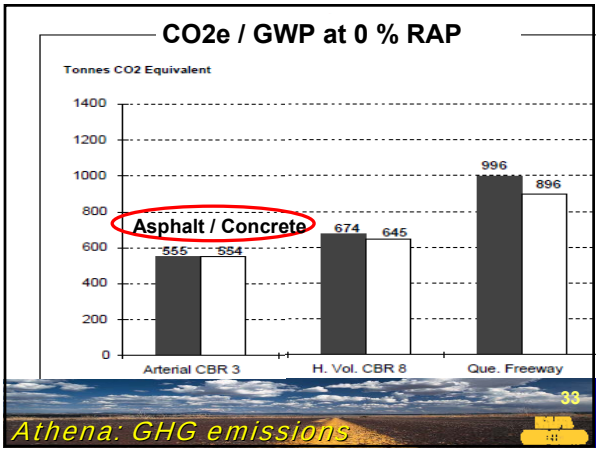


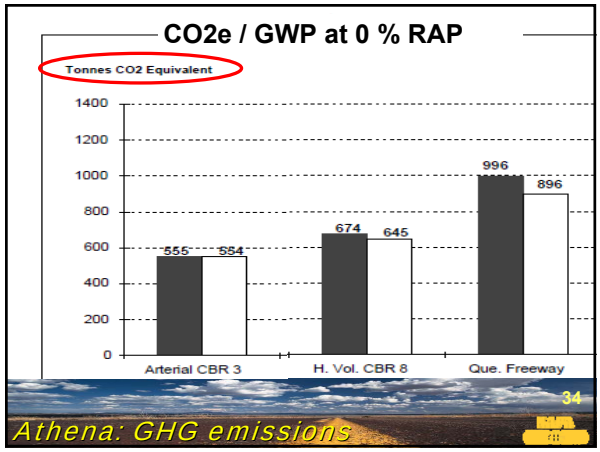
- Typical highway
- 50-year life span
- "unit" = 1 cu. meter; typical construction practices
- Twice as much aggregate base for asphalt pavement
- 9.5 - inch initial asphalt pavement
  - 4 x 3 - inch "mill-and-fill" maintenance regimes
  - 0% RAP
- 9.5 - inch concrete pavement
  - 1 3-inch asphalt overlay
  - 20% slag in cement; 15% fly ash in concrete
- "embodied" energy (includes "feedstock" energy of asphalt) – "energy" required to make the material
  - More on this later . . . .

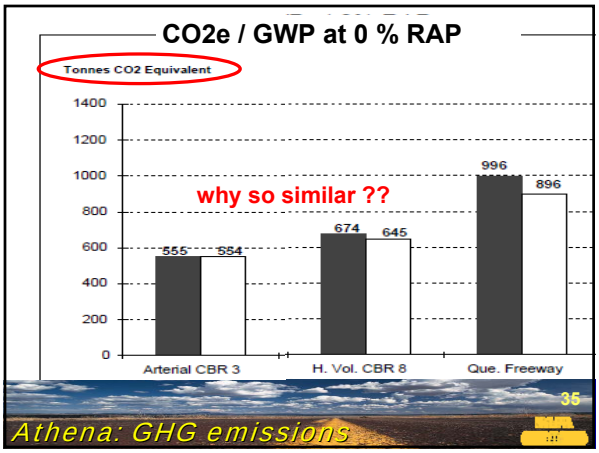
30
Athena: design characteristics

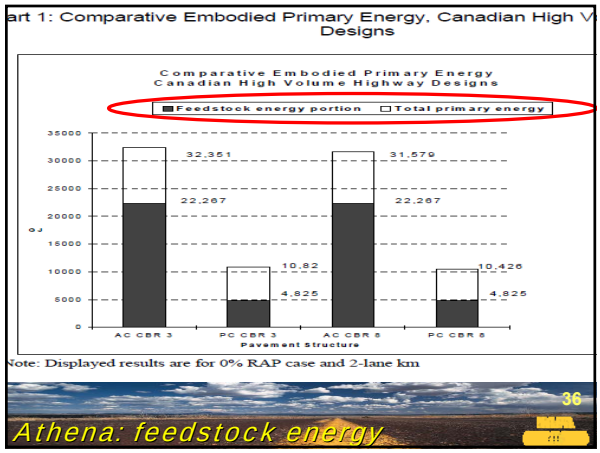

CO2e / GWP at 0 % RAP
Tonnes CO2 Equivalent
1400
1200
1000
800
600
400
200
0
555
584
674
645
996
896
Arterial CBR 3
H. Vol. CBR 8
Que. Freeway
31
Athena: GHG emissions


CO2e / GWP at 0 % RAP
Tonnes CO2 Equivalent
1400
1200
1000
800
600
400
200
0
555
584
674
645
996
896
Arterial CBR 3
H. Vol. CBR 8
Que. Freeway
32
Athena: GHG emissions


CO2e / GWP at 0 % RAP
Tonnes CO2 Equivalent
1400
1200
1000
800
600
400
200
0
Asphalt / Concrete
555
584
674
645
996
896
Arterial CBR 3
H. Vol. CBR 8
Que. Freeway
33
Athena: GHG emissions


CO2e / GWP at 0 % RAP
Tonnes CO2 Equivalent
1400
1200
1000
800
600
400
200
0
555
584
674
645
996
896
Arterial CBR 3
H. Vol. CBR 8
Que. Freeway
34
Athena: GHG emissions


CO2e / GWP at 0 % RAP
Tonnes CO2 Equivalent
1400
1200
1000
800
600
400
200
0
why so similar ??
555
584
674
645
996
896
Arterial CBR 3
H. Vol. CBR 8
Que. Freeway
35
Athena: GHG emissions


art 1: Comparative Embodied Primary Energy, Canadian High V
Designs
Comparative Embodied Primary Energy
Canadian High Volume Highway Designs
Feedstock energy portion
Total primary energy
35000
30000
25000
20000
15000
10000
5000
0
32,351
22,267
10,82
4,825
31,579
22,267
10,426
4,825
AC CBR 3
PC CBR 3
AC CBR 8
PC CBR 8
Pavement Structure
Note: Displayed results are for 0% RAP case and 2-lane km
36
Athena: feedstock energy

- "carbon footprint" = total GHG associated w/ . .
  - Remember . . . it's all about emissions of GHGs
- "energy footprint" ≠ "carbon footprint" (LC GHG)
  - "embodied" energy = "primary" energy
  - = "energy footprint" = loosely the "energy" required to "make the material"
  - Energy doesn't account for process GHGs
- Directly attributable to process and energy is key
- "embodied" energy ≠ "feedstock" energy
- "feedstock" energy = product's "caloric value"
  - If burned as fuel, would release GHGs
  - If not a fuel, NOT applicable to carbon footprint

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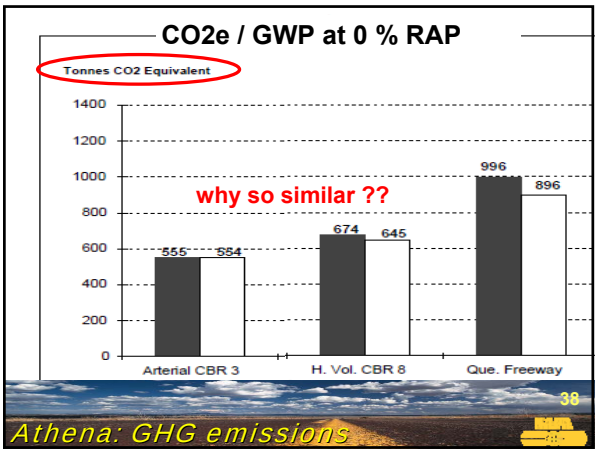
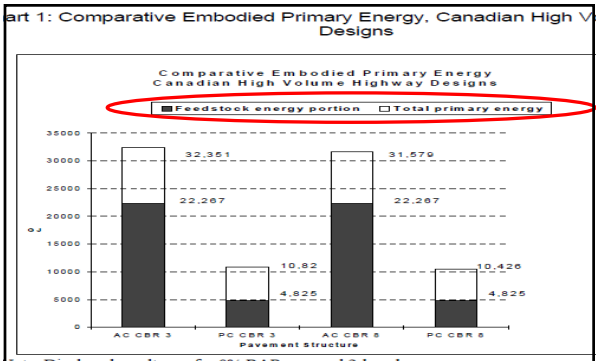
energy definitions



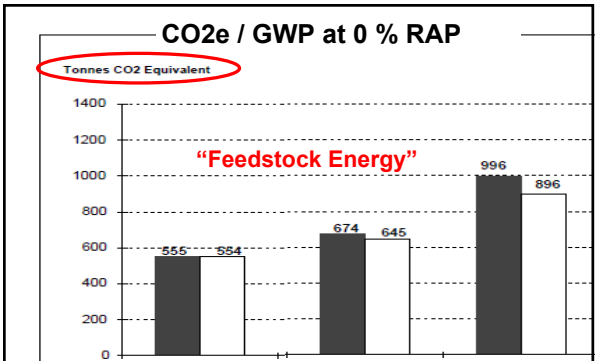
38

Athena: GHG emissions



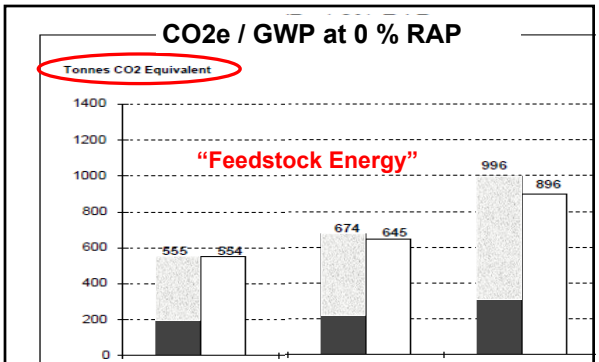
39

Athena: feedstock energy



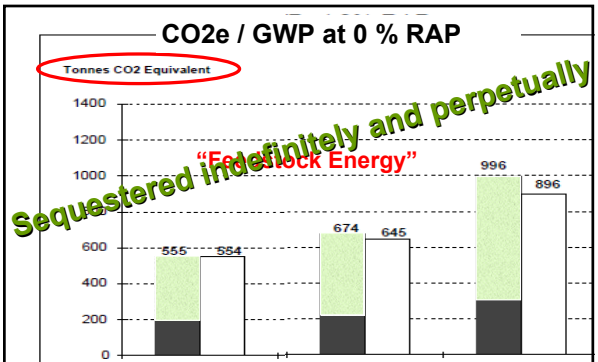
40

Athena: impact of feedstock E



41

Athena: impact of feedstock E



42

Athena: impact of feedstock E

- Contribution of "Feedstock Energy" was approximated
  - Between 50 and 70 % of total GHG emissions
- Removing "Feedstock Energy" would show carbon footprint similar to BEES results (total pvmt design)
  - asphalt pvmt @ ~ 30 – 40% vs PCC over 50 years
- What is "Feedstock Energy" . . . in a moment . . .
- Uses ISO standards and methodology (doesn't specify)
- Who is ~~NIST~~ Athena and why are they doing this
  - Consulting group that has run LCIs in the past
  - Study funded by Cement Association of Canada
  - Inconsistency in treating "Feedstock Energy" / GHG (carbon) footprint of different products; is it fuel?
- Report is difficult to critically review

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Athena Study: discussion

- "feedstock" energy: a little more unclear
  - Generally attributed to product's "caloric value"
  - If burned, would release GHGs
  - If NOT burned, considered "sequestered" (EIA)
    - DOE says: asphalt is the No.1 material to "sequester" carbon (GHGs)
    - NAPA says: indefinitely and perpetually
- How is "feedstock" energy viewed in carbon footprint LCAs ??

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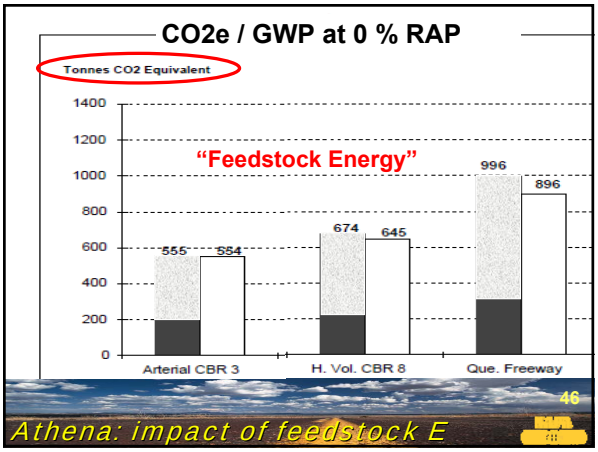
energy definitions

- "feedstock" energy generally NOT included in LCAs
- ISO 14040 says "don't double-count"
- Examples of LCA's not addressing "feedstock" energy
  - Timber used in wood-frame construction
  - Petroleum-based plastics in cups
  - Tires: typically don't include feedstock if recycled
    - Probably would if used as fuel, e.g., cement kiln
  - How should asphalt pavement be treated ?
    - Makes a HUGE difference in carbon footprint
    - Recall Athena results (~ 110%) vs others (~ 20%)
    - 2001: Sw. Nat'l Road Admin says no "feedstock"
- Remember . . . It's all about the ability to release GHGs

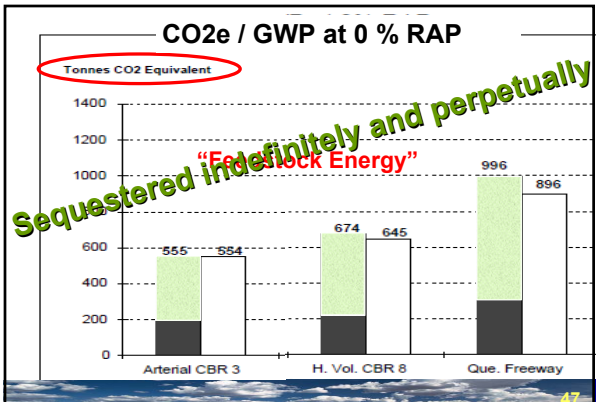
45

including feedstock energy in LCAs



46

Athena: impact of feedstock E



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Athena: impact of feedstock E

- Let's take a step back and do a quick review
- Carbon Footprint = GHG emissions associated w/ LCA of a material
- Studies we reviewed were somewhat simplified
  - Lumped all raw material acquisition together
  - No good indication of how RAP or Warm Mix can reduce GHG / offset carbon
  - "feedstock" energy = "sequestered" carbon
- Bottom line: asphalt pavement has a much lower carbon footprint vs concrete
- How do common technologies influence asphalt pavement's carbon footprint.

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quick review

- LCA based on a variety of mix designs
  - RAP, Warm Mix, other technologies
  - "unit" = either ton mtl placed or per lane km
  - Typical construction practices
- Published and utilized by a number of agencies
  - e.g., Natural Resources Canada
- 30-year life span
- Results are a little overwhelming . . . Here goes . . . .

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Colas: design characteristics

- "Carbon footprint" – consistent way to compare global GHG emissions associated with a product's life cycle
- "global" cradle-to-cradle: GHGs count even if material produced outside the US, and value of recycle counts
- energy footprint ≠ carbon footprint
  - Carbon footprint includes "process" GHG emissions
  - Carbon footprint does NOT include "feedstock" energy
- Be aware of conflicting terms: energy footprint, carbon footprint, feedstock energy, etc
- There are currently ~ half-dozen LCAs that look at cradle-to-cradle pavement life-cycle / GHG / carbon footprint
  - All look at "different" things associated with footprint
  - Understand exactly what an LCA is focusing on
- Bottom line: asphalt pavement has a much lower carbon footprint vs concrete; between ~ 15% - 45% depending . . .

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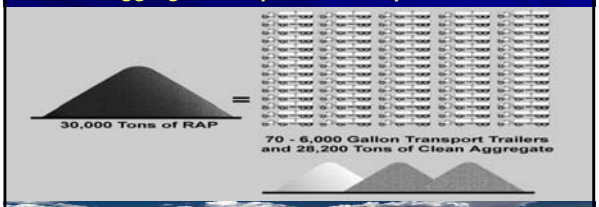
carbon footprint conclusions

The entire annual CO2 / greenhouse gas emissions / carbon footprint from a typical hot-mix plant (~ 2,500 tons) could be totally offset by using ~ +/- 30% RAP in pavement mix designs -- accomplished by minimizing acquisition of energy intensive (natural) raw materials such as aggregate and petroleum asphalt.



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RAP: sustainable & carbon neutral

ASPHALT:

the environmentally sustainable pavement

- Porous pavements manage stormwater
- OGFCs are safe, quiet, and better water quality
- Reflective / OGFC / Porous can mitigate UHI
- Great pavement to help with LEED certification
- Asphalt pvmts are most recycled and recycled RAP
- HMA pavements are environmentally preferred
  - lower carbon footprint, speed of construction
- Warm Mix reduces energy consumption / emissions
- RAP can offset entire annual HMA GHG emissions

RAP, porous, WMA, perpetual pvmts

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greening the blacktop

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www.pavegreen.com

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"it ain't easy being green!"