SUSTAINABILITY OF PVC (VINYL) PIPE:
A COMPREHENSIVE ENVIRONMENTAL REVIEW

ANTEC
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PRESENTED BY:
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THE PURPOSE OF THE PVC LCA

• Thorough review of LCA data

• Transparently report the findings to the water, sanitary sewer, and storm drainage industries

• Support the goals and vision of the 2010 USEPA Clean Water and Safe Drinking Water Infrastructure Sustainability Policy and the 2015 USEPA National Water Program on Climate Change

• Ensures the long-term sustainability of water and sewer infrastructure

• Comparative review of competing pipe products
WHAT IS A SUSTAINABLE PIPING PRODUCT?

- Lower Embodied Energy
- Sustainable Manufacturing Practices
- Minimal Waste During Manufacturing
- Transparent Disclosure of Environmental Impacts
- Reduced Transportation Impacts
- Reduced Installation Costs and Impacts
- Lower Initial and Operating Impacts and Cost
- Durable with a life of at least 100 years
- Reduced Pumping Energy over the lifetime
- Corrosion Resistance (no additional materials required to improve corrosion resistance)
- Low Maintenance
- Recyclable at End-of-Life
# PVC Pipes in the Study

<table>
<thead>
<tr>
<th>Application</th>
<th>Standard</th>
<th>Nominal Diameter</th>
<th>Dimension Ratio/ Pipe Stiffness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potable Water</td>
<td>AWWA C900</td>
<td>8 in.</td>
<td>DR 18</td>
</tr>
<tr>
<td></td>
<td>AWWA C900</td>
<td>8 in.</td>
<td>DR 25</td>
</tr>
<tr>
<td></td>
<td>AWWA C905</td>
<td>24 in.</td>
<td>DR 25</td>
</tr>
<tr>
<td>Storm Water</td>
<td>ASTM F794 AASHTO M304</td>
<td>24 in. (profile wall)</td>
<td>PS 46</td>
</tr>
<tr>
<td>Sanitary Sewer</td>
<td>ASTM F794</td>
<td>8 in. (profile wall)</td>
<td>PS 46</td>
</tr>
<tr>
<td></td>
<td>ASTM D3034</td>
<td>8 in. (solid wall)</td>
<td>PS 46</td>
</tr>
<tr>
<td></td>
<td>ASTM F679</td>
<td>24 in. (solid wall)</td>
<td>PS 46</td>
</tr>
</tbody>
</table>
COMPONENTS OF A LIFE CYCLE ANALYSIS

• **Product Stage (Cradle-to-Gate)**
  • Extraction and processing raw materials
    • Raw material supply
    • Raw material transport
    • Manufacturing

• **Construction Process Stage**
  • Transportation and distribution
  • Installation

• **Use Stage**
  • Use (operation)
  • Maintenance
  • Repair
  • Replacement
  • Refurbishment

• **End of Life Stage**
  • Demolition
  • Transport
  • Waster processing
  • Disposal (grave)
LIFE CYCLE OF A PIPE

Product Stage (Cradle-To-Gate)

Construction Process Stage

Use Phase

End of Life

Transportation

Manufacturing

Installation and Use

End of Life

Raw Materials

INGREDIENT A

TRANSPORT

INGREDIENT B

TRANSPORT

INGREDIENT C

TRANSPORT

COMPANY PRODUCT MANUFACTURING

PRODUCT SHIPPING

FINAL PRODUCT DISPOSITION

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LIFE CYCLE OF A PIPE

Product Stage (Cradle-To-Gate)

Construction Process Stage

Use Phase

End of Life

Transportation

Raw Materials

Manufacturing

Installation and Use

End of Life

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• Polyvinyl Chloride resin is a thermoplastic polymer. Vinyl Chloride is produced from:
  ▪ Chlorine (raw material: salt)
  ▪ Ethylene (raw material: natural gas)

• PVC resin is blended with other ingredients to make PVC compound

• Types of ingredients that are added include:
  ▪ Heat stabilizers
  ▪ Lubricants
  ▪ Modulus enhancers
  ▪ Pigments
  ▪ UV inhibitors
PRODUCT STAGE – Raw Material Supply

production process

- Cracking
- Ethylene
- Vinyl Chloride Monomer
- Ethylene Dichloride
- Polymerization
- Vinyl Resin
- Vinyl Compound
- Additives & Modifiers
- Chloride
- Natural Gas
- Petroleum Oil
- Salt
- Water
- Electrolysis
- Vinyl Resin
- Vinyl Compound

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PRODUCT STAGE - MANUFACTURING

The Gate
Pipe Out

Manufacturing

Raw Materials In

Power (electricity) In
PRODUCT STAGE - MANUFACTURING
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LIFE CYCLE OF A PIPE

Product Stage (Cradle-To-Gate)
- Transportation
  - Raw Materials
  - Manufacturing

Construction Process Stage
- Styrene and vinyl acetate copolymer (SPE ANTEC®)
- Installation and Use
- Final Product Disposition

Use Phase
- Transportation
- Installation and Use
- Final Product Disposition

End of Life
- Transportation
- Final Product Disposition

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Construction Process Stage

• Reduced Transportation Impacts
• Reduced Installation Costs and Impacts
CONSTRUCTION PROCESS STAGE – TRANSPORTATION AND DISTRIBUTION
CONSTRUCTION PROCESS STAGE – CONSTRUCTION/INSTALLATION
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LIFE CYCLE OF A PIPE

Product Stage (Cradle-To-Gate)

Construction Process Stage

Use Phase

End of Life

Raw Materials

Manufacturing

Installation and Use

End of Life

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PVC USE PHASE ADVANTAGES

• Lower Initial and Operating Impacts and Cost
• Potentially smaller pipe needed – efficient design parameters
• Durable with a life of at least 100 years
• Reduced Pumping Energy over the lifetime
• Less operation energy needed
• Corrosion Resistance (no additional materials required to improve corrosion resistance)
• Low Maintenance
• No replacement needed for 100 + years
## PIPES COMPARED & DESIGN LIVES

<table>
<thead>
<tr>
<th>Pipe Material</th>
<th>Standard</th>
<th>Design Life (years)</th>
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</thead>
<tbody>
<tr>
<td>PVC</td>
<td>AWWA C900</td>
<td>100</td>
</tr>
<tr>
<td>PVC</td>
<td>AWWA C905</td>
<td>100</td>
</tr>
<tr>
<td>PVC</td>
<td>ASTM D3034</td>
<td>100</td>
</tr>
<tr>
<td>PVC</td>
<td>ASTM F679</td>
<td>100</td>
</tr>
<tr>
<td>PVC</td>
<td>ASTM F794</td>
<td>100</td>
</tr>
<tr>
<td>PVCO</td>
<td>AWWA C909</td>
<td>100</td>
</tr>
<tr>
<td>DI</td>
<td>AWWA C151</td>
<td>50</td>
</tr>
<tr>
<td>DI</td>
<td>AWWA A746</td>
<td>50</td>
</tr>
<tr>
<td>HDPE</td>
<td>AWWA C906</td>
<td>50</td>
</tr>
<tr>
<td>HDPE</td>
<td>ASTM F2306</td>
<td>50</td>
</tr>
<tr>
<td>PCCP</td>
<td>AWWA C301</td>
<td>75</td>
</tr>
<tr>
<td>PP</td>
<td>ASTM F2736</td>
<td>50</td>
</tr>
<tr>
<td>VCP</td>
<td>ASTM C700</td>
<td>50</td>
</tr>
<tr>
<td>Concrete</td>
<td>ASTM C14</td>
<td>50</td>
</tr>
<tr>
<td>Pipe Material</td>
<td>Standards</td>
<td>H-W “C”</td>
</tr>
<tr>
<td>----------------------------</td>
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</tr>
<tr>
<td>PVC</td>
<td>C900, C905, F794, D3034, F679</td>
<td>155 - 150</td>
</tr>
<tr>
<td>PVCO</td>
<td>C909</td>
<td>155 - 150</td>
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<tr>
<td>DI</td>
<td>C151, C104, A746</td>
<td>≤ 140</td>
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<tr>
<td>HDPE</td>
<td>C906, F2306</td>
<td>155 - 150</td>
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<tr>
<td>PP</td>
<td>F2736</td>
<td>N/A</td>
</tr>
<tr>
<td>PCCP/Non-Reinf. Conc.</td>
<td>C301, C14</td>
<td>≤ 140</td>
</tr>
<tr>
<td>VCP</td>
<td>C700</td>
<td>N/A</td>
</tr>
</tbody>
</table>
USE STAGE – PUMPING
USE STAGE – PUMPING

- Pumping determines the use phase power requirements for different pipe materials.
- The pipe does not use power, but the pipe can cause the pump to use more power to push water through a pipeline.
- The smaller the pipe diameter and the greater the pipe friction, then the more pump power is needed.
DESIGN EXAMPLE:
30”RAW WATER TRANSMISSION PIPELINE

HYDRAULIC PROFILES PIPE MATERIAL OPTIONS

- PVC
- DI
- Steel
- PCCP
- HDPE
DESIGN EXAMPLE:
30” RAW WATER TRANSMISSION PIPELINE

Pump & System Curves

- **HDPE 4710**
  - Head: 508’
  - HP: 1,532

- **PCCP**
  - Head: 465’
  - HP: 1,410

- **Steel**
  - Head: 515’
  - HP: 1,584

- **PVC**
  - Head: 299’
  - HP: 890

**DESIGN EXAMPLE:**
30” RAW WATER TRANSMISSION PIPELINE
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100-YEAR PUMPING ENERGY COMPARISONS

Total 100 Year Pumping Energy Use per 100' of Pipe

Pumping Energy (kW-h/100'/100 yrs)

8" 235 psi
Flowrate: 312 gpm

8" 165 psi
Flowrate: 336 gpm

24" 165 psi
Flowrate: 2,730 gpm

PVC Size & Pressure Class
All pipes at 100 years of continuous service w/o replacement.

- PVC
- HDPE
- DI
- PCCP
Total 100 Year Pumping Energy Costs per 100' of Pipe

- 8" 235 psi, Flowrate: 312 gpm
- 8" 165 psi, Flowrate: 336 gpm
- 24" 165 psi, Flowrate: 2,730 gpm

PVC Size & Pressure Class
All pipes at 100 years of continuous service w/o replacement

- PVC
- HDPE
- DI
- PCCP
24” DR 25 EMBODIED ENERGY COMPARISONS

TOTAL 100-YEAR EMBODIED ENERGY FOR 24” PVC DR25 EQUIVALENT PIPES (USE PHASE WITHOUT REPLACEMENT)

- PVC DR25: Total = 260,000
- HDPE 4710 DR13.5: Total W/O Replacement = 419,000
- DI CL51 PC200: Total W/O Replacement = 388,000
- PCCP PC200: Total W/O Replacement = 263,000

Legend:
- Cradle-To-Gate
- Final Transportation & Installation
- 100-Year Hydraulic Energy
- 100-Year Water Loss
- Corrosion Protection
- Replacement Energy Cradle-Thru-Installation
WHAT HAPPENS WHEN PIPES ARE NOT REPLACED?

Pumping Energy Cost of 24" PVC DR 25 Equivalent Pipes

<table>
<thead>
<tr>
<th>Material</th>
<th>100-Year Pumping Cost ($/100/100 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC PC 165</td>
<td>$3,625</td>
</tr>
<tr>
<td>HDPE 4710 DR</td>
<td>$5,407</td>
</tr>
<tr>
<td>HDPE 4710 DR</td>
<td>$5,388</td>
</tr>
<tr>
<td>DI CL51 PC200</td>
<td>$4,646</td>
</tr>
<tr>
<td>DI CL51 PC200</td>
<td>$4,770</td>
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<tr>
<td>DI CL51 PC200</td>
<td>$5,356</td>
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<tr>
<td>PCCP PR200</td>
<td>$5,642</td>
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<tr>
<td>PCCP PR200</td>
<td>$5,793</td>
</tr>
<tr>
<td>PCCP PR200</td>
<td>$6,505</td>
</tr>
</tbody>
</table>

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Gravity Pipe Comparisons

- For each size and cross-section - 8” F794, 8” D3034, 24” F794, 24” F679
  - Cradle-to-gate embodied energy
  - Transportation and installation embodied energy
  - Required replacements for design lives of less than 100 years
    - DI
    - HDPE
    - Polypropylene
    - Non-reinforced concrete
    - VCP
  - The total of all of the above is the Total 100-year Embodied Energy
8” Solid Wall PVC Flow Comparisons with Equal Slope (0.0352%)
24” Solid Wall PVC Gravity Pipe Flow Comparisons with Equivalent Slope (0.08135%)
Total 100-Year Embodied Energy of 8" Gravity Pipe Products
(Cradle-Thru-Installation for Initial Installation and Replacements)
24” GRAVITY PIPES TOTAL EMBODIED ENERGY COMPARISONS

Total 100-Year Embodied Energy of 24” Gravity Pipe Products
(Cradle-Thru-Installation for Initial Installations and Replacements)
TOTAL 100-YEAR EMBODIED ENERGY FOR 8" PS46 F794 PVC COMPARISON PIPES

- Cradle To Gate
- Final Transportation & Installation
- Corrosion Protection
- Replacement Energy Cradle Thru Install
8" PS 46 D3034 EMBODIED ENERGY COMPARISONS

TOTAL 100-YEAR EMBODIED ENERGY FOR 8" PS46 D3034 SOLID WALL PVC COMPARISON PIPES

- PVC D3034 100-Yr.
- DI A746 50-Yr.
- VCP C700 50-Yr.

- Cradle To Gate
- Final Transportation & Installation

Embody Energy (MJ/100')

0 20,000 40,000 60,000 80,000 100,000 120,000 140,000

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TOTAL 100-YEAR EMBODIED ENERGY FOR 24" PS46 F794 PROFILE WALL PVC COMPARISON PIPES

- **Cradle To Gate**
- **Final Transportation & Installation**
- **Replacement Energy Cradle Thru Install**

PVC PS46 F794 100-Yr.  DI A746 50-Yr.  PP PS46 F2736 50-Yr.  HDPE PS34 F2306
24" PS 46 F679 EMBODIED ENERGY COMPARISONS

TOTAL 100-YEAR EMBODIED ENERGY FOR 24" PS46 F679 SOLID WALL PVC COMPARISON PIPES

- Cradle To Gate
- Final Transportation & Installation
- Corrosion Protection
- Replacement Energy Cradle Thru Install

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LIFE CYCLE OF A PIPE

Product Stage (Cradle-To-Gate)

Construction Process Stage

Use Phase

End of Life

Transportation

Raw Materials

Manufacturing

Installation and Use

Final Product Disposition
PVC LCA SUMMARY

• Utilities can use it to evaluate the sustainability of PVC pipe

• It proves the environmental benefits for using PVC pipe

• It gives PVC credits for reducing net embodied energy and greenhouse gas emissions

• It can be used to prove PVC pipe use can provide a reduction in a carbon tax if such a tax were to be instituted
THANK YOU

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