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# Life Cycle Analysis of Soil and Bio-Based Landfill Cover Systems

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&

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1. Introduction

2. Study Objectives

3. Cover System Design

4. Sustainability Analysis

5. Conclusions

# oduction – Landfill Cover
tems

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Purpose of
ndfill covers

- ❑ Minimize leachate generation; resist erosion
- ❑ Prevent waste exposure to disease-causing vectors & improve aesthetics
- ❑ Minimize LFG emissions

of cover systems to minimize $CH_4$ emissions from landfills has
ned increasing interest

& $CO_2$ are major greenhouse gases; 100 year GWP of $CH_4$ is 28

dfills - third largest source of anthropogenic $CH_4$ emissions in USA

FG collection systems serve as major controls for methane
missions

- ❑ Cost-intensive to operate
- ❑ Fugitive emissions can occur (addressed using cover systems)

# oduction – Landfill Cover tems

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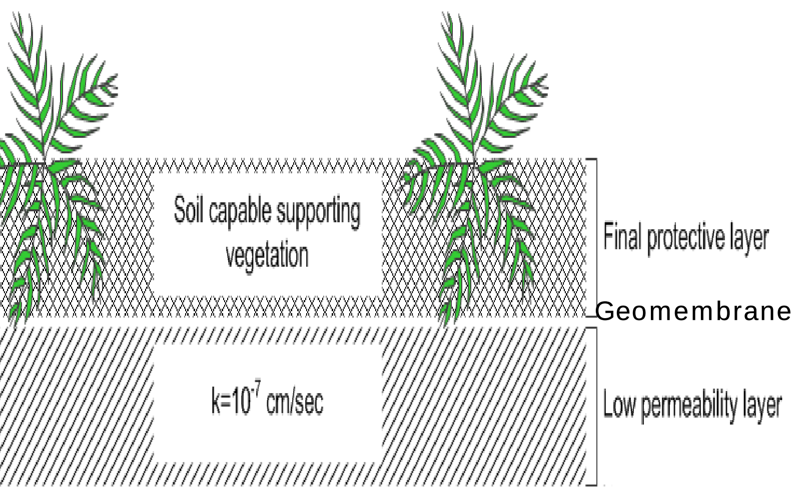
## Types of Landfill Cover Systems

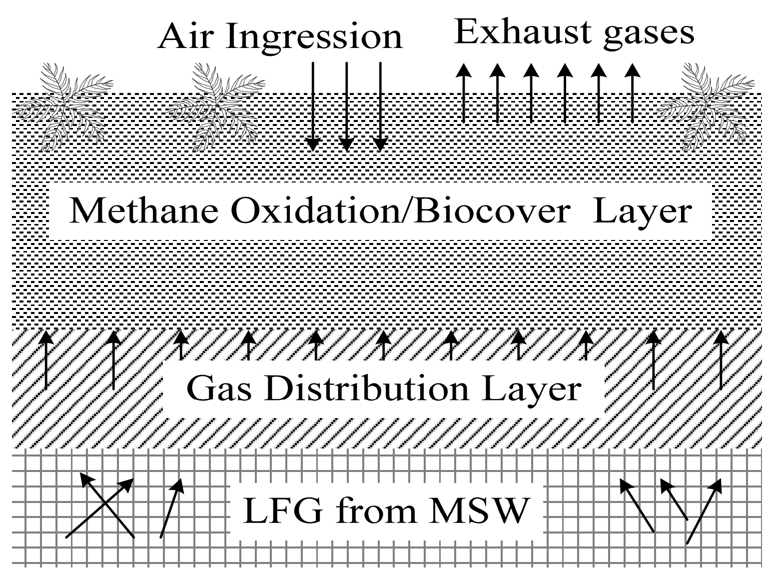
### ubtitle D Final Covers




nois administrative code requirements

USEPA minimum

### Biocovers



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# dy Objectives

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Design final cover systems (soil cover & biocover) capable of achieving maximum methane oxidation

Conduct LCA & compare the sustainability of using soil cover versus biocover for a landfill site in Illinois

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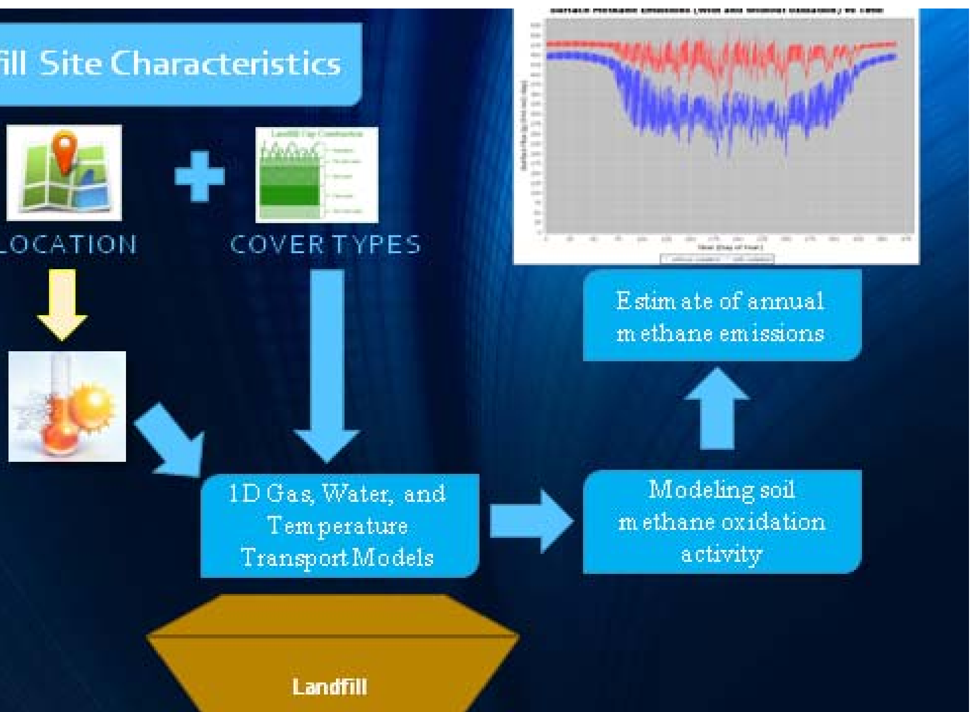
# er System Design



## ALMIM (Version 5.1) – California Landfill Methane Inventory Model

Field-validated model compliant with IPCC Tier III methods for $CH_4$ emissions from landfills




### Steps for Modeling

- ❑ Enter location
- ❑ Type of cover
- ❑ Cover material properties
- ❑ Extent of area covered by gas wells
- ❑ Cover layers

# ver Design Assumptions

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| CALMIM Assumptions | User Input Assumptions |
| --- | --- |
| Temperature: lower 40°C | ❑ Functional Unit (1 acre) |
| $CH_4$: upper 2 ppm (v/v) | ❑ Cover area – 100% |
| $CH_4$: lower 55% (v/v) | ❑ 85% Vegetation Cover |
| oxygen: upper 20% (v/v) | ❑ 0% Gas Extraction |
| oxygen: lower 0% (v/v) | ❑ "Low" Organic Matter |
| $CH_4$ oxidation rate (optimum for soils) 400 mg $CH_4$/g soil/d | ❑ $CH_4$ oxidation rate (optimum) for biocover is 3800 µg $CH_4$/g soil/d (Pederson et al. 2011) |

# al Cover Designs

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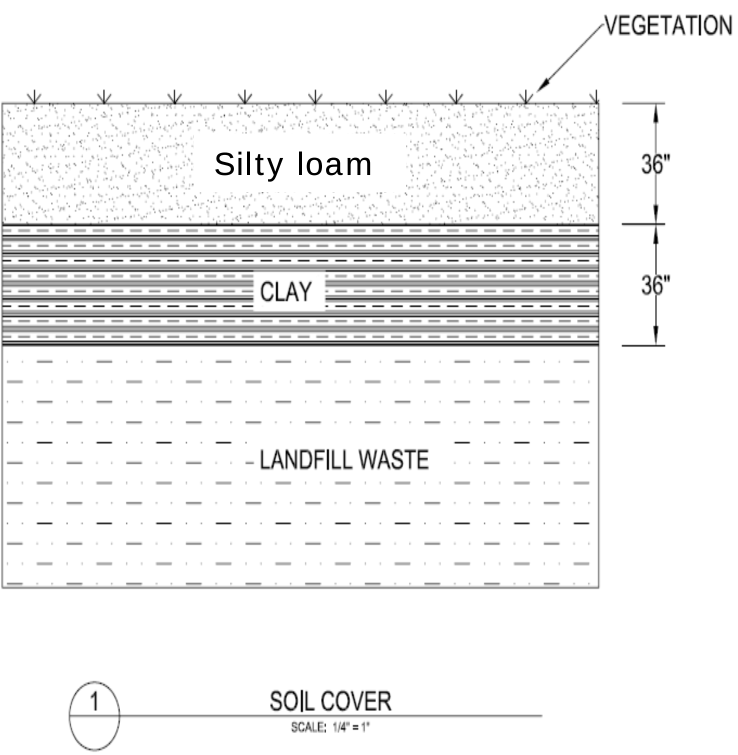
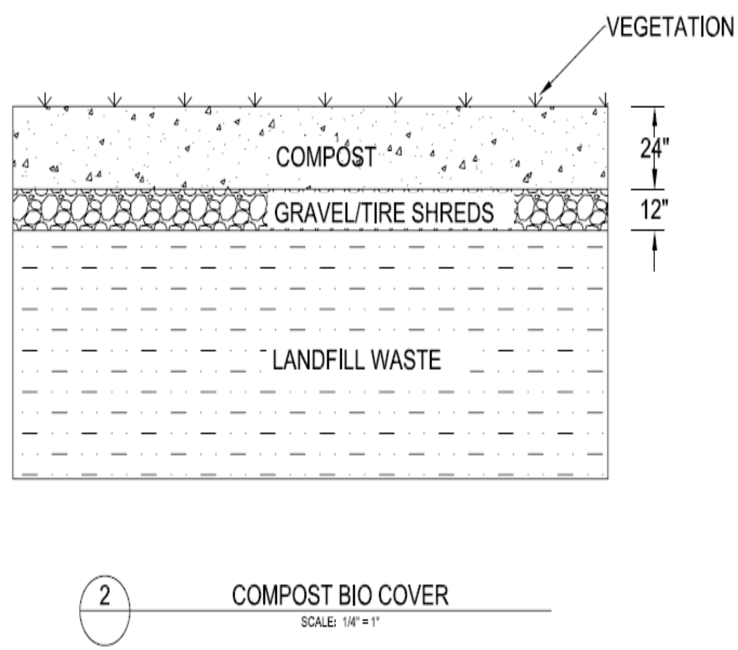
## Soil Cover




## Biocover



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# pe of LCA

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## System Boundary for LCA

Manufacture of cover components

Transport of materials to site

Placement of cover materials (compaction)

Monitoring emissions & cover maintenance

Functional unit – 1 acre of LF site

Design life – 50 yrs

imapro (Version 7) – Professional tool for LCA ('PRé Consultants')

e cover system options analyzed:
Soil cover (clay from stockpile on site)
Soil cover (silty loam & clay from offsite)
Biocover (tire shreds as GDL)
Biocover (gravel as GDL)

Emissions monitoring & cover maintenance assumed to be similar for cover systems

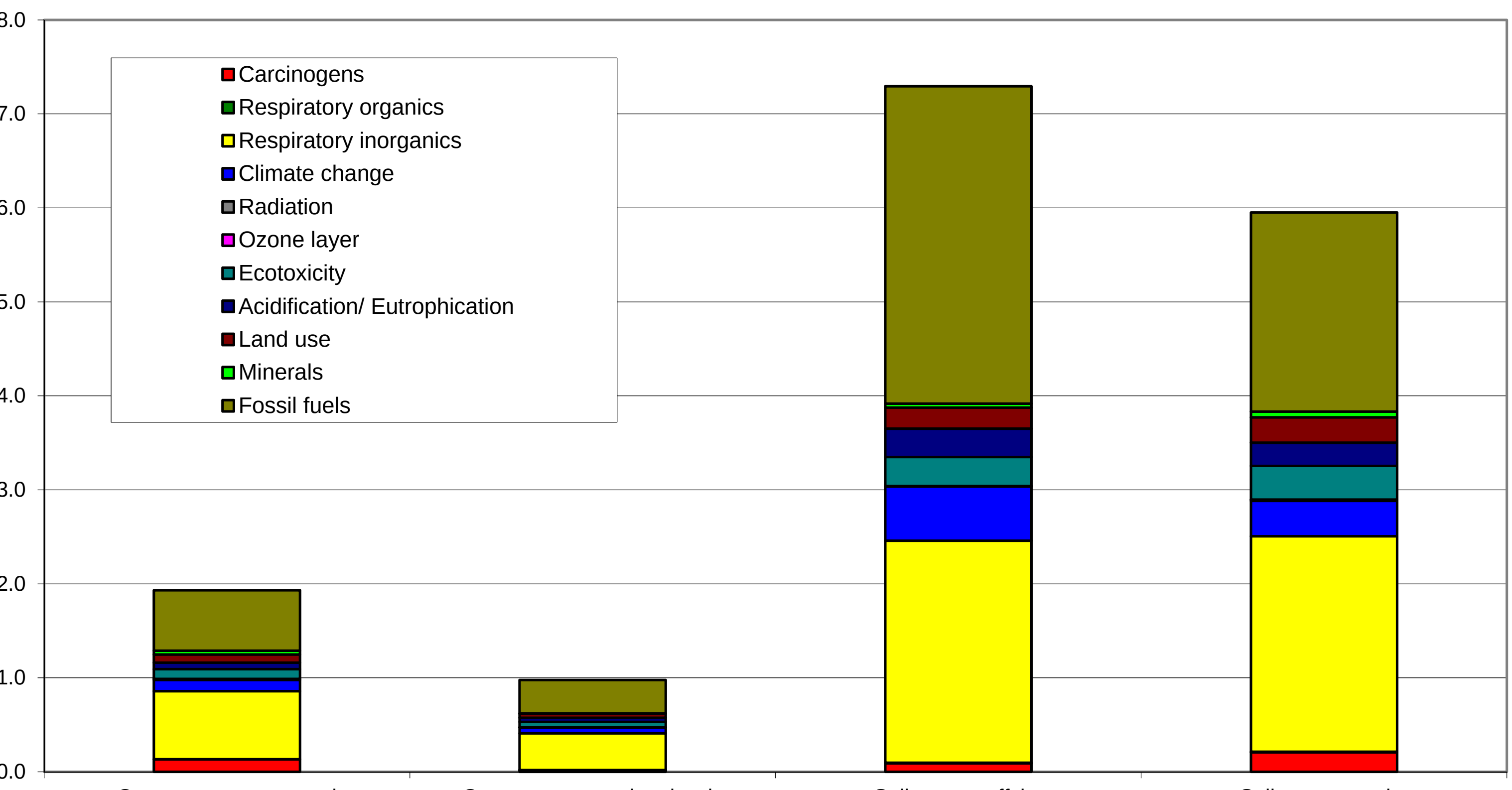
| Material Specification | Volume ($m^3$) | Material Density ($kg/m^3$) | Weight (tons) | Distance (Km) | tkm (ton-kilometer) |
|---|---|---|---|---|---|
| Compost | 2,467 | 500[a] | 1,234 | 17.1 | 21,044 |
| Gravel | 1,233 | 1,600 | 1,973 | 2.1 | 4,143 |
| Tire shreds | 1,233 | 450[b] | 1,989 | 3.2 | 6,364 |
| Clay | 3,700 | 1,250 | 4,625 | 16.0 | 74,000 |
| Silty loam | 3,700 | 1,380 | 5,107 | 16.0 | 81,705 |

# ironmental Sustainability
# ults



-Indicator 99(E) V2.08 method (European standards for normalization of
pact values)

veloped based on a series of complex damage assessment models; 3 damage
egories – human health, ecosystem & resources



# nomic Sustainability
# lysis



ost comparison was made between soil cover system & biocover stem w/ gravel as GDL

| terial | Material Vol. ($m^3$) | Location | Distance (Km) | Unit Cost (per 0.8 $m^3$) | Unit Cost Consideration |
|---|---|---|---|---|---|
| y | 3,700 | Available on Site | 0 | $4 | transport, spreading, and compaction |
| y am | 3,700 | Local sources | 16 | $17 | Material cost, transport, and spreading |
| avel | 1,233 | Local sources | 16 | $17 | Material cost, transport, and spreading |
| mpost | 2,467 | Local sources | 16 | $22 | Material cost, transport, and placement |

Total Soil Cover Cost
$101,640

Total Biocover Cost
$98,432

# ial Sustainability Analysis

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## Social Sustainability Rating Chart (Bennoit-Norris et al. 2011)

| akeholder oup | Impact Category | Soil Cover | Bicover |
|---|---|---|---|
| orkers | F | 0 | 0 |
| | | 0 | 0 |
| | | 0 | 0 |
| | | 0 | 0 |
| | | 0 | 0 |
| | | 0 | 0 |
| | | 1 | 1 |
| | | 0 | 0 |
| onsumers | | 1 | 1 |
| | | 0 | 0 |
| | | 0 | 0 |
| | | 0 | 0 |
| cal Community | | 1 | 1 |
| | | 1 | 0 |
| | | 0 | 0 |
| | | 0 | 1 |
| | | 1 | 0 |
| ociety | | 1 | 0 |
| | C | 0 | 0 |
| | Prevention and Mitigation of Armed Conflicts | 0 | 0 |

'Local Community' – The very existence of a landfill can cause migration;
Possibility of $CH_4$ build-up & lateral migration causing risk of explosions around the landfill

Workers – Possibility of hazardous environments in mines/ quarry;
Placement of cover materials can cause dust-related heath hazards

# vision$^{TM}$ Analysis

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Sustainability rating tool by ISI (Institute for Sustainable Infrastructure) & Harvard University Grad School of Design

| es | Some major questions answered in 14 sub-categories |
|---|---|
| | **Does the project preserve / enhance local resources?** |
| of | **Are there health risks for employees of nearby residents?** |
| | **Are local residents employed** |
| | Does project help growth/development of community? |
| | Is project located near public transportation? |
| | Is there a sustainability management system in place? |
| | Does project account for long-term maintenance? |
| nip | Are all stakeholders equally involved? |
| | Does the project pursue synergies with both products & other systems? |
| | **Does project minimize use of fossil fuel based energy?** |
| | **Does the project utilize local materials?** |
| e<br>on | Does project protect freshwater availability? |
| | How is waste from project handled? |
| | **Does project use sustainable materials (recycled / re-used)?** |
| | Does project preserve local habitats & biofiversity & manage invasive species? |
| | **Does project manage soils disturbed during construction?** |
| | Does project manage pollution in stormwater & groundwater? |
| | Does project minimize disruption to surface water & wetlands? |
| | **Does project minimize GHG emissions?** |
| & | **Does project reduce air pollutant emissions?** |

A comprehensive questionnaire; credits assigned based on performance levels – improved, enhanced, superior, conseravative of no added value

Higher points achieved by a project implies it is more sustainable

Applied to roads, bridges, pipelines, railways, airport, dams, levees, landfills, water treatment systems & other Civil infrastructure projects

# vision™ Analysis

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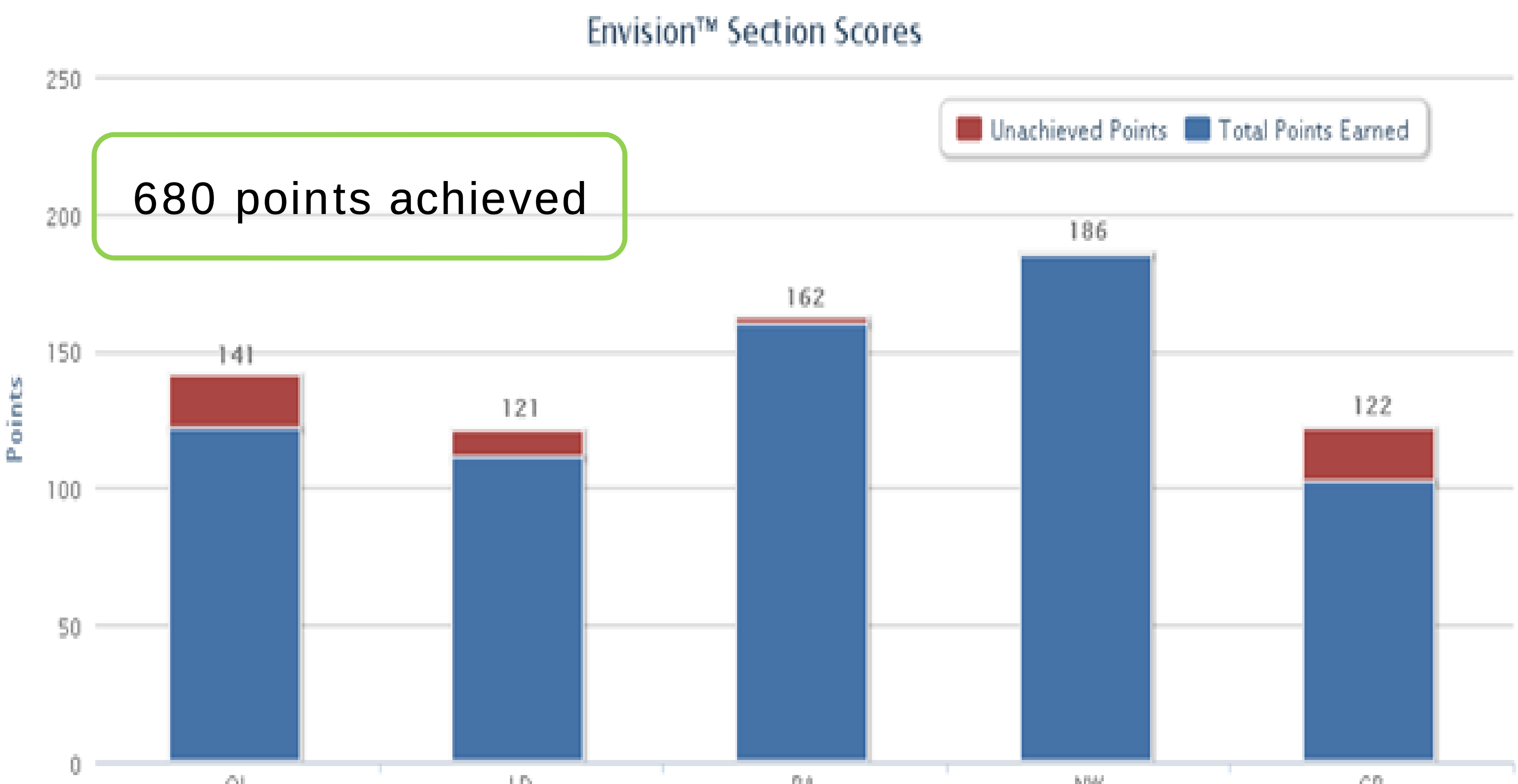
Scores for Biocover

680 points achieved



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# clusions

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Biocover appears to be an environmentally, economically and socially sustainable option compared to soil cover under the assumptions specific to this study

Envision™ analysis results indicate that biocover system achieves a higher sustainability rating score than the soil cover – this is an overall qualitative analysis

Social sustainability analysis is subjective – points to the need for developing a more methodical & definitive quantification tool

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# Thanks!

Discussions