Smart Growth Along the Proposed Phoenix Light Rail Expansions Can Reduce Future Urban Energy Consumption and Environmental Impacts
Extensions
Project Goals

- Different scenarios
  - Transit-Oriented Development (TOD) vs. Business as Usual (BAU)
  - Scenario 1 – TOD as single-family homes
  - Scenario 2 – TOD as high density apartments, mixed-use commercial/residential
  - Land use at each station
    - Conservative – vacant lots
    - Aggressive – vacant lots and parcels that could be acquired for TODs
- Diverse locations
  - Mesa (E. Main St and Mesa Dr) – Heavy Commercial/Office + Residential
  - I-10 corridor, Phoenix (I-10 and 35th Ave) – Smaller Apartment Mixed Use
  - North Phoenix (N 19th Ave and Dunlap Ave) – Smaller Apartment Mixed Use
- Comprehensive analysis of energy and environmental effects, barriers, and transition strategies
Life Cycle Assessment

- **Buildings**
  - Building Construction
  - Electricity Feedstock Production
  - Building Use

- **Transportation**
  - Vehicle Manufacturing
  - Gasoline Feedstock Production
  - Automobile Use

- **Environmental Indicators**
  - Energy Use
  - Greenhouse Gas Emissions
  - Criteria Air Pollutant Emissions (CO, VOCs, NOx, SOx, PM$_{10}$, PM$_{2.5}$)
Sustainability Approach

Diagram showing the interconnection of Social, Environmental, Economic, and Sustainable aspects.

- Social
  - Bearable
  - Equitable
- Environment
  - Viable
- Economic
  - Sustainable
Transition Intervention

Current Intervention
- Light Rail Investment

Post WWII Auto-Dominated Growth

Light Rail Investment

Successful TOD Implementation and Use

Business as Usual
## Barriers

<table>
<thead>
<tr>
<th>Conditions/Challenges</th>
<th>Resulting Barriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rapid Growth, 30 years</td>
<td>Weak Urban Core</td>
</tr>
<tr>
<td>Urban Sprawl</td>
<td>Uniform Mindset</td>
</tr>
</tbody>
</table>
  - Housing Industry Reliance | Housing Types |
  - Highway Infrastructure Dependence | Highway Infrastructure Dependence |
| Council-Manager Government | Competing Development Priorities |
| Private Property Rights Protection Act (Proposition 207; 2006) | Inefficient Land Assembly |
TOD Best Practices

- Walkable Neighborhoods
  - Walkscore

- Efficient Resident / Workers Ratio
  - Job Density
  - TOD Typologies

- Social Resident Interaction
  - Place Making
Project for Public Spaces

Place Making and Power of 10

- Number of women, children & elderly
- Social networks
- Volunteerism
- Evening use
- Street life

Uses & Activities
- Fun
- Active
- Vital
- Special
- Real
- Useful
- Indigenous
- Celebratory
- Sustainable

Sociability
- Pride
- Friendly
- Interactive
- Welcoming

Access & Linkages
- Continuity
- Proximity
- Connected
- Readable
- Walkable
- Convenient
- Accessible

Comfort & Image
- Safe
- Clean
- "Green"
- Walkable
- Sitable
- Spiritual
- Charming
- Attractive
- Historic

Measurements
- Local business ownership
- Land-use patterns
- Property values
- Rent levels
- Retail sales

Intangibles
- Environmental data
- Building conditions
- Sanitation rating
- Crime statistics

Key Attributes
- Environmental
- Sustainable
- Historically
- Attractive
- Charming
- Walkable
- Sitable
- "Green"
- Safe
- Clean
- Connected
- Readable
- Accessible
- Welcoming
- Interactive
- Friendly
- Prized
- Fun
- Vital
- Special
- Real
- Useful
- Celebratory
- Indigenous
- Sustainable

Solutions

- Walkable Neighborhoods
  - Encourage Place Making

- Flexible Form Base Code
  - Commercial/Resident Mix

- Market Light Rail Vision
  - Share Light Rail Vision
  - Relay TOD Benefits
  - Promote Transit-Oriented Choices
    - User Incentives
### Transitions
- **Conditions**
- **Barriers**
- **Solutions**

#### Roberta Bosfield
- Amelia Celoza
- Gilbert Flores
- Ryan Fucini

#### Nick Francis
- Mindy Kimball
- Ph.D. Candidate

### Buildings
- **Construction**
- **Energy Production**
- **Energy Use**

#### Andrew Fraser
- Sam Johnson
- Drew Rostain

#### Sam Johnson
- Andrew Kaehr
- Minghao Xu

#### Andrew Kaehr
- Valentina Prado

### Transportation
- **Vehicle Manufacturing**
- **Energy Production**
- **Gasoline Combustion**

#### Matt Nahlik
- Kieth Christian

#### Kieth Christian
- Madhav Garikapati
- Andy Yu
What are the energy and environmental effects of residential and commercial building densification around light rail stations?
Land Selection Methodology

- Light rail extension plan (Valley Metro)
- Land parcel selection (Maricopa County Assessor, Google Maps)
- Conservative strategy
  - Vacant lots within ½ mile radius
- Aggressive strategy
  - Vacant lots + currently occupied land that could be repurposed within ½ mile radius
19th Ave & Dunlap

5.8 Acres

Conservative
19th Ave & Dunlap

10.8 Acres
I-10 & 35th Ave

23.8 Acres

Conservative
I-10 & 35th Ave

26.3 Acres

Aggressive
Mesa

32.1 Acres

Conservative
Building Models & Allocation

<table>
<thead>
<tr>
<th>Type</th>
<th>TOD Conservative</th>
<th>TOD Aggressive</th>
<th>BAU Conservative</th>
<th>BAU Aggressive</th>
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<tr>
<td>Single Family Home</td>
<td>38</td>
<td>42</td>
<td>2494</td>
<td>3906</td>
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<tr>
<td>4 Floor (3R, 1C)</td>
<td>50</td>
<td>97</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6 Floor (5R, 1C)</td>
<td>-</td>
<td>7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>12 Floor (10R, 2C)</td>
<td>10</td>
<td>10</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3 Floor (3R)</td>
<td>19</td>
<td>19</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Commercial Space (1C)</td>
<td>3</td>
<td>3</td>
<td>169</td>
<td>277</td>
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<tr>
<td>Medium Commercial (6C)</td>
<td>16</td>
<td>25</td>
<td>-</td>
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<tr>
<td>Parking Spots</td>
<td>5808</td>
<td>1004</td>
<td>2028</td>
<td>3324</td>
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</table>
Building Life-cycle Modeling

- Building Construction
  - RS Means: Materials and Construction Processes
  - Athena: Energy use and emissions
- Building Use Phase (60 years)
  - Energy Plus: Electricity Consumption
  - GREET: Emissions
In 2006, Arizona Corporation Commission set a goal for increasing renewable energy use:

- **2006** – 1.25%
- **2012**
  - Projected – 3.5%
  - Actual – 3.1% Non-Hydro, 6.1% Hydro
- **2025** – 15%
Arizona’s Uncertain Energy Future

PRELIMINARY RESULTS. PLEASE VISIT urbansustainability.lab.asu.edu FOR INFORMATION ABOUT FINAL RESULTS.

Base Case Energy Mix Outlook

<table>
<thead>
<tr>
<th>Year</th>
<th>Natural Gas</th>
<th>Coal</th>
<th>Nuclear+Renewable</th>
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<tbody>
<tr>
<td>2012</td>
<td>30%</td>
<td>40%</td>
<td>30%</td>
</tr>
<tr>
<td>2022</td>
<td>20%</td>
<td>30%</td>
<td>20%</td>
</tr>
<tr>
<td>2032</td>
<td>10%</td>
<td>40%</td>
<td>10%</td>
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<tr>
<td>2042</td>
<td>0%</td>
<td>50%</td>
<td>0%</td>
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<tr>
<td>2052</td>
<td>0%</td>
<td>60%</td>
<td>0%</td>
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<tr>
<td>2062</td>
<td>0%</td>
<td>70%</td>
<td>0%</td>
</tr>
<tr>
<td>2072</td>
<td>0%</td>
<td>80%</td>
<td>0%</td>
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Optimistic Energy Mix Outlook

<table>
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<th>Year</th>
<th>Natural Gas</th>
<th>Coal</th>
<th>Nuclear+Renewable</th>
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<tbody>
<tr>
<td>2012</td>
<td>10%</td>
<td>90%</td>
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<tr>
<td>2022</td>
<td>30%</td>
<td>70%</td>
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<tr>
<td>2032</td>
<td>50%</td>
<td>50%</td>
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<tr>
<td>2042</td>
<td>70%</td>
<td>30%</td>
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</tr>
<tr>
<td>2052</td>
<td>90%</td>
<td>10%</td>
<td>0%</td>
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<td>2062</td>
<td>100%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>2072</td>
<td>100%</td>
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</table>

Pessimistic Energy Mix Outlook

<table>
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<th>Natural Gas</th>
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<th>Nuclear+Renewable</th>
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</thead>
<tbody>
<tr>
<td>2012</td>
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<tr>
<td>2022</td>
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<tr>
<td>2032</td>
<td>40%</td>
<td>60%</td>
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<tr>
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<td>80%</td>
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</tr>
<tr>
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<td>10%</td>
<td>90%</td>
<td>0%</td>
</tr>
<tr>
<td>2072</td>
<td>0%</td>
<td>100%</td>
<td>0%</td>
</tr>
</tbody>
</table>
Buildings Life Cycle GHG Emissions

Greenhouse Gas Emissions

Over 60 Years

CO2 Equivalence (Mg)

- Commercial Construction
- Commercial Energy Production
- Commercial Energy Use
- Residential Construction
- Residential Energy Production
- Residential Energy Use

TOD
BAU

PRELIMINARY RESULTS. PLEASE VISIT urbansustainability.lab.asu.edu FOR INFORMATION ABOUT FINAL RESULTS.
Building Life Cycle NOx Emissions

PRELIMINARY RESULTS. PLEASE VISIT urbansustainability.lab.asu.edu FOR INFORMATION ABOUT FINAL RESULTS.

Nitrous Oxides (NOx)
Over 60 Years

<table>
<thead>
<tr>
<th>Category</th>
<th>TOD</th>
<th>BAU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Commercial Construction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial Energy Production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial Energy Use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential Construction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential Energy Production</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Residential Energy Use</td>
<td>1600000</td>
<td></td>
</tr>
</tbody>
</table>

kg
What are the transportation energy and air emissions changes that occur from urban infill around light rail?
Transportation Methodology

Inputs
- 2009 NHTS
- Census Data
- Buildings Data
- Literature and Valley Metro Surveys

Methodology
- Number of HH and Trips within Buffer
- Densities within Buffer
- TOD Types and Total Dwelling Units

Calculations
- Average Trip Rate
- Total Number of Trips within Buffer
- Total Trips within TOD

Outputs
- Auto Travel Reductions
- Emissions Savings
Environmental Approach

- Quantify Vehicle Miles Traveled (VMT) for each scenario
- Life-Cycle Approach
- Vehicle Manufacturing, Well-to-Tank Fuel Production, Vehicle Operation
- GREET model by the EPA
- Examine Energy Use, Greenhouse Gas Emissions, and Criteria Pollutant Emissions
- Reduce travel distance with infill and number of car trips with mode-shift to light rail
Average Trip Rates and Densities

Residential-induced Travel

- Urban Infill Travel Characteristics
- Fringe Travel Characteristics

Commercial-induced Travel

- Institute of Transportation Engineers’ Trip Generation Manual
- Commercial real estate area from the buildings team
- Characteristic shopping travel from NHTS
# Vehicle Analysis

<table>
<thead>
<tr>
<th></th>
<th>Use % From NHTS</th>
<th>Characteristic Travel Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cars</td>
<td>49.1%</td>
<td>51.4%</td>
</tr>
<tr>
<td>Vans</td>
<td>7.8%</td>
<td>8.2%</td>
</tr>
<tr>
<td>SUVs</td>
<td>19%</td>
<td>19.9%</td>
</tr>
<tr>
<td>Pick-Up Trucks</td>
<td>19.6%</td>
<td>20.5%</td>
</tr>
<tr>
<td>Totals:</td>
<td><strong>95.5%</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

Commute travel assumed to be characterized by four categories of vehicles shown.


**Projected Fuel Economy**

- **Year**: 2012, 2022, 2032, 2042, 2052, 2062, 2072
- **Miles Per Gallon**: 0, 10, 20, 30, 40, 50, 60
- **Lightweighting**
Possible VMT Savings
High-density Mixed Use

Residential-induced and Commercial-induced
Daily Vehicle Miles Traveled (VMT) Totals

- Conservative savings between 100,000-150,000 miles per day
- Aggressive savings between 160,000-240,000 miles per day

PRELIMINARY RESULTS. PLEASE VISIT urbansustainability.lab.asu.edu FOR INFORMATION ABOUT FINAL RESULTS.
Critical Considerations

- Travel characteristics of TOD residents
- Maximum and minimum mode shift percentages
- Percentage of shopping trips per household
- Percentage of shopping trips generated from the TOD’s
- Commercial trip generation
- Light weighting of vehicles to reach 55mpg
Transportation Selected Results

Life-Cycle Energy Use Over 60 Years (TJ)

- High-density TOD Mixed Use
- Auto-Dependent Single Family Outfill

Life-Cycle NOx Emissions Over 60 Years (Mg)

- High-density TOD Mixed Use
- Auto-Dependent Single Family Outfill

PRELIMINARY RESULTS. PLEASE VISIT urbansustainability.lab.asu.edu FOR INFORMATION ABOUT FINAL RESULTS.
What are the comprehensive energy and air emissions changes that occur from urban infill around light rail?
Environmental Indicators

- **Energy**
  
- **Air Emissions**
  - $\text{SO}_x$: Respiratory irritant, acid deposition
  - $\text{CO}$: Asphyxiant
  - $\text{NO}_x$: Respiratory irritant, smog
  - $\text{VOC}$: Photochemical smog, cancerous
  - $\text{PM}$: Respiratory and cardiovascular damage

- **Greenhouse Gases**
  - $\text{CO}_2$, $\text{CH}_4$, $\text{N}_2\text{O}$

- **Human Health and Environmental Impact Potentials**
  - Respiratory: $\text{SO}_x$, $\text{NO}_x$, $\text{PM}_{10}$ and $\text{PM}_{2.5}$
  - Photochemical Smog Formation: $\text{CH}_4$, $\text{CO}$, $\text{VOC}$, and $\text{NO}_x$
Consolidated Results

60 Year Life-Cycle Greenhouse Gas Emissions ($10^6$ Mg CO$_2$e)

- 365 Single-Family TOD
- 365 Auto-dependent Single-Family Outfill
- 2500 High-density TOD Mixed Use
- 2500 Auto-dependent Residential+Commercial Outfill
- 568 Single-Family TOD
- 568 Auto-dependent Single-Family Outfill
- 3900 High-density TOD Mixed Use
- 3900 Auto-dependent Residential+Commercial Outfill

- Residential Building Construction
- Commercial Building Construction
- Vehicle Manufacturing HBNS
- Vehicle Manufacturing HBS
- Residential Building Energy Production
- Commercial Building Energy Production
- Energy Production for HBNS Travel
- Energy Production for HBS Travel
- Residential Building Energy Use
- Commercial Building Energy Use
- Gasoline Combustion for HBNS Travel
- Gasoline Combustion for HBS Travel

PRELIMINARY RESULTS. PLEASE VISIT urbansustainability.lab.asu.edu FOR INFORMATION ABOUT FINAL RESULTS.
60 Year Life-Cycle Human Greenhouse Gas Emissions ($10^6$ Mg CO₂e)

- 2500 High-density TOD Mixed Use
- 2500 Auto-dependent Residential+Commercial Outfill
- 3900 High-density TOD Mixed Use
- 3900 Auto-dependent Residential+Commercial Outfill

60 Year Life-Cycle Human Health Respiratory Potential (Gg PM$_{10}$e)

- 2500 High-density TOD Mixed Use
- 2500 Auto-dependent Residential+Commercial Outfill
- 3900 High-density TOD Mixed Use
- 3900 Auto-dependent Residential+Commercial Outfill

60 Year Life-Cycle Smog Formation Potential (Gg O₃e)

- 2500 High-density TOD Mixed Use
- 2500 Auto-dependent Residential+Commercial Outfill
- 3900 High-density TOD Mixed Use
- 3900 Auto-dependent Residential+Commercial Outfill

PRELIMINARY RESULTS. PLEASE VISIT urbansustainability.lab.asu.edu FOR INFORMATION ABOUT FINAL RESULTS.
What are the non-technical TOD implementation barriers and how can they be overcome?
Housing and Transportation Cost Burden

Cost Burden on Moderate-Income HH Budgets

- Miami MSA
- Riverside MSA
- Tampa MSA
- Los Angeles MSA
- San Diego MSA
- Atlanta MSA
- Sacramento MSA
- Phoenix MSA

#8 Phoenix MSA: 62% cost burden

Housing Costs
Transportation Costs
Recommendations

1. Standardize best practices: walkscores, worker / resident ratios, station typologies
2. Master plan ½ mile from each station
3. Evaluate the entire light rail system
4. Involve residents in business recruitment, project approval
5. Promote the TOD car-less lifestyle
Changing the Balance

TOD

Path Dependence

PUBLIC

Planning

Leadership

Developers

Previous Investments
For additional information, please contact:

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Arizona State University
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Presentation and report will be available:
urbansustainability.lab.asu.edu