Net Zero Energy Retrofit
Context

- Started with CMHC’s EQuilibrium Housing initiative.
- 5100°F (9180°F) Heating Degree Day Climate
- -34°C Design Temperature

Belgravia NetZero

Riverdale NetZero

Mill Creek NetZero

South Windsor Park NetZero

Parkland NetZero
Thanks

- Habitat Studio & Workshop Ltd.
- Howell-Mayhew Engineering
- Solnorth Engineering
- CMHC
- Conergy Canada Ltd
- SESCI-NAC
- NAIT
- City of Edmonton
- Servus Credit Union
- Alberta Research Council
- Pembina Institute
- Hydraft Development Services
- Eco Ammo
- Conrad Nobert and Family
- Dr Sam Wong
- Green Alberta
- Relumen Engineering Ltd.
- The Urban Farmer
- Hicklin Consulting
- Green Door Builders
- Ron Wickman Architect
- Shafraaz Kaba
- Philip Mees P.Eng.
- Tang Lee Architect
- Duxton Windows
- Mancap Ventures
- Climate Change Central
- Bob Heath
- Dennis and Christy Cuckoo
- Aaron and Nicki Dublenko
Retrofits of Existing Housing

• 85% of the housing stock we will be using in 2050 is already built

• The cost per kWh saved with energy retrofits is significantly higher than for new construction

• The hardest houses to fix will be those most recently built
Now House, Toronto

Achieve an annual energy cost of zero
1. Reduce electricity use by 59.8%
2. Reduce heat loss to achieve EGH rating of 84
3. Produce energy on site increasing EGH to 94
4. Use minimal new resources and produce minimal waste
Net Zero Energy

- Produces all of its own energy for Heating, DHW, Lighting and Appliances on site over the course of a year.
- Next to impossible without aggressive conservation and good solar orientation.
Starting Point

- 1960’s 2x4 construction
- Recently renovated
- 1200 sq. ft. bungalow with a finished basement
Existing Condition

- 1230 Sq.ft. bungalow with a finished basement
- L shaped
- South exposure, no south windows
- Large trees

Site

Objective

- Net Zero Annual Energy
- Add enough space to accommodate parents
- Minimize disruption to existing finishes

Floor Plan
Modelling

• HOT2000
• Essential for cost control
• Model early
• Model in house if possible
# Starting Energy Consumption

<table>
<thead>
<tr>
<th></th>
<th>Base Case</th>
<th>Belgravia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Space Heating Energy* - kWh/year</td>
<td>25743</td>
<td>3270</td>
</tr>
<tr>
<td>Lighting, Appliances, &amp; Miscellaneous Electrical (L.A.M.E.) kWh/year</td>
<td>8760</td>
<td>3150</td>
</tr>
<tr>
<td>Domestic Hot Water (DHW) kWh/year</td>
<td>5317</td>
<td>3430</td>
</tr>
<tr>
<td>Total Annual Energy - kWh/year</td>
<td>39820</td>
<td>9850</td>
</tr>
</tbody>
</table>

*This has already been reduced to take into account useable solar gains and internal gains.

All PV?
## Reduce L.A.M.E. and Domestic Hot Water

<table>
<thead>
<tr>
<th></th>
<th>Original</th>
<th>Reduced L.A.M.E. &amp; DHW</th>
<th>Belgravia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Space Heating - kWh/year</td>
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</tbody>
</table>
Electrical Load Reduction

- Energy Efficient Appliances
  - refrigerator
  - clothes washer
  - cooking
- Energy Efficient Lighting
  - compact fluorescents
  - LEDs
  - task lighting
  - day lighting
- Energy Efficient Motors
  - ventilation
  - heating
- Phantom Load Control
- Consumption Monitors
Domestic Hot Water Reduction

- Low Flow Showers and Faucet Aerators
- Efficient Appliances
- Aim for 150 litres of hot water per day or less
- Install a demand hot water tank or equivalent
Reduce Water Heating Energy

- Drain Water Heat Recovery - Configure plumbing for shower water collection
- Electric or Condensing Natural Gas - 90% + efficiency
- Demand Hot Water Tanks
- Insulate Hot Water Tanks
Cost per kWh/year of energy conservation measures

=  

Cost per kWh/year of Energy collection
Envelope Modelling/Optimization

• Determine Current PV cost or benchmark energy price.
• Evaluate envelope upgrades with respect to cost per kWh/year
• Optimize envelope specifications
• Extra conservation cost can often be offset by simpler mechanical systems
## Space Heat*- Where is it going?

<table>
<thead>
<tr>
<th>Description</th>
<th>Original (kWh/year)</th>
<th>Belgravia (kWh/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walls ~R10</td>
<td>11366</td>
<td>2283</td>
</tr>
<tr>
<td>Ventilation /Air leakage -assuming ~2.5ACH-50</td>
<td>8474</td>
<td>1989</td>
</tr>
<tr>
<td>Roof ~ R40</td>
<td>2044</td>
<td>636</td>
</tr>
<tr>
<td>Basement Walls ~R8 and Floor ~R 0.5</td>
<td>9143</td>
<td>2494</td>
</tr>
<tr>
<td>Windows and Doors - Dual Low E Argon</td>
<td>6269</td>
<td>6549</td>
</tr>
<tr>
<td><strong>Total Heating Energy Loss NIC Passive Solar and Internal Gains (kWh/year)</strong></td>
<td>37296</td>
<td>13951</td>
</tr>
</tbody>
</table>

*These numbers represent gross space heat before accounting for passive solar and internal gains
## Space Heat Upgrades*

<table>
<thead>
<tr>
<th>Upgrade</th>
<th>Original (kWh/year)</th>
<th>Saving (kWh/year)</th>
<th>After Upgrade (kWh/year)</th>
<th>Belgravia (kWh/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof from R40 to R80</td>
<td>2044</td>
<td>977</td>
<td>1067</td>
<td>636</td>
</tr>
<tr>
<td>Walls from R40 to R56</td>
<td>4037</td>
<td>488</td>
<td>3549</td>
<td>2283</td>
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<tr>
<td>Walls from R10 to R40</td>
<td>11366</td>
<td>7329</td>
<td>4037</td>
<td>2283</td>
</tr>
<tr>
<td>Basement Walls (R42) and Floor (R10)</td>
<td>9143</td>
<td>6193</td>
<td>2950</td>
<td>2494</td>
</tr>
<tr>
<td>Upgrade Windows and Doors</td>
<td>6269</td>
<td>1170</td>
<td>5099</td>
<td>6549</td>
</tr>
<tr>
<td>Air leakage from 2.5ACH** to .75 ACH</td>
<td>8474</td>
<td>2903</td>
<td>5571</td>
<td>1989</td>
</tr>
<tr>
<td><strong>Total Heating Energy Loss NIC Passive Solar and Internal Gains (kWh/year)</strong></td>
<td><strong>37296</strong></td>
<td><strong>19060</strong></td>
<td><strong>18236</strong></td>
<td><strong>13951</strong></td>
</tr>
</tbody>
</table>

*These numbers represent gross space heat before accounting for passive solar and internal gains  
** ACH - Air changes per hour at -50 pascals
Roof/ Ceiling

- Existing attic already has already R40
- Low heel trusses in existing attic
- HOT2000 predicted savings of 988kWh/year for R80
- 2 possible approaches
  - Add insulation and try to seal existing attic
  - Chainsaw retrofit
Work within the existing roof

- Low truss or rafter heel limits insulation at the edge
- Hard to seal existing attic in the ceiling plane- need to move existing insulation
- Saves building a new roof overhang, soffit and fascia.
- Less expensive
Chainsaw retrofit

- Saw off the existing overhang
- Wrap roof in new air/vapour barrier and tie into new wall sheathing
- Build new roof cavity
- Roof could be configured to accommodate PV
Chainsaw Retrofit - Roof Framing
Walls / Air Tightness

• Existing walls would likely have a system R value about R10 at best

• HOT2000 predicted savings for an upgrade to R40 would save 7300 kWh/year - R56 would save 7800 kWh/year

• Getting air tightness from 2.5 ACH down to .75 ACH would save 2900 kWh/year
Walls / Air Tightness 2

- Best to strip off existing wall finish
- Air/Vapour Barrier and additional insulation should be done simultaneously
- Could also use Larsen trusses or I joists.
Wall Upgrade
Air Sealing details

Sealing New Air Barrier to Top Plate

Sealing New Air Barrier at Window/ Door Openings

Sealing New Air Barrier to Concrete Wall
Saskatoon Chainsaw Retrofit
Basement Insulation

- Upgrading the basement wall insulation to R40 and the basement floor insulation to R10 will save 6190 kWh/ year
- Can be done either inside or outside
Basement Insulation - Inside

Advantages

- Possibility to control thermal bridging at footing. (This could be worth about 1400kWh/year)
- Faster, less costly in an unfinished basement.

Disadvantages

- Lost basement space
- Disruption of existing finishes
Basement Insulation- Outside

Advantages

- No disruption to existing finished basement
- Basement wall build out supports upper wall.
- Walls remain flush on outside
- Opportunity to repair, reinforce and waterproof old foundation

Disadvantages

- Major disruption to existing decks and landscaping
- No reduction in thermal bridging at footing
- Doesn’t simultaneously provide for insulation of basement floor: Insulating the basement floor to R10 saves about 1500 kWh/year
Basement Insulation- Outside

Wrap details
Thermal Bridging

- Lots of thermal bridging in older 2x4 framed walls
- Fireplace is a significant thermal bridge. It loses 1365 kWh/year from transmission alone. This doesn’t include air leakage. Very likely losing more heat than than it produces

- Continuous Thermal Break
  - 2" of EPS Insulation
  - Type II EPS Insulation
  - Polyisocyanurate Insulation
  - Batt Insulation

Need Continuity of Insulation here
Seal new upper wall air barrier here
Air Testing
HRVs

- Locate unit as close as possible to intake and exhaust hoods
- Ductwork should be carefully designed and installed for most efficient air flow
- Select for highest heat recovery efficiency and lowest electrical use.
- Control module is important too
Windows

R 8.3, SHGC .37 (COG)

- Upgrading the existing windows in the house will save 1170 kWh/year. The savings are small because we already have double glazed windows with argon and a low E coating.

- Adding 2 unobstructed south facing windows will save 660 kWh/year.

- No additional thermal mass yet

- Minimize South U value
- Maximize South SHGC
- Minimize East, West and North U value
- Minimize frame and spacer losses.
### Space Heat*-
**after upgrades to existing envelope.**

<table>
<thead>
<tr>
<th>Upgrade</th>
<th>Original (kWh/year)</th>
<th>Retrofit w/o addition</th>
<th>Belgravia (kWh/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walls ~R10 to R56</td>
<td>11366</td>
<td>3550</td>
<td>2283</td>
</tr>
<tr>
<td>Ventilation /Air leakage 2.5 ACH to .75 ACH and add HRV</td>
<td>8474</td>
<td>5570</td>
<td>1989</td>
</tr>
<tr>
<td>Roof R40 to R80</td>
<td>2044</td>
<td>1070</td>
<td>636</td>
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<td>9143</td>
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<td>2494</td>
</tr>
<tr>
<td>Windows and Doors - Dual Low E Argon to Tri Low Argon</td>
<td>6269</td>
<td>5100</td>
<td>6549</td>
</tr>
<tr>
<td>Total Heating Energy Loss NIC Passive Solar and Internal Gains (kWh/year)</td>
<td>37296</td>
<td>18240</td>
<td>13951</td>
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</table>

*These numbers represent gross space heat before accounting for passive solar and internal gains.*
# Total Energy Needed from Renewables

<table>
<thead>
<tr>
<th></th>
<th>Upgraded Existing House</th>
<th>Original</th>
<th>Belgravia</th>
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<tr>
<td>Net Space Heating - kWh/year*</td>
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<td>Lighting, Appliances, &amp; Miscellaneous Electrical (L.A.M.E.) kWh/year</td>
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<td>3800</td>
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<td>3700</td>
<td>3430</td>
</tr>
<tr>
<td><strong>Total Annual Energy - kWh/year</strong></td>
<td><strong>16360</strong></td>
<td><strong>35595</strong></td>
<td><strong>9850</strong></td>
</tr>
</tbody>
</table>

*These numbers represent net space heat after accounting for passive solar and internal gains.*
## Renewable Energy Collection (kWh/year)

<table>
<thead>
<tr>
<th></th>
<th>Upgraded house</th>
<th>Mill Creek</th>
<th>Belgravia</th>
<th>Parkland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Useable Passive Solar</td>
<td>3800</td>
<td>8,200</td>
<td>8,300</td>
<td>17,470</td>
</tr>
<tr>
<td>Solar thermal</td>
<td>?</td>
<td>2,500</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Photo voltaic</td>
<td>?</td>
<td>8,000</td>
<td>9,900</td>
<td>21,000</td>
</tr>
<tr>
<td>Total</td>
<td>?</td>
<td>18,700</td>
<td>18,200</td>
<td>38,740</td>
</tr>
</tbody>
</table>
Mill Creek Passive Solar

- Maximum south window area
- Thermal Mass -64 mm concrete floor overlay
- Summer shading
- Over 50% of total annual space heat needs
Effect of Adding Mass

Upper Line
Light, wood frame, construction

Triple paned, low-e, argon filled, windows

Lower Line
Same windows, change construction to very high thermal mass

Space Heating (kWh)

South Window Area / Heated Floor Area [%]

Slide courtesy of Dr Rob Dumont
Higher Performance Windows & High Thermal Mass

Upper Line
Light, wood frame, construction

Triple paned, low-e, argon filled, windows

Lower Line
Change construction to very high thermal mass and install new windows

Slide courtesy of Dr Rob Dumont
Useful Volume and Area compared to Heat Loss Surface Area

<table>
<thead>
<tr>
<th></th>
<th>Original</th>
<th>Belgravia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Loss Surface Area (Square metres)</td>
<td>461</td>
<td>436</td>
</tr>
<tr>
<td>Total Enclosed Volume (Cubic metres)</td>
<td>564</td>
<td>637</td>
</tr>
<tr>
<td>Heat Loss Surface Area to Enclosed Volume Ratio</td>
<td>0.82</td>
<td>0.68</td>
</tr>
<tr>
<td>Inside Floor Area NIC Basement (Sq. metres)*</td>
<td>113</td>
<td>150</td>
</tr>
<tr>
<td>Ratio of Heat Loss Surface Area to Floor Area</td>
<td>4.07</td>
<td>2.90</td>
</tr>
</tbody>
</table>
Two Scenarios

Plan A

• 500 sq. foot second story addition

• ground level solar green house

Plan B

• 300 sq. foot main floor addition to fill in the ‘L’

• Roof shaped to accommodate PV array
Plan B

Pros

• Filling in the ‘L’ means very little extra heat loss
• Straighten out the front so one section of the building isn’t shading another.
• Opportunity to add mass on the main floor in the sun.
• New space is prime living space - in the sun
• Roof can accommodate PV
• More space with slightly less heat loss.

Cons

• Needs more work in the architecture department
• May not add as much space as required
• More disruption of existing space
## Plan B: Changes to Net Space Heating*

### Needs

<table>
<thead>
<tr>
<th>Upgrade</th>
<th>Marginal Benefit (kWh/year)</th>
<th>Remaining Space Heat (kWh/year)</th>
<th>Belgravia (kWh/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Add PlanB space with 2 more south windows</td>
<td>-122</td>
<td>8255</td>
<td>-</td>
</tr>
<tr>
<td>Add mass</td>
<td>-854</td>
<td>7401</td>
<td>-</td>
</tr>
<tr>
<td>Add more mass</td>
<td>-748</td>
<td>6653</td>
<td>-</td>
</tr>
<tr>
<td>Reduce overhang and add awning</td>
<td>-400</td>
<td>6253</td>
<td>-</td>
</tr>
<tr>
<td>Attic to R90</td>
<td>-102</td>
<td>6151</td>
<td>-</td>
</tr>
<tr>
<td><strong>Total Heating Energy Loss</strong> (kWh/year)</td>
<td></td>
<td><strong>6151</strong></td>
<td><strong>3270</strong></td>
</tr>
</tbody>
</table>

*Net space heat after deducting useable passive solar gains and internal gains
Plan A

Pros

• Aaron’s first suggestion
• Private master suite upstairs
• Minimal disruption to existing space.
• Accommodates some on site food production

Cons

• More expensive
• Harder to incorporate thermal mass.
• Hard to control passive solar
• Potential for summer overheating
• Less room for PV
## Plan A: Changes to Net Space Heating*

### Needs

<table>
<thead>
<tr>
<th>Upgrade</th>
<th>Marginal Benefit (kWh/year)</th>
<th>Remaining Space Heat (kWh/year)</th>
<th>Plan B (kWh/year)</th>
<th>Belgravia (kWh/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing house with energy upgrades</td>
<td></td>
<td>8865</td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Add second storey with 3 south</td>
<td>532</td>
<td>9397</td>
<td></td>
<td></td>
</tr>
<tr>
<td>facing windows</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Add mass</td>
<td>-1231</td>
<td>8698</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Add solar greenhouse</td>
<td>-1355</td>
<td>6644</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Heating Energy Loss (kWh/year)</td>
<td>6644</td>
<td>6151</td>
<td>3270</td>
<td></td>
</tr>
</tbody>
</table>

*Net space heat after deducting useable passive solar gains and internal gains
Total Annual Energy Use Summary (kWh/year)

- **Net annual space heating**
- **Domestic Water Heating**
- **Lighting and Appliances**

*After including passive solar and internal gains*
## Total Energy Needed from Renewables

<table>
<thead>
<tr>
<th></th>
<th>Plan A</th>
<th>Plan B</th>
<th>Original</th>
<th>Belgravia</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Net Space Heating - kWh/year</strong></td>
<td>6640</td>
<td>6150</td>
<td>28095</td>
<td>3270</td>
</tr>
<tr>
<td><strong>Lighting, Appliances, &amp; Miscellaneous Electrical (L.A.M.E.) kWh/year</strong></td>
<td>3800</td>
<td>3800</td>
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<td>3700</td>
<td>3700</td>
<td>3430</td>
</tr>
<tr>
<td><strong>Total Annual Energy - kWh/year</strong></td>
<td>14140</td>
<td>13650</td>
<td>35595</td>
<td>9850</td>
</tr>
</tbody>
</table>
Solar Thermal

• 2 Collector DWH systems make good sense

• Solar thermal space heating is still unproven in cold climates
PV Considerations

- Solar array is mounted at 53° tilt or steeper to:
  - Maximize annual electricity production
  - Minimize snow cover;
- Try to match roofing and module longevity
- Higher efficiency modules cost more per watt
- Cost is coming down quickly
## Photovoltaic Systems

<table>
<thead>
<tr>
<th></th>
<th>Riverdale</th>
<th>Mill Creek</th>
<th>Belgravia</th>
<th>Plan B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Module Area (Sq. M)</strong></td>
<td>33</td>
<td>35</td>
<td>45</td>
<td>64</td>
</tr>
<tr>
<td><strong>Total Peak Capacity (watts)</strong></td>
<td>5600</td>
<td>6080</td>
<td>7380</td>
<td>10965</td>
</tr>
<tr>
<td><strong>Annual Output (kWh/year)</strong></td>
<td>6300</td>
<td>8008</td>
<td>9761</td>
<td>13315</td>
</tr>
<tr>
<td><strong>Rough Cost (w/o mark up)</strong></td>
<td>~$37000</td>
<td>~$49000</td>
<td>~$48000</td>
<td>~$60000</td>
</tr>
</tbody>
</table>
### Energy Profile (kWh/year)

<table>
<thead>
<tr>
<th></th>
<th>Riverdale</th>
<th>Mill Creek</th>
<th>Belgravia</th>
<th>Parkland</th>
<th>Plan A</th>
<th>Plan B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Annual Heating Energy</strong></td>
<td>2980</td>
<td>3720</td>
<td>3270</td>
<td>6720</td>
<td>6640</td>
<td>6150</td>
</tr>
<tr>
<td><strong>Annual DHW</strong></td>
<td>3100</td>
<td>3450</td>
<td>3150</td>
<td>4480</td>
<td>3700</td>
<td>3700</td>
</tr>
<tr>
<td><strong>Annual L.A.M.E</strong></td>
<td>3870</td>
<td>3360</td>
<td>3400</td>
<td>8760</td>
<td>3800</td>
<td>3800</td>
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<tr>
<td><strong>Total Annual Consumption</strong></td>
<td>9950</td>
<td>10520</td>
<td>9850</td>
<td>20210</td>
<td>14140</td>
<td>13650</td>
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<tr>
<td><strong>Solar Thermal</strong></td>
<td>4100</td>
<td>2500</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Photovoltaic</strong></td>
<td>6600</td>
<td>8000</td>
<td>9910</td>
<td>21000</td>
<td>6626</td>
<td>13350</td>
</tr>
<tr>
<td><strong>Total Renewable Production</strong></td>
<td>10500</td>
<td>10500</td>
<td>9910</td>
<td>21000</td>
<td>6626</td>
<td>13350</td>
</tr>
<tr>
<td><strong>Net Zero?</strong></td>
<td>-550</td>
<td>20</td>
<td>-60</td>
<td>-790</td>
<td>7514</td>
<td>300</td>
</tr>
</tbody>
</table>

*Net space heat after deducting useable passive solar gains and internal gains
# Designing for Net Zero

<table>
<thead>
<tr>
<th>New Construction</th>
<th>Retrofit/Renovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Site assessment</td>
<td>• Model Energy Performance in Hot 2000*</td>
</tr>
<tr>
<td>• Preliminary design</td>
<td>• Reduce lighting and appliances loads</td>
</tr>
<tr>
<td>• Model Energy Performance in Hot 2000*</td>
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</tr>
<tr>
<td>• Optimize envelope</td>
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</tr>
<tr>
<td>• Examine / Model solar DHW</td>
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</tr>
<tr>
<td>• Size PV to meet remaining total load</td>
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</tr>
<tr>
<td>• Detailed architectural and system design</td>
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</tbody>
</table>