Photochemical Technologies Assessed.
The Case Of Rose Oxide.

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ELECTRONIC SUPPLEMENTARY INFORMATION
1. GENERAL.

2. TABLE OF PARAMETERS FOR ROUTES #1-#6.

3. SOLVENT RECYCLING PROCEDURE MODELLING.

4. EATOS RESULTS.

5. LCA RESULTS.

6. SOLVENT RECYCLING PROCEDURE RESULTS.

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1. GENERAL

The environmental assessment has been carried out by using the software **EATOS** (Environmental Assessment Tool for Organic Syntheses; downloaded from Professor J. O. Metzger web site: http://www.chemie.uni-oldenburg.de/oc/metzger/eatos/) and the software **SimaPro** (version: 7; Eco-Indicator99 as the evaluation method; see http://www.pre.nl/simapro/ for details). Physical and environmental information (including risk and safety phrases, toxicity and ecological parameters) of considered compounds were obtained from the safety data sheets available on Sigma Aldrich web site (www.sigma-aldrich.com). The price of used compounds and materials (of reasonable purity) were obtained from Sigma Aldrich web site too, by choosing the largest quantity offered.

2. TABLE OF PARAMETERS FOR ROUTES #1-#6.

The following tables contain all the data used for both methods to carry out the assessments. As mentioned in the text, these values refers to a medium-scale process, viz. the isolation of 100 g of final product.
ROUTE #1

**CHEMICALS**

<table>
<thead>
<tr>
<th>Substance</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citronellol - Reagent</td>
<td>188 g</td>
</tr>
<tr>
<td>Oxygen - Reagent</td>
<td>30.0 L</td>
</tr>
<tr>
<td>Bengal Rose - Sensitizer</td>
<td>750 mg</td>
</tr>
<tr>
<td>Methanol - Solvent</td>
<td>150 mL</td>
</tr>
<tr>
<td>Sodium Sulfite - Reagent</td>
<td>375 g</td>
</tr>
<tr>
<td>Water - Solvent</td>
<td>1.70 L</td>
</tr>
<tr>
<td>Water - Solvent</td>
<td>80.0 mL</td>
</tr>
<tr>
<td>Sulfuric Acid - Reagent</td>
<td>2.40 g</td>
</tr>
</tbody>
</table>

**ENERGETIC CONTRIBUTIONS**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamp consumption (18 h @ 170 W) - Irradiation</td>
<td>3.0 kWh</td>
</tr>
<tr>
<td>Heater (1 h) - Reduction step</td>
<td>250 Wh</td>
</tr>
<tr>
<td>Vacuum pump (3 h @ 500 W) - Distillation of glycols</td>
<td>1.5 kWh</td>
</tr>
<tr>
<td>Heater (3 h) - Distillation of glycols</td>
<td>750 Wh</td>
</tr>
<tr>
<td>Heater (30 min) - Cyclization step</td>
<td>125 Wh</td>
</tr>
</tbody>
</table>

**AUXILIARY MATERIALS**

<table>
<thead>
<tr>
<th>Substance</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice</td>
<td>1.00 kg</td>
</tr>
<tr>
<td>Cooling water - Lamp (18 h @ 500 mL/min)</td>
<td>540 L</td>
</tr>
<tr>
<td>Cooling water (3 h @ 500 mL/min)</td>
<td>90.0 L</td>
</tr>
<tr>
<td>Cooling water (0.5 h @ 500 mL/min)</td>
<td>15.0 L</td>
</tr>
<tr>
<td>Acetone - Washing</td>
<td>100 mL</td>
</tr>
</tbody>
</table>

**EXTERNAL CONTRIBUTIONS**

<table>
<thead>
<tr>
<th>Activity</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparatus ageing</td>
<td></td>
</tr>
<tr>
<td>Transports</td>
<td></td>
</tr>
<tr>
<td>Waste Treatment</td>
<td></td>
</tr>
</tbody>
</table>

* The references given for this process provide many examples. As far as the first Patent is concerned, the example #1 has been considered. On the other hand, for the second patent, the example #7 has been taken as reference. However, since in the database there was no data concerning “oxalic acid”, the alternative presented in the example #4 has been taken into account. This is the reason why the cyclization step uses sulfuric acid.
ROUTE #2

**CHEMICALS**

<table>
<thead>
<tr>
<th>Compound</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citronellol - Reagent</td>
<td>188 g</td>
</tr>
<tr>
<td>Air - Reagent</td>
<td>160 L</td>
</tr>
<tr>
<td>Ruthenium complex - Sensitizer</td>
<td>9.00 g</td>
</tr>
<tr>
<td>Ethanol - Solvent</td>
<td>12.0 L</td>
</tr>
<tr>
<td>Sodium Sulfite - Reagent</td>
<td>375 g</td>
</tr>
<tr>
<td>Water - Solvent</td>
<td>1.70 L</td>
</tr>
<tr>
<td>Water - Solvent</td>
<td>80.0 mL</td>
</tr>
<tr>
<td>Sulfuric Acid - Reagent</td>
<td>2.40 g</td>
</tr>
</tbody>
</table>

**ENERGETIC CONTRIBUTIONS**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Energy Consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED consumption (65 h with 48000 LEDs @ 120 mW each) - Irradiation</td>
<td>374 kWh *</td>
</tr>
<tr>
<td>Heater (1 h) - Reduction step</td>
<td>250 Wh</td>
</tr>
<tr>
<td>Vacuum pump (3 h @ 500 W) - Distillation of glycols</td>
<td>1.5 kWh</td>
</tr>
<tr>
<td>Heater (3 h) - Distillation of glycols</td>
<td>750 Wh</td>
</tr>
<tr>
<td>Heater (30 min) - Cyclization step</td>
<td>125 Wh</td>
</tr>
</tbody>
</table>

**AUXILIARY MATERIALS**

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice</td>
<td>1.00 kg</td>
</tr>
<tr>
<td>Cooling water (3 h @ 500 mL/min)</td>
<td>90.0 L</td>
</tr>
<tr>
<td>Cooling water (0.5 h @ 500 mL/min)</td>
<td>15.0 L</td>
</tr>
<tr>
<td>Acetone - Washing</td>
<td>100 mL</td>
</tr>
</tbody>
</table>

**EXTERNAL CONTRIBUTIONS**

- Apparatus ageing
- Transports
- Waste Treatment

* This value has been determined by assuming the use of the published number of LEDs scaled by the proper factor in order to obtain 100 g of rose-oxide, while maintaining the power of the LEDs and the irradiation time as previously reported. The nominal power of each LED has been taken from the technical data sheet of the article L-7113PBC-A. For details, see: [www.kingbright.com](http://www.kingbright.com).
ROUTE #3

<table>
<thead>
<tr>
<th>CHEMICALS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Citronellol - Reagent</td>
<td>203 g</td>
</tr>
<tr>
<td>Oxygen - Reagent</td>
<td>70.0 L</td>
</tr>
<tr>
<td>Bengal rose - Sensitizer</td>
<td>815 mg</td>
</tr>
<tr>
<td>iso-Propanol - Solvent</td>
<td>1.60 L</td>
</tr>
<tr>
<td>Sodium Sulfite - Reagent</td>
<td>405 g</td>
</tr>
<tr>
<td>Water - Solvent</td>
<td>1.84 L</td>
</tr>
<tr>
<td>Water - Solvent</td>
<td>86.4 mL</td>
</tr>
<tr>
<td>Sulfuric Acid - Reagent</td>
<td>2.60 g</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ENERGETIC CONTRIBUTIONS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Heater (1 h) - Reduction step</td>
<td>250 Wh</td>
</tr>
<tr>
<td>Vacuum pump (3 h @ 500 W) - Distillation of glycols</td>
<td>1.5 kWh</td>
</tr>
<tr>
<td>Heater (3 h) - Distillation of glycols</td>
<td>750 Wh</td>
</tr>
<tr>
<td>Heater (30 min) - Cyclization step</td>
<td>125 Wh</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AUXILIARY MATERIALS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice</td>
<td>1.00 kg</td>
</tr>
<tr>
<td>Cooling water - solar collector (18 h @ 1 L/min)</td>
<td>180 L</td>
</tr>
<tr>
<td>Cooling water (3 h @ 500 mL/min)</td>
<td>90.0 L</td>
</tr>
<tr>
<td>Cooling water (0.5 h @ 500 mL/min)</td>
<td>15.0 L</td>
</tr>
<tr>
<td>Acetone - Washing</td>
<td>100 mL</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EXTERNAL CONTRIBUTIONS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparatus ageing</td>
<td></td>
</tr>
<tr>
<td>Transports</td>
<td></td>
</tr>
<tr>
<td>Waste Treatment</td>
<td></td>
</tr>
</tbody>
</table>
ROUTE #4

**CHEMICALS**

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citronellol - Reagent</td>
<td>317 g</td>
</tr>
<tr>
<td>Hydrogen peroxide - Reagent</td>
<td>276 g</td>
</tr>
<tr>
<td>Sodium Molybdate - Catalyst</td>
<td>82.4 g</td>
</tr>
<tr>
<td>Methanol - Solvent</td>
<td>4.05 L</td>
</tr>
<tr>
<td>Sodium Sulfite - Reagent</td>
<td>634 g</td>
</tr>
<tr>
<td>Water - Solvent</td>
<td>2.87 L</td>
</tr>
<tr>
<td>Water - Solvent</td>
<td>135 mL</td>
</tr>
<tr>
<td>Sulfuric Acid - Reagent</td>
<td>4.06 g</td>
</tr>
</tbody>
</table>

**ENERGETIC CONTRIBUTIONS**

<table>
<thead>
<tr>
<th>Task</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heater (1 h) - Reduction step</td>
<td>250 Wh</td>
</tr>
<tr>
<td>Vacuum pump (3 h @ 500 W) - Distillation of glycols</td>
<td>1.5 kWh</td>
</tr>
<tr>
<td>Heater (3 h) - Distillation of glycols</td>
<td>750 Wh</td>
</tr>
<tr>
<td>Heater (30 min) - Cyclization step</td>
<td>125 Wh</td>
</tr>
</tbody>
</table>

**AUXILIARY MATERIALS**

<table>
<thead>
<tr>
<th>Material</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice</td>
<td>1.00 kg</td>
</tr>
<tr>
<td>Cooling water (3 h @ 500 mL/min)</td>
<td>90.0 L</td>
</tr>
<tr>
<td>Cooling water (0.5 h @ 500 mL/min)</td>
<td>15.0 L</td>
</tr>
<tr>
<td>Acetone - Washing</td>
<td>100 mL</td>
</tr>
</tbody>
</table>

**EXTERNAL CONTRIBUTIONS**

<table>
<thead>
<tr>
<th>Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparatus ageing</td>
</tr>
<tr>
<td>Transports</td>
</tr>
<tr>
<td>Waste Treatment</td>
</tr>
</tbody>
</table>
ROUTE #5

<table>
<thead>
<tr>
<th>CHEMICALS</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citronellol - <em>Reagent</em></td>
<td>954 g</td>
</tr>
<tr>
<td>tert-Butyl hydroperoxide - <em>Reagent</em></td>
<td>551 g</td>
</tr>
<tr>
<td>Cuprous chloride - <em>Catalyst</em></td>
<td>30.6 g</td>
</tr>
<tr>
<td>Acetic acid - <em>Solvent</em></td>
<td>1.47 kg</td>
</tr>
<tr>
<td>Water - <em>Solvent</em></td>
<td>1.00 L</td>
</tr>
<tr>
<td>Sodium hydroxide - <em>Auxiliary material</em></td>
<td>950 g</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ENERGETIC CONTRIBUTIONS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Heater (3 h) - <em>Reaction step</em></td>
<td>750 Wh</td>
</tr>
<tr>
<td>Vacuum pump (3 h @ 500 W) - <em>Distillation step</em></td>
<td>1.5 kWh</td>
</tr>
<tr>
<td>Heater (3 h) - <em>Distillation step</em></td>
<td>750 Wh</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AUXILIARY MATERIALS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling water (3 h @ 500 mL/min)</td>
<td>90.0 L</td>
</tr>
<tr>
<td>Acetone - <em>Washing</em></td>
<td>100 mL</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EXTERNAL CONTRIBUTIONS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Apparatus ageing</td>
<td></td>
</tr>
<tr>
<td>Transports</td>
<td></td>
</tr>
<tr>
<td>Waste Treatment</td>
<td></td>
</tr>
</tbody>
</table>
## ROUTE #6

### CHEMICALS

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Citronellol - Reagent</td>
<td>604 g</td>
</tr>
<tr>
<td>Lead oxide - Reagent</td>
<td>2.23 kg</td>
</tr>
<tr>
<td>Air - Auxiliary material</td>
<td>58.0 L</td>
</tr>
<tr>
<td>Acetic acid - Solvent</td>
<td>2.80 kg</td>
</tr>
<tr>
<td>Sodium hydroxide - Auxiliary material</td>
<td>1.10 kg</td>
</tr>
</tbody>
</table>

### ENERGETIC CONTRIBUTIONS

<table>
<thead>
<tr>
<th>Process</th>
<th>Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heater (1 h) - Reaction step</td>
<td>250 Wh</td>
</tr>
<tr>
<td>Vacuum pump (3 h @ 500 W) - Distillation step</td>
<td>1.5 kWh</td>
</tr>
<tr>
<td>Heater (3 h) - Distillation step</td>
<td>750 Wh</td>
</tr>
</tbody>
</table>

### AUXILIARY MATERIALS

<table>
<thead>
<tr>
<th>Material</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling water (3 h @ 500 mL/min)</td>
<td>90.0 L</td>
</tr>
<tr>
<td>Acetone - Washing</td>
<td>100 mL</td>
</tr>
</tbody>
</table>

### EXTERNAL CONTRIBUTIONS

- Apparatus ageing
- Transports
- Waste Treatment
3. SOLVENT RECYCLING PROCEDURE MODELLING

The following table contains all the parameters used in the LCA modelling of the solvent recycling procedure.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CHEMICALS</strong></td>
<td></td>
</tr>
<tr>
<td>Alcoholic solvent (exhaust)</td>
<td>5 kg</td>
</tr>
<tr>
<td><strong>ENERGETIC CONTRIBUTIONS</strong></td>
<td></td>
</tr>
<tr>
<td>Heater (6 h) – Distillation procedure</td>
<td>1.50 kWh</td>
</tr>
<tr>
<td><strong>AUXILIARY MATERIALS</strong></td>
<td></td>
</tr>
<tr>
<td>Cooling water (6 h @ 500 mL/min)</td>
<td>180.0 L</td>
</tr>
<tr>
<td><strong>EXTERNAL CONTRIBUTIONS</strong></td>
<td></td>
</tr>
<tr>
<td>Waste Treatment</td>
<td></td>
</tr>
<tr>
<td><strong>OUTPUT</strong></td>
<td></td>
</tr>
<tr>
<td>Alcoholic solvent (distilled - 95% yield)</td>
<td>4.75 kg</td>
</tr>
</tbody>
</table>
4. EATOS RESULTS

Table S1. The four EATOS indexes calculated for the processes considered.

<table>
<thead>
<tr>
<th>Route (#)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>S$^{-1}$ [kg/kg]</td>
<td>25.03</td>
<td>118.76</td>
<td>39.10</td>
<td>77.63</td>
<td>47.82</td>
<td>81.57</td>
</tr>
<tr>
<td>E [kg/kg]</td>
<td>24.03</td>
<td>117.76</td>
<td>38.10</td>
<td>76.63</td>
<td>46.82</td>
<td>80.57</td>
</tr>
<tr>
<td>EI$_{in}$ [PEI/kg]</td>
<td>30.75</td>
<td>168.44</td>
<td>54.12</td>
<td>200.99</td>
<td>99.10</td>
<td>267.33</td>
</tr>
<tr>
<td>EI$_{out}$ [PEI/kg]</td>
<td>29.24</td>
<td>310.95</td>
<td>41.18</td>
<td>159.83</td>
<td>194.63</td>
<td>467.81</td>
</tr>
</tbody>
</table>

Table S2. Details for the EI$_{out}$ EATOS indexes for the processes considered.

<table>
<thead>
<tr>
<th>Route (#)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL EI$_{out}$</td>
<td>29.24</td>
<td>310.95</td>
<td>41.18</td>
<td>159.83</td>
<td>194.63</td>
<td>467.81</td>
</tr>
<tr>
<td>Solvents</td>
<td>21.35</td>
<td>302.21</td>
<td>31.78</td>
<td>125.83</td>
<td>73.42</td>
<td>83.55</td>
</tr>
<tr>
<td>Catalysts</td>
<td>0.08</td>
<td>0.90</td>
<td>0.08</td>
<td>4.53</td>
<td>1.62</td>
<td>--</td>
</tr>
<tr>
<td>Auxiliaries</td>
<td>0.12</td>
<td>0.12</td>
<td>0.43</td>
<td>2.80</td>
<td>50.44</td>
<td>88.84</td>
</tr>
<tr>
<td>Substrates</td>
<td>2.24</td>
<td>2.27</td>
<td>2.91</td>
<td>11.59</td>
<td>0.07</td>
<td>2.53</td>
</tr>
<tr>
<td>By-Products</td>
<td>3.03</td>
<td>3.03</td>
<td>3.56</td>
<td>12.43</td>
<td>67.76</td>
<td>248.14</td>
</tr>
<tr>
<td>Coupled Products</td>
<td>2.42</td>
<td>2.42</td>
<td>2.42</td>
<td>2.65</td>
<td>1.32</td>
<td>44.75</td>
</tr>
</tbody>
</table>
4. LCA RESULTS

In the following the details of the results of LCA assessment are reported for each procedure.
Table S3. LCA assessment for route #1.

<table>
<thead>
<tr>
<th>Impact category</th>
<th>Total</th>
<th>Carcinogens</th>
<th>Respiratory organics</th>
<th>Respiratory inorganics</th>
<th>Climate change</th>
<th>Radiation</th>
<th>Ozone layer</th>
<th>Ecotoxicity</th>
<th>Acidification/Eutrophication</th>
<th>Land use</th>
<th>Minerals</th>
<th>Fossil fuels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit</td>
<td>Pt</td>
<td>Pt</td>
<td>Pt</td>
<td>Pt</td>
<td>Pt</td>
<td>Pt</td>
<td>Pt</td>
<td>Pt</td>
<td>Pt</td>
<td>Pt</td>
<td>Pt</td>
<td>Pt</td>
</tr>
<tr>
<td>Total</td>
<td>7.79E-01</td>
<td>1.59E-02</td>
<td>9.45E-05</td>
<td>1.13E-01</td>
<td>7.84E-02</td>
<td>7.37E-04</td>
<td>1.51E-05</td>
<td>2.13E-02</td>
<td>4.95E-02</td>
<td>6.32E-03</td>
<td>4.01E-02</td>
<td>4.53E-01</td>
</tr>
<tr>
<td>CITRONELLOL</td>
<td>1.78E-01</td>
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**Table S4. LCA assessment for route #2.**

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<th>Climate change</th>
<th>Radiation</th>
<th>Ozone layer</th>
<th>Ecotoxicity</th>
<th>Acidification/Eutrophication</th>
<th>Land use</th>
<th>Minerals</th>
<th>Fossil fuels</th>
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Table S5. LCA assessment for route #3.

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**ELECTRICAL POWER**

| (overall)               | 1.51E-01 | 7.53E-04 | 1.67E-05 | 1.95E-02 | 8.33E-03 | 1.82E-05 | 3.38E-06 | 1.59E-03 | 2.12E-03 | 8.12E-04 | 6.20E-03 | 1.12E-01 |

| WATER (cooling)         | 6.64E-03 | 3.81E-04 | 6.75E-07 | 1.18E-03 | 3.20E-04 | 2.67E-05 | 9.67E-08 | 8.29E-05 | 8.19E-05 | 2.67E-04 | 3.23E-04 | 3.97E-03 |
| ICE                     | 2.75E-03 | 1.77E-08 | 0.00E+00 | 0.00E+00 | 3.66E-08 | 6.70E-07 | 0.00E+00 | 3.54E-06 | 9.39E-06 | 2.74E-03 |
| ACETONE (washing)       | 1.49E-02 | 2.15E-04 | 2.53E-06 | 1.35E-03 | 1.10E-03 | 3.89E-07 | 2.81E-04 | 9.85E-04 | 1.02E-04 | 5.13E-04 | 1.04E-02 |

| APPARATUS AGEING        | 1.33E-02 | 1.82E-03 | 3.89E-07 | 1.98E-03 | 2.07E-04 | 1.06E-05 | 6.86E-08 | 2.35E-03 | 9.68E-05 | 2.44E-04 | 3.74E-03 | 2.89E-03 |
| WASTE TREATMENT         | 2.93E-01 | 6.30E-03 | 3.52E-05 | 2.75E-02 | 2.94E-02 | 3.44E-04 | 8.29E-06 | 9.00E-03 | 3.51E-02 | 2.38E-03 | 1.81E-02 | 1.72E-01 |
| TRANSPORTS              | 1.50E-02 | 1.40E-04 | 2.90E-06 | 1.09E-03 | 2.56E-04 | 2.01E-05 | 5.91E-07 | 1.87E-04 | 1.71E-04 | 3.64E-04 | 7.20E-04 | 1.20E-02 |
Table S6. LCA assessment for route #4.

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<th>Radiation</th>
<th>Ozone layer</th>
<th>Ecotoxicity</th>
<th>Eutrophication</th>
<th>Acidification</th>
<th>Land use</th>
<th>Minerals</th>
<th>Fossil fuels</th>
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6. SOLVENT RECYCLING PROCEDURE RESULTS.

Table S9. LCA assessment variations by taking into account the solvent recycling procedure for routes #1-#4.

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<th>Impact category</th>
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<th>Climate change</th>
<th>Radiation</th>
<th>Ozone layer</th>
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<th>Eutrophication</th>
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