

## Additional data tables

**Table Additional file 1-1. Building statistics of Kuopio in year 2010.**

| Building                 | Floor area |
|--------------------------|------------|
| Apartment houses         | 2417060.9  |
| Commercial               | 553297.0   |
| Detached houses          | 858954.8   |
| Educational              | 412216.2   |
| Health and social sector | 270451.1   |
| Industrial               | 319897.1   |
| Leisure houses           | 484323.0   |
| Offices                  | 330593.0   |
| Other                    | 245381.1   |
| Public                   | 92082.9    |
| Row houses               | 499020.2   |
| Sports                   | 95904.8    |
| TOTAL                    | 6579182    |

**Table Additional file 1-2. Building statistics of Basel in year 2010.**

| <b>Building class</b>                                      | <b>Floor area</b> | <b>Number of buildings</b> |
|------------------------------------------------------------|-------------------|----------------------------|
| Residential building with one dwelling                     | 2272971           | 9719                       |
| Residential building with two dwellings                    | 487379            | 1086                       |
| Residential building with three ore more dwellings         | 11682636          | 11898                      |
| Residential building for communities                       | 482472            | 129                        |
| Hotels                                                     | 399793            | 88                         |
| Other buildings for short host stay                        | 26898             | 13                         |
| Office building                                            | 2458193           | 614                        |
| Retail and wholesale trade buildings                       | 917470            | 182                        |
| Public transport stations, communication related buildings | 123497            | 25                         |
| Garage                                                     | 87287             | 63                         |
| Industry                                                   | 1107927           | 185                        |
| Storage buildings                                          | 167818            | 58                         |
| Cultural and leisure related buildings                     | 176756            | 71                         |
| Museum, libraries                                          | 135030            | 29                         |
| Schloos, Universities, Science buildings                   | 643841            | 202                        |
| Hospitals and other health related buildings               | 627517            | 87                         |
| Sports halls (buildings)                                   | 9491              | 4                          |
| Agricultural buildings                                     | 19649             | 20                         |

|                                     |          |       |
|-------------------------------------|----------|-------|
| Church and other cultural buildings | 96467    | 50    |
| All other buildings                 | 48324    | 75    |
| TOTAL                               | 23746143 | 25588 |

**Table Additional file 1-3. Energy demand of buildings in Kuopio in year 2010.**

| <b>Building type</b>     | <b>Heat (kWh/m<sup>2</sup>/a)</b> | <b>User electricity (kWh/m<sup>2</sup>/a)</b> | <b>Total electricity (kWh/m<sup>2</sup>/a)</b> |
|--------------------------|-----------------------------------|-----------------------------------------------|------------------------------------------------|
| Detached houses          | 135                               | 50                                            | 185                                            |
| Row houses               | 169                               | 74                                            | 74                                             |
| Apartment houses         | 172                               | 42                                            | 42                                             |
| Commercial               | 162                               | 230                                           | 230                                            |
| Offices                  | 161                               | 93                                            | 93                                             |
| Health and social sector | 215                               | 123                                           | 123                                            |
| Public                   | 165                               | 110                                           | 110                                            |
| Sports                   | 121                               | 86                                            | 86                                             |
| Educational              | 170                               | 116                                           | 116                                            |
| Industrial               | 168                               | 212                                           | 212                                            |
| Other                    | 138                               | 170                                           | 170                                            |

**Table Additional file 1-4. Energy demand of buildings in Basel in year 2010.**

| Use         | Building type           | Space heating demand (kWh/m2) | Warm water demand (kWh/m2) | Electricity demand (kWh/m2) |
|-------------|-------------------------|-------------------------------|----------------------------|-----------------------------|
| Working     | Commercial building     | 113                           | 123                        | 8                           |
|             | Industry                | 113                           | 123                        | 8                           |
| Mixed use   | Old buildings <1840     | 95                            | 20                         | 31                          |
|             | Buildings <1938         | 86                            | 20                         | 31                          |
|             | Villas <1938            | 106                           | 20                         | 31                          |
| Residential | Multifamily house <1938 | 106                           | 20                         | 31                          |
|             | Social flats >1950      | 111                           | 20                         | 31                          |
|             | Building towers         | 104                           | 20                         | 31                          |
|             | Flats 1960-80           | 97                            | 20                         | 31                          |
|             | Flats since 1990        | 54                            | 20                         | 31                          |
|             | Single-family house     | 69                            | 13                         | 31                          |
|             | New buildings           | 63                            | 20                         | 31                          |

**Table Additional file 1-5. Energy saving potentials of different renovations in Basel and Kuopio.**

| <b>Renovation</b> | <b>Relative saving (%)</b> | <b>Renovation details</b>                                                                                                       |
|-------------------|----------------------------|---------------------------------------------------------------------------------------------------------------------------------|
| General           | 15                         | General renovation                                                                                                              |
| Windows           | 15                         | New windows and doors                                                                                                           |
| Technical systems | 50                         | New windows, sealing of building's sheath, improvement of building's technical systems                                          |
| Sheath reform     | 65                         | New windows, sealing of building's sheath, improvement of building's technical systems, significant reform of building's sheath |

**Table Additional file 1-6. PM<sub>2.5</sub> and CO<sub>2</sub> emission factors for different fuels and burners (mg/MJ). Direct CO<sub>2</sub> is what comes out of the stack. We also calculated *CO<sub>2</sub>official* where biofuels (wood and waste) were assumed to be carbon neutral.**

| Burner              | Fuel          | PM <sub>2.5</sub> | Direct CO <sub>2</sub> | Description and assumptions                                                                                                                                               |
|---------------------|---------------|-------------------|------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Domestic            | Wood          | 140<br>(65.8-263) | 74200                  | Other stoves and ovens. Karvosenoja et al. 2008                                                                                                                           |
| Domestic            | Light oil     | 0-10              | 74200                  | Light oil <5 MW Emission factors for burning processes. Light oil 267 kg /MWh                                                                                             |
| Domestic            | Other sources | 0-10              | 74200                  | Same as oil.                                                                                                                                                              |
| Domestic            | Gas           | 0-3               | 55650                  | For PM <sub>2.5</sub> : one third of that of oil. For CO <sub>2</sub> : 3/4 of that of oil.                                                                               |
| Large fluidized bed | Wood          | 2-20              | 74200                  | Large plant (100-300 MW). Karvosenoja et al., 2008                                                                                                                        |
| Large fluidized bed | Peat          | 2-20              | 106000                 | 100-300 MW                                                                                                                                                                |
| Large fluidized bed | Heavy oil     | 8-22              | 106000                 | 100-300 MW                                                                                                                                                                |
| Large fluidized bed | Gas           | 0-3               | 55650                  | For PM <sub>2.5</sub> : one third of that of oil. For CO <sub>2</sub> : 3/4 of that of oil.                                                                               |
| Large fluidized bed | Coal          | 2-20              | 106000                 | Same as peat.                                                                                                                                                             |
| Large fluidized bed | Waste         | 2-20              | 74200                  | Same as wood.                                                                                                                                                             |
| Grid                | Electricity   | 01-10             | 53000                  | 50 % of large-scale burning (because of nuclear and hydro). Heavy oil 279 kg /MWh. Officially, electricity is not CHP but requires a double amount of coal to produce it. |

**Table Additional file 1-7. An example of an output table (data.frame in R) from the model: the first rows (out of 67680) of the modelled building stock for Basel.**

| Row | Time | City_area | Building                                  | Heating                     | Renovation | RenovationPolicy  | buildingsResult | buildingsSource |
|-----|------|-----------|-------------------------------------------|-----------------------------|------------|-------------------|-----------------|-----------------|
| 1   | 2010 | 4055      | Buildings with partial residential use    | Centrifuge, hydro-extractor | None       | Active renovation | 4485.6          | Formula         |
| 2   | 2010 | 4052      | Multiple-family houses                    | Centrifuge, hydro-extractor | None       | Active renovation | 352.8           | Formula         |
| 3   | 2010 | 4055      | Multiple-family houses                    | Centrifuge, hydro-extractor | None       | Active renovation | 1078.2          | Formula         |
| 4   | 2010 | 4054      | Residential buildings with subsidiary use | Centrifuge, hydro-extractor | None       | Active renovation | 109.8           | Formula         |
| 5   | 2010 | 4055      | Residential buildings with subsidiary use | Centrifuge, hydro-extractor | None       | Active renovation | 1658.4          | Formula         |
| 6   | 2010 | 4055      | Single-family houses                      | Centrifuge, hydro-extractor | None       | Active renovation | 72              | Formula         |