**Technical Appendix**
**GHG Emission Reduction Measures: Assumptions and Methods**

The LRCA team has employed a thoughtfully chosen array of methods to model estimated GHG reductions for the proposed measures. These methods have been carefully selected to ensure realistic GHG reduction estimates for the proposed initiatives. These methods compare estimated business as usual (BAU) emissions with the emissions that would be achieved by implementing the proposed GHG reduction measures.

To reiterate, the sectors addressed by the LRCA measures are described below:

| LRCA's CPRG Implementation Grant Objectives | Corresponding PCAP Actions | Corresponding Louisville KY-IN MSA PCAP Measure | Corresponding EPA Emissions Sector |
|---|---|---|---|
| Objective 1: Establish and capitalize a green bank | Actions R2, C3, I2, W1, and W2 | Measures 1: Residential Energy Upgrade Program (R)<br><br>Measure 2: Commercial/Institutional Energy Upgrade Program (C)<br><br>Measure 3: Industrial Efficiency Program (I)<br><br>Measure 5: Waste and Wastewater Upgrade Program (W) | Industry<br>Commercial and residential buildings<br>Waste |
| Objective 2: Institute a GHG reduction technical advisory service | Actions R1, C1, C2, and I1 | Measures 1: Residential Energy Upgrade Program (R)<br><br>Measure 2: Commercial/Institutional Energy Upgrade Program (C)<br><br>Measure 3: Industrial Efficiency Program (I) | Industry<br>Commercial and residential buildings<br>Waste |
| Objective 3: Initiate and expand equitable energy jobs | Actions R3 and C5 | Measures 1: Residential Energy Upgrade Program (R)<br><br>Measure 2: Commercial/Institutional Energy Upgrade Program (C) | Commercial and residential buildings |
| Objective 4: Build a utility scale solar project | Action C4 | Measure 2: Commercial/Institutional Energy Upgrade Program (C) | Electric Power |

Objectives 1, 2, and 4 are expected to contribute directly to GHG reductions and the assumptions and methodology for those proposed measures are below. Objective 3 is not assumed to directly reduce emissions.

For each sector of activity – residential buildings; commercial and institutional buildings; industrial facilities and processes; waste; and electric power – financial resources have been allocated to the GHG reduction measures per the LRCA's proposed budget. These measures have been selected by the LRCA team to maximise GHG reduction impacts, and to align with regional issues, priorities and opportunities. GHG reduction measures have been sized according to the resources allocated and impacts have been assessed accordingly. Where appropriate, financial instruments (such as loans and revolving funds) have been selected as means to reduce costs and maximise long-term impacts through recycling funds for reinvestment in future GHG reduction measures.

To ensure the specific circumstances of Louisville KY-IN MSA are appropriately taken into account in calculating GHG emissions, regional and county-level data has been incorporated for energy production and consumption in from nationally recognised sources and models (such as the National Emissions Inventory, NREL SLOPE, and local utility companies).

Further, during the CPRG PCAP and Implementation grant stakeholder engagement process, LMG requested regional partners to supply GHG reducing candidate projects so that we may better understand the needs and opportunities in our community and build out a potential pipeline of quickly implementable projects. Over 100 projects were collected during this process, with aggregated total capital costs nearing $1.5 billion. The list of projects with a high level description of their proposed GHG reduction measures is provided in an attachment titled *ProjectPipeline_Louisville-Jefferson County Metro Government.pdf*. While no specific green bank financial assistance recipients are being identified at this time, we utilised some of these real project examples to calculate expected emissions reductions for green bank supported projects. While we expect to receive a range of green bank assistance applications that will be vetted according to a predetermined evaluation criteria, projects that appear to meet desired cost effectiveness thresholds have been included in the calculations for illustrative purposes. The LRCA intends to establish a formal threshold cost effectiveness criteria, for instance $450/metric ton of CO2e, to ensure that assisted projects deliver meaningful reductions. Data from these other sources – including energy consumption, GHG emissions, building dimensions, operational data – for specific project buildings, facilities, systems, and GHG reduction measures have been incorporated where appropriate.

BAU stationary emissions have been estimated using the following carbon intensity values.

**Stationary Energy Emissions**

<u>Grid Emissions Factor</u>

Electricity grid emissions factors for the Louisville MSA for 2025-2030 have been calculated using the following data:

- LG&E grid emissions data
- EPA eGRID 2022 data for Kentucky and Indiana

LG&E's grid emissions factor has been used for Jefferson County, Trimble County, and Oldham County as LG&E is the main electricity supplier for these counties[1] . For other MSA counties within Kentucky, the EPA eGRID 2022 grid emission factor for Kentucky has been used. For MSA counties within Indiana, the EPA eGRID 2022 grid emission factor for Indiana was used. These grid emissions factors were then weighted in proportion to the electricity consumed in the relevant MSA counties (data source NREL SLOPE 2020[2]) to give a weighted average grid factor for Louisville KY-IN MSA. An average grid emissions factor for 2025-2030 was then calculated based on approved plans for cleaner

[1] https://psc.ky.gov/agencies/psc/images/Electric_Service_Areas_Legal_Size_Map.pdf
[2] https://maps.nrel.gov/slope/

generation for LG&E's generation portfolio[3]. These are expected to achieve a 17% reduction in LG&E's grid emissions factor by 2030[4] – with an average 16% reduction in grid emissions between 2025 and 2030. A similar improvement over the period has been assumed for other parts of Louisville MSA. A similar rate of improvement in the generation portfolio has been assumed up to 2050 – giving an additional 34% reduction from 2030 in the average grid emissions factor for the period 2030 to 2050.

| Area | Grid Emissions Factor – Metric tons CO2e per MWh 2020 | Weight |
|---|---|---|
| LG&E (Jefferson County, Trimble County, Oldham County)[5] 2020 | 0.84 | 67.5 |
| EPA eGRID (Kentucky) 2022[6] | 0.787 | 10.3 |
| EPA eGRID (Indiana) 2022 | 0.715 | 22.1 |
| **Weighted MSA Average 2022** | **0.81** | |
| **Forecast MSA Average 2025-2030** | **0.76** | |
| **Forecast MSA Average 2025-2050** | **0.56** | |
| **Forecast MSA Average 2030-2050** | **0.54** | |

Other emissions factors for relevant fuels have been applied as follows:
(Source: EPA Emissions Factors Hub 2024)

| **Fuel** | |
|---|---|
| Natural Gas | 53.06 kg CO2e per mmBtu |
| Industrial coal | 94.67 kg CO2e per mmBtu |
| Fuel oil | 75.1 kg CO2 per mmBtu |
| Diesel | 10.21 kg CO2e per gallon |
| Gasoline | 8.78 kg CO2e per gallon |

**Residential GHG reduction Measures**

<u>Building Energy Efficiency (Objective 1)</u>

*Residential buildings*

GHG reductions from residential building energy efficiency measures have been assessed using data and analysis from the Lawrence Berkeley National Laboratory[7]. This study suggests that simple low cost weatherization and seal-and-insulate fabric schemes are more cost effective than full deep retrofit projects.

[3] https://psc.ky.gov/Case/ViewCaseFilings/2023-00122
[4] Projection supplied by LG&E and confirmed using emission calculations for LG&E revised generation portfolio
[5] LG&E grid emissions factor for 2020 supplied by LG&E.
[6] https://www.epa.gov/system/files/documents/2024-01/egrid2022_summary_tables.pdf
[7] https://buildings.lbl.gov/publications/cost-decarbonization-and-energy

**Table 9.** Median cluster annual energy metrics.

| Cluster | Net-Site Energy Savings (%) | $CO_2$ Savings (%) | Net-Site Energy Savings (kWh/ft²) | Energy Cost Savings ($/ft²) | $CO_2$e Savings (lbs. $CO_2$e/ft²) | Levelized Cost of Saved Net-Site Energy ($/kWh) 15-year 3% discount | Net-Monthly Cashflow ($) 30-year, 3% interest | Simple Payback (years) |
|---|---|---|---|---|---|---|---|---|
| Basic | 20% | 19% | 2.3 | $0.15 | 1.1 | $0.077 | -$5 | 15 |
| HVAC | 33% | 31% | 4.2 | $0.38 | 2.4 | $0.118 | -$6 | 16 |
| Advanced HVAC | 40% | 25% | 6.8 | $0.14 | 2.1 | $0.155 | $86 | 60 |
| Large Home Geothermal | 56% | 39% | 9.0 | $0.25 | 3.1 | $0.238 | $270 | 82 |
| Superinsulation | 64% | 51% | 14.0 | $0.61 | 5.8 | $0.385 | $355 | 120 |
| Electrification with PV | 72% | 68% | 14.5 | $0.89 | 5.0 | $0.178 | $90 | 31 |

The LBNL study provides a cost of $5,000 per household for basic weatherization programs. This is similar to the $6,000 cost per household proposed for LG&E's WeCare programme which has been included in the LRCA proposal for residential financial assistance. Based on NREL Open Energy Data Initiative[8] load profiles for specific energy improvements, the annual energy saving from a basic weatherization and energy efficiency upgrade program would be 5280kWh per household for a house with electric resistance heating. The grid electricity emission factor for the MSA (see above) means that focusing on all-electric households (without heat pumps) would give greater GHG reductions than focusing on households using natural gas. At 100% grant funding this contributes the following impact:

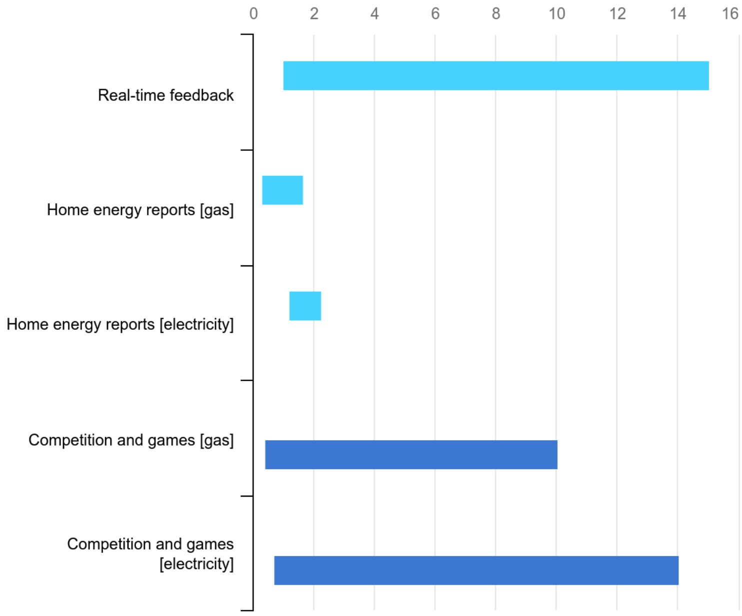
- 167 homes upgraded per $1 million grant (2025-2030)
- 4.03 metric tons CO2e annual reduction per home (2025-2030)
- 673 metric tons CO2e annual reduction per $1 million grant (2025-2030)
- 2,692 metric tons CO2e reduction per $1 million grant 2025-2030 (assumes 1 year implementation timescale)
- $371 per metric ton CO2e (2025-2030)
- 11,902 metric tons CO2e reduction per $1 million grant 2025-2050

In practice a larger impact will be achieved through use of targeted loans and a revolving loan fund.

<u>Residential Behavioural Change Programs (Resulting from Objective 2)</u>

Estimated impacts of programs to promote adoption of GHG reduction measures in the residential sector – including behavioural change (such as altering desired building thermostat temperatures), adoption of energy efficiency measures, and adoption of renewable energy measures - have been based on previous relevant studies that analysed the impact of such programs in the US (Sussman and Chikumbo 2016 – see diagram below). A broad range of types of behavioural change programs have been deployed in the US – including positive messaging, educational programs, community programs, feedback, real time feedback (e.g. through smart meters and apps), home energy reports, bulk purchasing, and gamification models. The LRCA's proposed measures are a holistic mix of these techniques that will target homes across the whole of the MSA (with a focus on LIDAC areas) for the whole of the program period.

[8] https://data.openei.org/submissions/4520




A conservative overall 2% long-term reduction in GHG emissions from residential behavioural change measures has been assumed for the proposed residential behavioural change program – though GHG reductions may prove to be higher in reality.

The NREL SLOPE model was used to project residential energy consumption up to 2050. For the MSA counties, the NREL SLOPE model projects a BAU 23% reduction in residential gas consumption, and 11% reduction in electricity consumption by 2050. Allowing for the projected reduction in electricity grid emissions this equates to a projected 14% BAU reduction in carbon emissions for the residential sector over the period 2025 to 2050.

**Commercial and Institutional GHG Reduction Measures**

<u>Building Energy Efficiency (Objective 1)</u>
GHG reductions from commercial and institutional building energy efficiency measures have been estimated using previous studies from ASHRAE[9] and City of Philadelphia[10] that modelled energy reduction measures and costs for schools, hospitals, retail, hotels and offices. The Louisville KY-IN MSA is in the same climate zone (4). Figures have been adjusted for inflation. These studies estimate costs to implement ASHRAE recommendations to deliver a 50% reduction in energy use in schools as:

**Schools**

- $133/m2 in K12 schools
- ~$1.5m - $2m per school
- 121.9 Kwh/m2 annual energy consumption reduction
- 926 – 1,389 metric tons CO2e annual reduction per school (assumes all electric)
- 617 metric tons CO2e annual reduction per $1m grant
- 2,468 metric tons CO2e reduction per $1 million grant 2025-2030 (assumes 1 year implementation timescale)
- $405 per metric ton CO2e reduction 2025-2030

[9] https://www.ashrae.org/technical-resources/aedgs/50-percent-aedg-free-download
[10] https://drexel.edu/~/media/Files/now/pdfs/Reducing%20GHG%20in%20Philadelphia.ashx?la=en

The ASHRAE model has been applied to assess the cost and impact of retrofitting energy efficiency measures in schools across Louisville KY-IN MSA. Again, the LRCA team expects to receive a range of project applications with differing parameters for green bank financial assistance. The school project has been used for illustrative purposes in the calculations, however, the pipeline projects received from potential applicants indicated projects ranging from around $250-$450 per metric ton CO2e reductions from 2025-2030. The school project has been chosen as a reasonable and relatively conservative estimate.

In practice a larger impact will be achieved through use of targeted loans and a revolving loan fund.

Solar PV (Objectives 1 and 4)

The NREL PVWATTs calculator (https://pvwatts.nrel.gov/) has been used to calculate solar PV electricity generation for different potential PV installations in Kentucky. The NREL calculator takes into account different designs of PV installations and the average solar flux for the proposed location. NREL analysis has also been used to estimate total costs associated with installing photovoltaic (PV) systems for residential rooftop, commercial rooftop, and utility-scale ground-mounted systems. Solar PV costs have been estimated using NREL's research into solar installed system cost analysis (https://www.nrel.gov/solar/market-research-analysis/solar-installed-system-cost.html ).

For Louisville Metro's proposed utility scale solar PV facility, costs provided by LG&E were used.

Based on information received from proposed implementation partners, brownfield and other vacant land for solar PV facilities will be available at zero cost to the program. Forecast solar PV electricity production has been taken as an equivalent reduction in consumption of grid electricity. The above grid emissions factors calculated for Louisville KY-IN MSA have been used to calculate forecast GHG emission reductions.

Commercial and Industrial Energy Advisory Services (Objective 2)

The impact of promoting behavioural change and providing GHG reduction advisory services in the commercial and industrial has been estimated using previous studies and audits of such services. The National Audit Office (NAO) audit of the UK Carbon Trust (which provides energy advisory services to the commercial and industrial sectors) – "The Carbon Trust – Accelerating the move to a low carbon economy (2008)" found the average cost per ton of carbon reduced by advisory services to be £32.70 ($41.39). This is based on assumed lifetimes for implementation and persistence of the GHG reduction measures proposed by energy audits. Based on a review of Carbon Trust persistence factors (ref Salix Compliance Tool and Business Case V36) we have applied an average GHG reduction persistence factor of 11 years (though this clearly varies dependent on the measures identified).

Adjusting the NAO audit figure for inflation and applying an assumed 11 year persistence factor gives a cost of $150 per metric ton CO2e over a 5 year period. This has been applied to calculate the estimated outcomes of the proposed commercial and industrial advisory service.

**Industrial**

Energy Advisory (Objective 2)

Industrial energy advisory services have been assessed on the basis given above.

Process Energy Efficiency (Objective 1)

The Louisville KY-IN MSA includes a significant number of large manufacturing and chemical facilities that utilise thermal processes (both heating and chilling) – with some using coal as a fuel.
The impact of updated and appropriate sizing of chilling facilities has been assessed using data supplied by these plants in terms of reduced energy consumption and refrigerant leakage with standard carbon emissions factors applied.

The impact of applying enhanced process and furnace control systems, and updated process equipment, to enhance energy efficiency at such facilities has been assessed using previous research by the University of Louisville. This research involved testing enhanced control systems on live operational plants and applied standard carbon emissions factors.

Estimated efficiency gains (based on live testing data) are:

- 10% reduction in process energy consumption (higher reductions may be possible)
- Estimated annual GHG reduction for cement plant – 4%
- Estimated annual GHG reduction for chemical plant thermal processes - 10%
- Estimated implementation cost $200,000 per facility
- Estimated measure lifespan – greater than 25 years
- Cost effectiveness - $12 MTon CO2e

Chiller refurbishment

GHG reductions from chiller refurbishment have been calculated on the basis of a reduction of refrigerant leakage. The relevant chiller facility uses refrigerant R507. In 2023, a total of 3200 lb (1.451 ton) of R507 refrigerant is estimated by the operators to have leaked from the system into the atmosphere. The proposed chiller refurbishment measures are estimated to completely eliminate the leaks. The Global Warming Potential of R507 is 3985. A reduction of 1.451 ton emissions of R507 is equivalent to 5,782 tons of CO2.

Fuel Switching (Objective 1)

A number of GHG reduction projects proposed by industrial, commercial, and institutional partners involve switching from higher carbon fuels to lower carbon fuels – for example:

- Coal fired furnaces to natural gas
- Natural gas to renewable electricity
- Gasoline to renewable electricity

GHG reductions for these projects have been calculated using current energy consumption and emissions from the proposed facility as a baseline (based on known current fuel consumption, and carbon intensity of the current fuel). This is then compared with estimated future emissions – calculated using estimated future consumption of replacement fuel, and carbon intensity of the replacement fuel.

For the MSA, the most significant proposed fuel switching projects relate to the switching of industrial coal-fired furnaces to natural gas. The costs and impacts of switching from coal to natural gas have been based on energy, emissions, and costs data received from a major manufacturer in Louisville MSA for specific proposed projects that will switch facilities from utilising coal to natural gas.

Distillery biofuel digester

A 4 MW system  the biofuel digester  is estimated to deliver approximately 35,040,000 kwh a year that will be used to displace an equivalent amount of grid supplied electricity at the above emissions factors.  This gives a GHG reduction of 26,630 tons CO2e a year.  A 4MW biofuel duster is estimated to cost $20m.

Solar PV  (Objective 1)

The NREL PVWATTs calculator and NREL costs data (as above) have been applied to assess the costs and GHG reduction impacts of proposed Solar PV facilities.

**Waste**

MSD Wastewater Treatment Source Control  (Objective 1)

GHG reduction for the MSD sources control programme has been assessed using data supplied by MSD.  Data has been supplied for the proposed Sewer Rehabilitation Program, Private Property Illicit Discharge Program, and Urban Reforestation Program will work together to reduce MSA greenhouse by restoring ageing infrastructure, addressing private property source control for residents, and improving a diminished tree canopy.  Stormwater and groundwater inflow and infiltration into wastewater collection systems contribute fugitive emissions and add significant unnecessary energy consumption—and resulting Greenhouse Gas (GHG) emissions— through increasing the overall volume of wastewater that must be pumped and treated.

*Example of Failing Sewer in a West Louisville LIDAC*

GHG emission reductions have been assessed through calculating the estimated reduction in energy required for pumping and treatment – and consequent reduction in GHG emissions.

Carbon Dioxide is a byproduct of the treatment process and is also produced from consumption of the energy needed to pump and process wastewater. Infiltration is caused by ageing infrastructure and inflow is often caused by direct illicit connections such as downspouts and sump pumps.

Following assessment of GHG reduction cost-effectiveness, only the MSD illicit discharge program has been included in the final program budget and GHG calculations.

| **Cleaner Air through Clean Water Measures – Wastewater Source Control Actions** | | | |
|---|---|---|---|
| | **Sewer Rehabilitation Program** | **Private Property Illicit Discharge Program** | **Urban Reforestation Program** |
| 5-year Program Cost | $100 million | $10 million | $1.25 million |
| CPRG Funding Request | $36 million | $2 million | $1 million |
| Scalability | $36 - $100 million | $1 - $10 million | $0.5 - $1.25 million |
| Planned 25-year program activities | $25 million per year Asset Management investment, totaling $500 million for wastewater | | $2.5 million |

| Cleaner Air through Clean Water Measures – Wastewater Source Control Actions | | | |
|---|---|---|---|
| | **Sewer Rehabilitation Program** | **Private Property Illicit Discharge Program** | **Urban Reforestation Program** |
| 5-year Program Cost | $100 million | $10 million | $1.25 million |
| CPRG Funding Request | $36 million | $2 million | $1 million |
| GHG (CO2e) and co-pollutant reductions | Annual CO2e reduction: 2,993 mt | Annual CO2e reduction: 880 mt | 2025-2030 CO2 reduction: 188 mt; 2030-2050 CO2 reduction: 1,620 mt |
| GHG reduction 2025-2030 | 14,965 m tons CO2e | 4,400 m tons CO2e | 188 m tons CO2e |
| Cost effectiveness $/mton CO2e (2025-2030) | $2,379 | $455 | $5,320 |
| Geographic Area and LIDAC impacts | Focus on West Louisville LIDACs for urban area and risk-based asset management for regional service area prioritization | Focus on separate system LIDACs burdened with backups and SSO pollution | Focus on LIDACs, with opportunities for full drainage service area |
| Readiness | Program in place. Projects are shovel-ready | Program in development; Shovel-ready in August 2024 | Program in place. Projects are shovel-ready |

<u>Food diversion programs  (Objective 1)</u>

GHG emission reductions from diverting food waste from landfill have been assessed by using the EPA WARM factors for emissions from food waste in landfill with landfill gas recovery and flaring (see EPA Documentation for Greenhouse Gas Emission and Energy Factors Used in the Waste Reduction Model – WARM v14).  The relevant factor is 0.68 – ie 0.68 tons CO2e emitted per ton of food waste. The potential scale and costs for operating food diversion projects have been calculated using operational data supplied by existing food diversion projects in the Louisville area.  These projects divert 1,000,000 lbs (454 metric tons) of food annually for an operational budget of $100,000 a year.