**COMMONWEALTH OF KENTUCKY**
**BEFORE THE PUBLIC SERVICE COMMISSION**

In the Matter of:

| | | |
|---|---|---|
| ELECTRONIC TARIFF FILINGS OF LOUISVILLE GAS AND ELECTRIC COMPANY AND KENTUCKY UTILITIES COMPANY TO REVISE PURCHASE RATES FOR SMALL CAPACITY AND LARGE CAPACITY COGENERATION AND POWER PRODUCTION QUALIFYING FACILITIES AND NET METERING SERVICE-2 CREDIT RATES | ) ) ) ) ) ) ) ) | Case No. 2023-00404 |

**TESTIMONY OF ANDREW MCDONALD**
**ON BEHALF OF JOINT INTERVENORS**
**KENTUCKY SOLAR ENERGY SOCIETY AND**
**MOUNTAIN ASSOCIATION**

**February 29, 2024**

**TABLE OF CONTENTS**

## I. INTRODUCTIONS & QUALIFICATIONS

**Q. Please state your name and business address.**

A. My name is Andrew McDonald. My business address is 316 Wapping St., Suite 204, Frankfort, KY 40601.

**Q. By whom are you employed and in what position?**

A. I am employed by Apogee – Climate & Energy Transitions, a program of Earth Tools, Inc.

**Q. On whose behalf are you testifying in this proceeding?**

A. I am testifying on behalf of Kentucky Solar Energy Society ("KYSES") and Mountain Association ("MA") (together, "Joint Intervenors").

**Q. Are you a member of either of the organizations you are testifying on behalf of here?**

A. Yes, I am a member of KYSES, and I currently serve on the KYSES Board of Directors.

**Q. Please describe your professional background.**

A. I have been working to address climate change and sustainability for thirty years. My experience spans solar energy system design and installation; green building and energy efficiency; state and local energy policy; and community outreach and education. I have written technical and public-education documents on energy issues, including co-authoring *The Kentucky Solar Energy Guide* in 2004 with Joshua Bills. For twenty years I have been actively involved in efforts to establish, expand, and defend net metering in Kentucky. I have participated in numerous utility rate cases and Integrated Resource Planning processes as a concerned citizen, intervenor, and expert witness. I was the Director of the Kentucky Solar Partnership for Appalachia-Science in the Public Interest from 2004 to 2012. In 2013, I joined Earth Tools, where I established our Sustainable Systems Program, and in 2020, founded Apogee-Climate & Energy Transitions. I am a Certified Energy Manager and I hold an M.Sc. in Sustainable Systems from Slippery Rock University of Pennsylvania and a B.A. in Philosophy from the University of Buffalo. I am attaching my resume as Exhibit AM-1.

**Q. Have you previously filed expert testimony in other proceedings before this Commission or before other regulatory commissions?**

A. Yes. I have provided expert testimony before the Kentucky Public Service Commission in Case Nos. 2023-00159, 2022-00402, and 2020-00174. In Case No. 2013-00287, I submitted testimony that the Commission construed as a public comment.

**Q. What is the purpose of your testimony**

A. My testimony addresses two issues: (1) the value of avoided carbon emissions in LG&E-KU's NMS-2 tariff rates; and (2) the value of job creation as a component of the avoided costs of net metering.

## II. UPDATING THE AVOIDED CARBON COST COMPONENT OF LG&E-KU'S NMS-2 RATE

**Q: How was the avoided cost of carbon emissions addressed when LG&E-KU's NMS-2 rates were established?**

A: In the Commission order establishing LG&E-KU's net metering successor rates (NMS-2) in Case Nos. 2020-00349 and 2020-00350, the Commission established a methodology for determining the avoided cost of solar energy exports from the customer-generator to the utility. The methodology identified eight avoided cost components to be considered, including avoided carbon cost. As stated in the order,

> The IRP's anticipation of climate legislation is evidence that avoiding carbon emissions impacts LG&E/KU's concerns and consideration in studying resource procurement and environmental compliance plans.[173] For these reasons, eligible net metering facilities should receive export compensation that includes an avoided carbon cost component.[1]

LG&E-KU used the methodology approved by the Commission in Case No. 2020-00174 to calculate the avoided cost of carbon for NMS-2 customers, using the "high" carbon price forecast from the Companies' 2018 Integrated Resource Plan (IRP).[2] In the present case, the Companies have proposed adjustments to their NMS-2 compensation rates, but have only proposed adjustments to two of the eight components of the avoided cost methodology, avoided energy and generation capacity. In the six years that have passed since the Companies' developed their 2018 IRP, significant developments have occurred that impact the value of avoided carbon emissions, justifying an update of this component of NMS-2 rates in addition to the two selectively proposed for updating by the Companies.

Figure 1 shows the carbon price used in the Companies' avoided cost calculations, for each year from 2022 to 2046. The price begins at $0/ton CO2 for 2022-2025, then increases to $17.00/ton in 2026 and rises to a maximum of $48.56/ton in 2046.[3] The Companies' state that their "high" carbon price forecast was based on the *Synapse Energy Economics Spring 2016 National Carbon Dioxide Price Forecast*. The Synapse forecast includes a Low, Mid, and High case and the Companies appear to have

[1] Kentucky Public Service Commission Final Order in Case Nos. 2020-00349 and 2020-00350, 9-24-21, p.56.
[2] LG&E-KU Response to Commission Staff's Eighth Data Request (8-13-21), Q21 and attachment to Q21, p.1237 of pdf, Case Nos. 2020-00349 and 2020-00350.
[3] Ibid.

used a blend of Synapse's Low and Mid cases. While the Synapse Low case forecasted a carbon price for 2022 – 2025 increasing from $15.00 - $17.25, the Companies assigned a price of zero to those years. On the other hand, the Companies' forecast rises at a faster rate than the Synapse Low case, and while Synapse's Low case reaches $33.00/ton in 2046, the Companies' forecast peaks that year at $48.56. The Synapse Mid case reaches $71.00 in 2046.[4]

[4] Luckow, et al., *Spring 2016 National Carbon Dioxide Price Forecast*, Updated March 16, 2016, Synapse Energy Economics, Inc., p.4, https://www.synapse-energy.com/sites/default/files/2016-Synapse-CO2-Price-Forecast-66-008.pdf, accessed 2-28-2024.

*Figure 1 - Comparison of CO2 Pricing Used in LG&E-KU's Avoided Cost of Carbon Calculation for NMS-2 Rates and Synapse 2016 CO2 Price Forecast*[5]

**LGE-KU 2018 IRP**

| | 2018IRP CO2 ($/ton) |
|---|---|
| 2022 | 0 |
| 2023 | 0 |
| 2024 | 0 |
| 2025 | 0 |
| 2026 | 17.00 |
| 2027 | 18.17 |
| 2028 | 19.37 |
| 2029 | 20.62 |
| 2030 | 21.90 |
| 2031 | 23.23 |
| 2032 | 24.59 |
| 2033 | 26.00 |
| 2034 | 27.44 |
| 2035 | 28.94 |
| 2036 | 30.47 |
| 2037 | 32.05 |
| 2038 | 33.68 |
| 2039 | 35.36 |
| 2040 | 37.09 |
| 2041 | 38.87 |
| 2042 | 46.51 |
| 2043 | 48.56 |
| 2044 | 44.52 |
| 2045 | 46.51 |
| 2046 | 48.56 |

**Synapse 2016 CO2 price forecasts**
**(2015 dollars per short ton CO2)**

| | | | |
|---|---|---|---|
| 2020 | $0.00 | $0.00 | $0.00 |
| 2021 | $0.00 | $0.00 | $0.00 |
| 2022 | $15.00 | $20.00 | $25.00 |
| 2023 | $15.75 | $20.75 | $26.00 |
| 2024 | $16.50 | $21.50 | $27.00 |
| 2025 | $17.25 | $22.25 | $28.00 |
| 2026 | $18.00 | $23.00 | $29.00 |
| 2027 | $18.75 | $23.75 | $30.00 |
| 2028 | $19.50 | $24.50 | $34.25 |
| 2029 | $20.25 | $25.25 | $38.50 |
| 2030 | $21.00 | $26.00 | $42.75 |
| 2031 | $21.75 | $29.00 | $47.00 |
| 2032 | $22.50 | $32.00 | $51.25 |
| 2033 | $23.25 | $35.00 | $55.50 |
| 2034 | $24.00 | $38.00 | $59.75 |
| 2035 | $24.75 | $41.00 | $64.00 |
| 2036 | $25.50 | $44.00 | $68.25 |
| 2037 | $26.25 | $47.00 | $72.50 |
| 2038 | $27.00 | $50.00 | $76.75 |
| 2039 | $27.75 | $53.00 | $81.00 |
| 2040 | $28.50 | $56.00 | $85.25 |
| 2041 | $29.25 | $58.50 | $87.75 |
| 2042 | $30.00 | $61.00 | $90.25 |
| 2043 | $30.75 | $63.50 | $92.75 |
| 2044 | $31.50 | $66.00 | $95.25 |
| 2045 | $32.25 | $68.50 | $97.75 |
| 2046 | $33.00 | $71.00 | $100.25 |
| 2047 | $33.75 | $73.50 | $102.75 |
| 2048 | $34.50 | $76.00 | $105.25 |
| 2049 | $35.25 | $78.50 | $107.75 |
| 2050 | $36.00 | $81.00 | $110.00 |
| **Levelized 2022-2050** | $23.02 | $38.13 | $55.27 |

*Note: Levelized price based on a discount rate of 5 percent.*

The Synapse report states that the Low case "forecast represents a scenario in which Clean Power Plan compliance is relatively easy, and a similar level of stringency is

[5] LG&E-KU Response to Commission Staff's Eighth Data Request (8-13-21), Q21 and attachment to Q21, p.1237 of pdf, Case Nos. 2020-00349 and 2020-00350; and Luckow, et al., p.8.

assumed after 2030."[6] For their Mid case forecast, Synapse states that it "represents a scenario in which federal policies are implemented with challenging but reasonably achievable goals. Clean Power Plan compliance is achieved and science-based climate targets mandate at least an 80 percent reduction in electric section emissions from 2005 levels by 2050."[7] The Synapse High forecast "is consistent with a stringent level of Clean Power Plan targets that recognizes that achieving science-based emissions goals by 2050 will be difficult. In recognition of this difficulty, implementation of standards more aggressive than the Clean Power Plan may begin as early as 2027. New regulations may mandate that electric-sector emissions are reduced to 90 percent or more below 2005 levels by 2050, in recognition of lower-cost emission reduction measures expected to be available in this sector."[8]

The carbon prices used in the Companies' NMS-2 rate calculations were therefore based on a forecast which is now eight years old and scenarios which assumed achieving Clean Power Plan Compliance would be "relatively easy" or implemented with "challenging but reasonably achievable goals." The Companies' carbon price forecast was also developed during the Trump administration, when the Clean Power Plan had been scrapped, the United States had withdrawn from the Paris Climate Agreement, and the Federal government had dramatically scaled back its efforts to restrain carbon emissions.

[6] Luckow, et al, p.4.
[7] Ibid.
[8] Ibid.

Since the 2018 IRP was produced, a major shift has occurred in the national and international response to climate change. When President Biden took office in January 2021, he made addressing climate change one of his highest priorities. The U.S. returned to the Paris Climate Agreement and set the following ambitious climate goals:

Reducing U.S. greenhouse gas emissions 50-52% below 2005 levels in 2030;
Reaching 100% carbon pollution-free electricity by 2035;
Achieving a net-zero emissions economy by 2050.[9]

The Biden Administration has taken action to achieve these goals on multiple fronts, including the passage of the Inflation Reduction Act and the Bipartisan Infrastructure Bill, and regulatory actions by the EPA. In May 2023 the EPA issued new draft Greenhouse Gas Rules under sections 111(b) and 111(d) of the Clean Air Act which, if implemented, could significantly impact LG&E-KU's generation fleet. As stated by the Kentucky Public Service Commission in their Final *Order* in the LG&E-KU Case No. 2022-00402:

> The risk of Greenhouse Gas regulation is also more certain now than it was when LG&E/KU filed their application in this matter. On May 23, 2023, the EPA proposed CO2 emission limits for new and existing electric generating units that would impact the cost-effectiveness of LG&E/KU's existing coal units, including Mill Creek 1 and 2, Ghent 2, and Brown 3, and the NGCC units LG&E/KU is proposing in this matter. Pursuant to the EPA's proposed emission limits, Mill Creek 1 and 2, Ghent 2, and Brown 3 would not be able to operate beyond 2032 without significantly reducing the capacity factor of the unit and agreeing to retire the unit by 2035; adding natural gas co-firing to the unit and agreeing to retire the unit by 2040; or adding CCS to the unit with 90 percent capture efficiency.[300] In order to operate beyond 2032, the EPA's proposed regulation would require new NGCC units, like those proposed by LG&E/KU in this matter, to (1) operate at a capacity

[9] The White House National Climate Task Force, https://www.whitehouse.gov/climate/, accessed 2-28-2024.

> factor of 50 percent and operate as an intermediate-load unit indefinitely with a CO2 emission restriction of no more than 1,000 lbs./MWh gross; (2) meet a lowered 680 lbs./MWh gross CO2 emission standard, which EPA stated will be achievable by co-firing low-Greenhouse Gas hydrogen; or (3) meet the 90 lbs./MWh gross CO2 emission standard by 2035, which EPA stated will be achievable by adding CCS to the units.[10]

The risk that the GHG Rule will be finalized has direct implications for the avoided cost of carbon emissions. Two of the three compliance pathways for the Companies' natural gas units rely on technologies which are currently not commercially available or operational at the scale required. The infrastructure for supplying low-Greenhouse Gas hydrogen to the Companies' power plants does not exist, nor the supply of the hydrogen. CCS technology continues to be extremely costly and would require infrastructure that does not yet exist at-scale (such as CO2 pipelines and storage reservoirs). The third compliance pathway, reducing the capacity factor of their NGCC units to 50 percent, risks increasing costs for customers by reducing the availability of these units.[11]

In response to a data request from Commission staff in Case No. 2022-00402, the Companies stated:

> [T]he Companies do not have such necessary information needed to perform the analysis requested such as…
>
> ▪ Carbon capture costs, transportation costs to storage fields, and storage field costs. Furthermore, based on work by the Kentucky Geological Survey,[10] the Companies already know that potential CO2 storage volumes are limited near Ghent, Mill Creek, and Brown. Therefore, storage sites outside of Kentucky would

---

[10] Kentucky Public Service Commission Final Order, Case No. 2022-00402, November 6, 2023, p.84.
[11] LG&E-KU Response to Commission Staff Fifth Data Request, Q-2, Case No. 2022-00402.

likely need to be identified and the necessary pipelines would need to be sited and built, perhaps for hundreds of miles.

- Low-GHG hydrogen sources have not been developed and pricing is uncertain. As discussed below and in response to KCA 3-3, even the EPA did not address hydrogen production in their Regulatory Impact Analysis ("RIA") of the proposed New GHG Rules.

- The Companies do not have any information from gas turbine manufacturers on the feasibility of using 96% hydrogen even if the fuel were available. As discussed in the previous section concerning the requirements of the proposed New GHG Rules, hydrogen utilization or CCS would be necessary only if a NGCC operated above a 50 percent annual capacity factor or a SCCT operated above a 20 percent annual capacity factor.[11] Therefore, the Companies would retrofit the proposed Mill Creek and Brown NGCCs for hydrogen or CCS only if it would be lower cost than constraining operations to a 50 percent annual capacity factor. That is a decision the Companies and the Commission do not need to make at this time.[12]

This response should be considered in the context of the Companies' 2018 IRP and the Synapse Carbon Price Forecast, which was the basis for their IRP's carbon prices. Synapse characterized their Low and Mid case forecasts as representing pathways in which CO2 emissions compliance would be "relatively easy" or "challenging but reasonably achievable."[13] The reality the Companies are facing today, with the challenge presented by the EPA's draft GHG Rule, will be far from easy and perhaps not even "reasonably achievable" for the Companies' existing fleet, which is so heavily reliant on fossil generation. Synapse's High carbon price case was characterized as "difficult to achieve," with stringent limits on carbon emissions and a focus on reducing emissions in

[12] Ibid.
[13] Luckow, et al., p.4.

the electricity sector 90 percent by 2050. The Biden Administration's goals are even more aggressive than Synapse's High case, aiming to reduce electricity sector carbon emissions 100 percent by 2035. The EPA's GHG Rule reflects this ambition.

**Q: Are there estimates of the cost of Carbon Capture and Sequestration?**

A: A study from the Harvard Belfer Center reviewed fifteen reports estimating the cost of Carbon Capture, Utilization, and Storage (CCUS) in various industries. The total cost of carbon avoided via CCUS includes energy required to operate the CCUS facility and associated emissions, plus the cost to capture, compress, transport, and store (or utilize) the CO2 (see Figure 2). For coal generation units, they found the estimated cost of avoided CO2 via CCUS to be \$58 - \$170 per ton CO2. For natural gas generators, the avoided cost is \$87 - \$188 per ton CO2.[14]

It should be noted that the costs for compression, transport, and sequestration in the Harvard study are estimates and subject to many uncertainties, including the need for new pipeline infrastructure to support widespread deployment of CCS. The Harvard study estimated a new pipeline network of about 110,000 km may be needed in the US to transport CO2 to storage, and as the Companies' noted above, they are unaware of suitable storage sites within Kentucky near their generating stations.

[14] Moch, J., Xue, W., and Holdren, J., Carbon Capture, Utilization, and Storage: Technologies and Costs in the US Context, Harvard Kennedy School, Belfer Center for Science and International Affairs, January 2022, p.7-8.

*Figure 2 - Cost of Carbon Capture, Utilization, and Storage, Harvard Belfer Center Estimates*[15]

| | |
|---|---|
| CO2 Capture, Coal generation units | $20 - $132/ton CO2 |
| CO2 Capture, Natural Gas generation units | $49 - $150/ton CO2 |
| CO2 Compression | $12/ton |
| CO2 Transport | $15/ton |
| CO2 Sequestration | $11/ton |

**Q: What are carbon prices in the state and regional cap-and-trade programs in the United States?**

A: There are a number of state and regional programs that have established carbon prices through auctions of emissions allowances. "The Regional Greenhouse Gas Initiative (RGGI) is a cooperative effort among the states of Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont to cap and reduce power sector $CO_2$ emissions."[16] The California Air Resources Board operates the California Greenhouse Gas Cap-and-Trade program, which has been linked to Quebec's cap-and-trade system since 2014.[17] In 2023 Washington State began operation of its Cap-and-Invest program to reduce greenhouse gas emissions.[18] Massachusetts, in addition to participating in RGGI, operates its own greenhouse gas emissions reduction program.[19] Figure 3 shows the quarterly carbon prices from January 2020 to the present in the California and RGGI cap-and-trade

[15] Ibid.
[16] https://www.rggi.org/program-overview-and-design/elements, accessed 2-28-2024.
[17] https://ww2.arb.ca.gov/resources/documents/faq-cap-and-trade-program, accessed 2-28-2024.
[18] https://ecology.wa.gov/air-climate/climate-commitment-act/cap-and-invest, accessed 2-28-2024.
[19] https://www.mass.gov/greenhouse-gas-emissions-mitigation, accessed 2-28-2024.

programs.[20] Figure 4 shows the quarterly prices in the Washington program since it started in February 2023.

The most recent carbon prices in these programs range from $12.98/ton in Massachusetts to $14.88/ton in RGGI to $41.76/ton in California-Quebec to $51.89 in Washington. The Massachusetts Program Monitor noted that the state's emissions have dropped dramatically since the program started in 2018, such that emissions allowances now greatly exceed emissions.[21] By reducing demand for allowances this has kept carbon prices low in Massachusetts.

*Figure 3*

| **Quarterly CO2 Auction Settlement Prices in RGGI and California-Quebec Cap-and-Trade Programs - 2020 - 2023** | | | | |
|---|---|---|---|---|
| | | | | |
| **RGGI** | **\$/ton CO2** | | **California-Quebec** | **\$/ton CO2** |
| | | | February-24 | $ 41.76 |
| December-23 | $ 14.88 | | November-23 | $ 38.73 |
| September-23 | $ 13.85 | | August-23 | $ 35.20 |
| June-23 | $ 12.73 | | May-23 | $ 30.33 |
| March-23 | $ 12.50 | | February-23 | $ 27.85 |
| December-22 | $ 12.99 | | November-22 | $ 26.80 |
| September-22 | $ 13.45 | | August-22 | $ 27.00 |
| June-22 | $ 13.90 | | May-22 | $ 30.85 |
| March-22 | $ 13.50 | | February-22 | $ 29.15 |
| December-21 | $ 13.00 | | November-21 | $ 28.26 |
| September-21 | $ 9.30 | | August-21 | $ 23.30 |
| June-21 | $ 7.97 | | May-21 | $ 18.80 |
| March-21 | $ 7.60 | | February-21 | $ 17.80 |
| December-20 | $ 7.41 | | November-20 | $ 16.93 |
| September-20 | $ 6.82 | | August-20 | $ 16.68 |
| June-20 | $ 5.75 | | May-20 | $ 16.68 |
| March-20 | $ 5.65 | | February-20 | $ 17.87 |

[20] Massachusetts' prices were on par with RGGI prices but reported in numerous individual reports and in an unclear format, so were not collated for this summary.
[21] "QUARTERLY REPORT ON THE ELECTRICITY GENERATOR EMISSIONS LIMITS PROGRAM (310 CMR 7.74): THIRD QUARTER 2023," Prepared for: Massachusetts Department of Environmental Protection on behalf of the Commonwealth of Massachusetts, Potomac Economics, November 2023, p.2.

*Figure 4*

| Quarterly CO2 Auction Settlement Prices in Washington Cap-and-Invest Auction - 2023 | |
|---|---|
| **Washington State** | **$/ton CO2** |
| December-23 | $ 51.89 |
| August-23 | $ 63.03 |
| May-23 | $ 56.01 |
| February-23 | $ 48.50 |
| Washington's program started in February 2023. | |

**Q: What is the social cost of carbon as used in regulatory and policy analyses?**

A: Another reference for setting a carbon price is the social cost of carbon, a measure of the societal impact of carbon emissions. For more than a decade the US EPA and the Interagency Working Group (IWG) on the Social Cost of Greenhouse Gases have used estimates of the social cost of greenhouse gas emissions to support policy and regulatory analyses. In 2023 the EPA provided updated figures for the social cost of carbon that "reflect recent advances in the scientific literature on climate change and its economic impacts and incorporate recommendations made by the National Academies of Science, Engineering, and Medicine (National Academies 2017). The SC-GHG allows analysts to incorporate the net social benefits of reducing emissions of greenhouse gases (GHG), or the net social costs of increasing GHG emissions, in benefit-cost analysis and, when appropriate, in decision-making and other contexts. The SCGHG is the monetary value of the net harm to society from emitting a metric ton of that GHG into the atmosphere in a given year."[22] Appendix A provides the EPA's annual social cost of carbon for 2020 through 2050.

[22] Supplementary Material for the Regulatory Impact Analysis for the Final Rulemaking, "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas

The EPA's social cost of carbon estimate provides low, mid, and high-cost scenarios, depending upon the discount rate used. For 2020, the low case is $117, the mid case $193, and the high case $337 per metric ton CO2.[23] A detailed analysis published in the journal *Nature* in 2022 is in line with the EPA's approach and recommended a social cost of carbon of $185, on par with the EPA's mid case.[24]

**Q: What do you recommend for LG&E-KU's avoided cost of carbon emissions?**

A: The costs and risks of carbon emissions have clearly changed in the eight years since Synapse developed their last carbon price forecast, the basis for LG&E-KU's 2018 IRP carbon prices and the forecast used to set the avoided cost of carbon for NMS-2 customers. In that time we have gone from an Administration that stalled efforts to address climate change to one who has committed to decarbonizing the electricity sector by 2035 and the economy by 2050. The science around climate change has advanced dramatically, as has our experience of its impacts in the form of wildfires, floods, and other natural disasters.

The carbon pricing presently used by LG&E-KU in their IRP's and their NMS-2 rate calculations is unreasonably low and unfair to NMS customers. The Companies face a tremendous challenge in transitioning their fossil generation fleet to clean, zero carbon sources, with significant risks for their customers. Those customers who choose to install solar are providing a service to the Companies and their neighbors, supplying

Sector Climate Review," EPA Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances, US EPA, November 2023, p.1.

[23] Ibid, p.154.

[24] Rennert, K., Errickson, F., Prest, B.C. *et al.* Comprehensive evidence implies a higher social cost of $CO_2$. *Nature* **610**, 687–692 (2022). https://doi.org/10.1038/s41586-022-05224-9, accessed 2-29-2024.

clean energy to the local grid and reducing reliance on the existing fossil fuel fleet, reducing the cost of the transition.

Figure 5 summarizes the different carbon prices that have been discussed in my testimony for the sake of comparison. The forecasts are in reference to 2025, while the actual auction prices are from 2023 or 2024. (Two prices are shown for LG&E-KU to indicate that their forecast uses $0 until 2026, when the price then starts at $17).

As CCS is a main compliance alternative for the Companies' coal and natural gas plants, the cost of avoided CO2 via CCS would be a reasonable benchmark for the avoided cost of carbon for other resources, such as net metering. I recommend that a carbon price in this range ($58 - $188 per ton CO2 starting in 2024 and then escalating annually on par with the escalation rate used in the Synapse forecast or EPA SC-CO2 Estimate) be used in the formulas utilized to determine the avoided cost of carbon for NMS-2 customers.

*Figure 5 - Comparison of CO2 prices per metric ton in forecasts, actual cap-and-trade programs, EPA Social Cost of Carbon guidance, and for CCS (from Harvard study).*

| LGE-KU NMS-2 | Synapse forecast | | | RGGI actual | California actual | Washington actual | EPA SC-CO2 estimate | EPA SC-CO2 estimate | CCS w/ Coal | CCS w/ Nat. Gas |
|---|---|---|---|---|---|---|---|---|---|---|
| | Low | Med | Hi | | | | Low | Mid | | |
| $0 (2025)<br>$17 (2026) | $17 | $22 | $28 | $15 | $42 | $52 | $130 | $212 | $58 - $170 | $87 - $188 |

## III. EVALUATING THE JOBS AND ECONOMIC BENEFITS OF NET METERING

In the Commission's final order in Case No. 2020-00349 and 2020-00350, the Commission directed "LG&E/KU to evaluate job benefits and economic development as an export rate component for LG&E/KU's next rate case filing." Despite the Commission's direction, the Companies failed to provide any analysis of this issue in the present proceeding and have not offered any value for a jobs and economic development component of the NMS-2 export rate.

As one example of software the Companies could use for this analysis, the National Renewable Energy Laboratory (NREL) has produced the JEDI modelling software to enable the analysis of Jobs and Economic Development Impacts (JEDI) of solar PV deployment. The JEDI model "allows users to estimate the statewide economic impacts associated with developing solar projects." The JEDI model is a:

- Freely available input-output tool to estimate employment and economic impacts that result from an investment in new power generation or fuel production.
- JEDI default inputs are from developers and industry experts, based on existing projects.
- User input can be minimal using defaults or be very detailed for more precise results.[25]

I recommend the Companies use the JEDI model or other similar software tools to analyze the jobs and economic development impacts of solar deployment in their territories. Then use this analysis to determine a value for compensating NMS-2 customer-generators, as the Commission has directed them to do. The JEDI software can be downloaded at https://www.nrel.gov/analysis/jedi/pv.html.

**Q: Does this conclude your testimony?**

A: Yes.

[25] Scenario Solar PV Jobs and Economic Development Impact (JEDI) Model, slideshow, US Department of Energy, August 12, 2013, https://www.energy.gov/eere/solar/articles/scenario-jedi, accessed 2-29-2024.

**Appendix A – EPA Social Cost of Greenhouse Gases**[26]

## A.5. Annual Unrounded SC-$CO_2$, SC-$CH_4$, and SC-$N_2O$ Values, 2020-2080

*Table A.5.1: Unrounded SC-$CO_2$, SC-$CH_4$, and SC-$N_2O$ Values, 2020-2080*

| | SC-GHG and Near-term Ramsey Discount Rate | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | SC-$CO_2$ *(2020 dollars per metric ton of $CO_2$)* | | | SC-$CH_4$ *(2020 dollars per metric ton of $CH_4$)* | | | SC-$N_2O$ *(2020 dollars per metric ton of $N_2O$)* | | |
| Emission | Near-term rate | | | Near-term rate | | | Near-term rate | | |
| Year | 2.5% | 2.0% | 1.5% | 2.5% | 2.0% | 1.5% | 2.5% | 2.0% | 1.5% |
| 2020 | 117 | 193 | 337 | 1,257 | 1,648 | 2,305 | 35,232 | 54,139 | 87,284 |
| 2021 | 119 | 197 | 341 | 1,324 | 1,723 | 2,391 | 36,180 | 55,364 | 88,869 |
| 2022 | 122 | 200 | 346 | 1,390 | 1,799 | 2,478 | 37,128 | 56,590 | 90,454 |
| 2023 | 125 | 204 | 351 | 1,457 | 1,874 | 2,564 | 38,076 | 57,816 | 92,040 |
| 2024 | 128 | 208 | 356 | 1,524 | 1,950 | 2,650 | 39,024 | 59,041 | 93,625 |
| 2025 | 130 | 212 | 360 | 1,590 | 2,025 | 2,737 | 39,972 | 60,267 | 95,210 |
| 2026 | 133 | 215 | 365 | 1,657 | 2,101 | 2,823 | 40,920 | 61,492 | 96,796 |
| 2027 | 136 | 219 | 370 | 1,724 | 2,176 | 2,910 | 41,868 | 62,718 | 98,381 |
| 2028 | 139 | 223 | 375 | 1,791 | 2,252 | 2,996 | 42,816 | 63,944 | 99,966 |
| 2029 | 141 | 226 | 380 | 1,857 | 2,327 | 3,083 | 43,764 | 65,169 | 101,552 |
| 2030 | 144 | 230 | 384 | 1,924 | 2,403 | 3,169 | 44,712 | 66,395 | 103,137 |
| 2031 | 147 | 234 | 389 | 2,002 | 2,490 | 3,270 | 45,693 | 67,645 | 104,727 |
| 2032 | 150 | 237 | 394 | 2,080 | 2,578 | 3,371 | 46,674 | 68,895 | 106,316 |
| 2033 | 153 | 241 | 398 | 2,157 | 2,666 | 3,471 | 47,655 | 70,145 | 107,906 |
| 2034 | 155 | 245 | 403 | 2,235 | 2,754 | 3,572 | 48,636 | 71,394 | 109,495 |
| 2035 | 158 | 248 | 408 | 2,313 | 2,842 | 3,673 | 49,617 | 72,644 | 111,085 |
| 2036 | 161 | 252 | 412 | 2,391 | 2,929 | 3,774 | 50,598 | 73,894 | 112,674 |
| 2037 | 164 | 256 | 417 | 2,468 | 3,017 | 3,875 | 51,578 | 75,144 | 114,264 |
| 2038 | 167 | 259 | 422 | 2,546 | 3,105 | 3,975 | 52,559 | 76,394 | 115,853 |
| 2039 | 170 | 263 | 426 | 2,624 | 3,193 | 4,076 | 53,540 | 77,644 | 117,443 |
| 2040 | 173 | 267 | 431 | 2,702 | 3,280 | 4,177 | 54,521 | 78,894 | 119,032 |
| 2041 | 176 | 271 | 436 | 2,786 | 3,375 | 4,285 | 55,632 | 80,304 | 120,809 |
| 2042 | 179 | 275 | 441 | 2,871 | 3,471 | 4,394 | 56,744 | 81,714 | 122,586 |
| 2043 | 182 | 279 | 446 | 2,955 | 3,566 | 4,502 | 57,855 | 83,124 | 124,362 |
| 2044 | 186 | 283 | 451 | 3,040 | 3,661 | 4,610 | 58,966 | 84,535 | 126,139 |
| 2045 | 189 | 287 | 456 | 3,124 | 3,756 | 4,718 | 60,078 | 85,945 | 127,916 |
| 2046 | 192 | 291 | 462 | 3,209 | 3,851 | 4,827 | 61,189 | 87,355 | 129,693 |
| 2047 | 195 | 296 | 467 | 3,293 | 3,946 | 4,935 | 62,301 | 88,765 | 131,469 |
| 2048 | 199 | 300 | 472 | 3,378 | 4,041 | 5,043 | 63,412 | 90,176 | 133,246 |
| 2049 | 202 | 304 | 477 | 3,462 | 4,136 | 5,151 | 64,523 | 91,586 | 135,023 |
| 2050 | 205 | 308 | 482 | 3,547 | 4,231 | 5,260 | 65,635 | 92,996 | 136,799 |

*Table A.5.1: Unrounded SC-$CO_2$, SC-$CH_4$, and SC-$N_2O$ Values, 2020-2080 (continued...)*

| | SC-GHG and Near-term Ramsey Discount Rate | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | SC-$CO_2$ *(2020 dollars per metric ton of $CO_2$)* | | | SC-$CH_4$ *(2020 dollars per metric ton of $CH_4$)* | | | SC-$N_2O$ *(2020 dollars per metric ton of $N_2O$)* | | |
| Emission Year | 2.5% | 2.0% | 1.5% | 2.5% | 2.0% | 1.5% | 2.5% | 2.0% | 1.5% |
| 2051 | 208 | 312 | 487 | 3,624 | 4,320 | 5,363 | 66,673 | 94,319 | 138,479 |
| 2052 | 211 | 315 | 491 | 3,701 | 4,409 | 5,466 | 67,712 | 95,642 | 140,158 |
| 2053 | 214 | 319 | 496 | 3,779 | 4,497 | 5,569 | 68,750 | 96,965 | 141,838 |
| 2054 | 217 | 323 | 500 | 3,856 | 4,586 | 5,672 | 69,789 | 98,288 | 143,517 |
| 2055 | 220 | 326 | 505 | 3,933 | 4,675 | 5,774 | 70,827 | 99,612 | 145,196 |
| 2056 | 222 | 330 | 510 | 4,011 | 4,763 | 5,877 | 71,866 | 100,935 | 146,876 |
| 2057 | 225 | 334 | 514 | 4,088 | 4,852 | 5,980 | 72,904 | 102,258 | 148,555 |
| 2058 | 228 | 338 | 519 | 4,165 | 4,941 | 6,083 | 73,943 | 103,581 | 150,235 |
| 2059 | 231 | 341 | 523 | 4,243 | 5,029 | 6,186 | 74,981 | 104,904 | 151,914 |
| 2060 | 234 | 345 | 528 | 4,320 | 5,118 | 6,289 | 76,020 | 106,227 | 153,594 |
| 2061 | 236 | 348 | 532 | 4,389 | 5,199 | 6,385 | 76,920 | 107,385 | 155,085 |
| 2062 | 239 | 351 | 535 | 4,458 | 5,280 | 6,480 | 77,820 | 108,542 | 156,576 |
| 2063 | 241 | 354 | 539 | 4,527 | 5,361 | 6,576 | 78,720 | 109,700 | 158,066 |
| 2064 | 244 | 357 | 543 | 4,596 | 5,442 | 6,671 | 79,620 | 110,857 | 159,557 |
| 2065 | 246 | 360 | 547 | 4,666 | 5,523 | 6,767 | 80,520 | 112,015 | 161,048 |
| 2066 | 248 | 363 | 550 | 4,735 | 5,604 | 6,862 | 81,419 | 113,172 | 162,539 |
| 2067 | 251 | 366 | 554 | 4,804 | 5,685 | 6,958 | 82,319 | 114,330 | 164,030 |
| 2068 | 253 | 369 | 558 | 4,873 | 5,765 | 7,053 | 83,219 | 115,487 | 165,521 |
| 2069 | 256 | 372 | 562 | 4,942 | 5,846 | 7,149 | 84,119 | 116,645 | 167,012 |
| 2070 | 258 | 375 | 565 | 5,011 | 5,927 | 7,244 | 85,019 | 117,802 | 168,503 |
| 2071 | 261 | 378 | 569 | 5,085 | 6,013 | 7,344 | 86,012 | 119,027 | 170,013 |
| 2072 | 263 | 382 | 573 | 5,160 | 6,099 | 7,444 | 87,006 | 120,252 | 171,523 |
| 2073 | 266 | 385 | 576 | 5,234 | 6,184 | 7,545 | 87,999 | 121,477 | 173,033 |
| 2074 | 269 | 388 | 580 | 5,309 | 6,270 | 7,645 | 88,992 | 122,702 | 174,543 |
| 2075 | 271 | 391 | 583 | 5,383 | 6,355 | 7,745 | 89,985 | 123,926 | 176,053 |
| 2076 | 274 | 394 | 587 | 5,458 | 6,441 | 7,845 | 90,978 | 125,151 | 177,563 |
| 2077 | 276 | 398 | 591 | 5,532 | 6,527 | 7,946 | 91,971 | 126,376 | 179,073 |
| 2078 | 279 | 401 | 594 | 5,607 | 6,612 | 8,046 | 92,964 | 127,601 | 180,582 |
| 2079 | 282 | 404 | 598 | 5,681 | 6,698 | 8,146 | 93,958 | 128,826 | 182,092 |
| 2080 | 284 | 407 | 601 | 5,756 | 6,783 | 8,246 | 94,951 | 130,050 | 183,602 |

[26] Supplementary Material for the Regulatory Impact Analysis for the Final Rulemaking, "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review," EPA Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances, US EPA, November 2023, p.154.

**VERIFICATION**

The undersigned, Andrew McDonald, being first duly sworn, deposes and says that he has personal knowledge of the matters set forth in the foregoing testimony and that the information contained therein is true and correct to the best of his information, knowledge, and belief, after reasonable inquiry.

Andrew McDonald
signature

Subscribed and sworn to before me by Charles Pearl this 29 day of Feburary, 2024.

Charles Pearl KYNP49614
Notary Public

CHARLES WILFORD PEARL III NOTARY PUBLIC STATE AT LARGE KENTUCKY

My commission expires: 04/06/26

# ANDREW MCDONALD, CEM, M.SC.

316 Wapping St., Rm. 204 (502)699-2553
Frankfort, KY 40601 andyboeke@yahoo.com

---

#### EDUCATION & CERTIFICATIONS

- **Certified Energy Manager, Association of Energy Engineers, 2020, #26142.**
- **Slippery Rock University of Pennsylvania, 2003, *M.S. in Sustainable Systems.***
- **State University of New York at Buffalo, 1992**. ***B.A. Philosophy.***

#### WORK EXPERIENCE

- September 2013 – present. ***Director, Apogee-Climate & Energy Transitions, Earth Tools, Inc.***
  Providing design, consulting, project development, and installation services for solar energy, energy conservation, green building, and other sustainability-related projects. Performing research, advocacy, and education on sustainable energy issues, especially concerning Kentucky electric utilities.
- January 2013 – September 2013. ***Independent consultant***.
  Provided consulting services for green building and solar energy projects.
- January 2004 – January 2013. ***Director, Kentucky Solar Partnership, Appalachia – Science in the Public Interest*.**
  Implemented programs to advance the use of solar, other renewable energy resources, and energy efficiency in Kentucky. Responsibilities included public education, organizing contractor training, policy research and advocacy, technical consulting, and development of demonstration projects.
- January 2003 – January 2004. ***Independent Contractor***.
  Provided research, design, and construction services for green building projects.
- August 2001 - December 2002: ***Graduate Assistant, Robert A. Macoskey Center for Sustainable Systems Education and Research at Slippery Rock University of PA*.**
  Responsible for monitoring resource use at Center and developing strategies for increased resource conservation; special focus on energy systems.
- January 2001 - May 2001: ***Graduate Assistant, Pennsylvania Center for Environmental Education, Slippery Rock University.***
  Performed data analysis and edited a published report concerning environmental education.
- January 2000 - July 2000: ***Conservation Assistant, Frontera Audubon Society, Harlingen, Texas.***
  Provided research, networking and logistical support for a federal lawsuit.
- April 2000 - June 2000: ***Crew Leader, U.S. Census Bureau, Harlingen, Texas.***
- October 1995 - May 1999: ***Staff and Resident, Proyecto Fe y Esperanza/Casa Juliana, Alamo, Texas.***
  Proyecto Fe y Esperanza (PFE) operated a demonstration center for sustainable living and environmentally appropriate technology. Located in a low-income, Mexican-American immigrant farm-worker community, PFE worked in various ways to improve the quality of life in this community.
  - January 1998 - May 1999: ***Project Director***
    Coordinated the reorganization of PFE during transitional period. Managed merger of PFE with a program offering experiential education tours of the US/Mexico border.
  - May 1997 - May 1999: ***Appropriate Technology Program Coordinator***
    Maintained and developed PFE's Appropriate Technology (AT) Demonstration Center; consulted with regional groups and individuals regarding AT and sustainable living; contracted to build various AT systems (i.e. solar water heaters, solar cookers, cisterns, compost toilets); collaborated with local organizations, e.g. Habitat for Humanity, on community development projects; designed and co-authored technical manuals and other educational materials.

- ♦ October 1997 - December 1997: ***Member, Solar Cooker Team, Cuzco and Arequipa, Peru.***
  Introduced solar cookers in three communities, trained local people in their construction and use, and did follow-up work in two communities we had worked with in 1994 (see below).
- ♦ July 1996 - October 1996: ***Educator for Composting Program, City of Alamo, Texas.***
- ♦ January 1995 - September 1995: ***Volunteer, United Farm Workers Organic Farm Cooperative, Alamo, Texas.***
  Assisted in all aspects of farm operations, management, and organizational development.
- ♦ January 1994 - June 1994: ***Member, Solar Cooker Team, Arequipa, Peru.***
  At invitation of Medical Mission Sisters, we worked to design an economical, efficient solar cooker using locally available materials. We trained local people in construction and use of solar cookers; helped design Spanish-language pamphlet explaining use and construction of cooker.
- ♦ September 1992 - October 1993: ***Waste Watch Coordinator, Appalachia - Science in the Public Interest, Livingston, Kentucky.***
  Performed research, authored publications, and organized workshops.

**Other Work Experiences**

- ♦ Performed complete renovation of farm house using green building strategies to achieve an energy efficient, net-zero-electricity passive solar home for my family (2010 – present).
- ♦ Installed 2.1 KW solar photovoltaic system at my home, achieving net-zero electricity usage for our home and farm (2011, expanded in 2017). Expanded solar photovoltaic system to 7.3 KW in 2020.
- ♦ Assisted my wife in operation of a certified organic vegetable farm (2005 – 2022).
- ♦ Designed and installed battery-based PV system, solar water heater, and water pumping system from rainwater cistern for off-grid straw-bale house, Frankfort, Kentucky, 2013.
- ♦ Designed and developed 30 grid-tied or off-grid solar PV systems, including first solar lease in Kentucky, 2014 – present.
- ♦ Provided consulting services for Stonebridge Hospitality, Inc., owner of four hotels in Frankfort, Kentucky, regarding energy efficiency and sustainability improvements to their hotels (2010 – 2011).
- ♦ Designed 12 KW solar photovoltaic system for Earth Tools, Inc. and provided technical support in drafting a successful USDA REAP Grant application. Installation completed September 2011. Have prepared four successful USDA REAP Grant applications in total.
- ♦ Designed and managed installation of 17 solar water heating systems, serving 68 apartments, for the Housing Authority of Owensboro, Kentucky, 2010.
- ♦ Consulted with the Frankfort YMCA on renovation of solar thermal pool heating system, 2007 – 2010.
- ♦ Managed installation of solar water heaters on homes of seven families in Eastern Kentucky, 2008 – 2009.
- ♦ Developed and managed statewide rebate program for solar water heaters, 2006 – 2007.
- ♦ Provided educational presentations to the public about solar electric and solar water heating systems.
- ♦ Co-chaired the Frankfort Mayor’s Task Force on Energy Efficiency and Climate Change, 2007.
- ♦ Participated in Al Gore’s Climate Reality Project training (2008) and have made numerous public presentations about climate change and the energy transition.
- ♦ Consulted on green design features for the CHIPS Group Home in Pulaski, Pennsylvania, for RCI Company Architects, 2002 - 2003.
- ♦ Have implemented and managed multiple Federal and state grant projects, including from US Departments of Energy, Agriculture, EPA, and Kentucky Office of Energy Policy.

- ♦ Co-authored "Greening the New Science and Technology Center" for the Dean of the College of Health, Environment and Science at Slippery Rock University, April 2002.
- ♦ Designed and installed a solar electric system at the Robert A. Macoskey Center for Sustainable Systems Education and Research, April 2002, Slippery Rock, Pennsylvania.
- ♦ Led reconstruction of a root cellar, summer 2001, Frankfort, Kentucky.
- ♦ Assisted construction of a passive solar, timber frame house, including installation of a solar electric system and composting toilet in Frankfort, Kentucky, 2000.
- ♦ Led Composting Toilet Design workshop at Cedar Ring Congress, Frankfort, Kentucky, April 1997.
- ♦ Co-hosted weekend solar oven construction workshops, Frankfort, Kentucky, October 1994 and 1995.

### PUBLICATIONS

- ♦ Testimony to Kentucky PSC, Case No. 2022-00159, regarding distributed energy resources, October 2023.
- ♦ Testimony to Kentucky PSC, Case No. 2022-00402, regarding distributed energy resources, July 2023.
- ♦ Testimony to Kentucky PSC, Case No. 2020-00174, regarding net metering, October 2020.
- ♦ *Local Solar, Local Savings: How to Cut Electricity Costs in Half for Public Schools and Local Governments in Frankfort, Kentucky*, with Walt Baldwin, February 2021.
- ♦ *Frankfort's Energy Future: Exploring the Benefits of Renewable Energy and Energy Efficiency for the Frankfort Plant Board*, with Daniel Holder and Nathan Shuler, August 2016.
- ♦ *Recommendations to the City of Frankfort from the Mayor's Task Force on Energy Efficiency and Climate Change*, co-author, December 2007, Frankfort, KY.
- ♦ *The Kentucky Solar Energy Guide*, with Joshua Bills. 2005. Appalachia – Science in the Public Interest.
- ♦ *High Performance Buildings: Bringing Environmentally Sound Building Practices Into the Mainstream in Kentucky*. 2004. Appalachia – Science in the Public Interest, Mt. Vernon, KY.
- ♦ *Developing a Strategic Plan for the Implementation of a Campus Sustainability Initiative at Slippery Rock University of Pennsylvania: A Master's Thesis*. 2003. Slippery Rock University (SRU), Slippery Rock, PA.
- ♦ *A Study of Energy Use at the Macoskey Center for Sustainable Systems Education and Research: Social Costs, Ecological Impacts, and Sustainable Energy Solutions*. 2002. [A series of four posters with accompanying Power Point presentation and pamphlet.] SRU, Slippery Rock, PA.
- ♦ *Inclusion of Environmental Education in Pennsylvania Teacher Preparation Curricula* (with Dr. Thomas Mastrilli and Dr. Paulette Johnson). 2002. Penn. Center for Environmental Education, Slippery Rock, PA.
- ♦ "In Memory of Lorenzo Cleofas Mejia." *Mesquite Review: International Literature, Art and Culture*. August/September 2000, no. 18.
- ♦ *The Casa Juliana Solar Water Heater* (with David Omick). 1998. Proyecto Fe y Esperanza, Alamo, Texas.
- ♦ *The Casa Juliana Compost Toilet* (with David Omick). 1997. Proyecto Fe y Esperanza, Alamo, Texas.
- ♦ *A Solar Cooker* (with Mark Schimmoeller). 1996. Self-published.
- ♦ "Solar Cooking in Southern Peru" (with Mark Schimmoeller), *Home Power Magazine*. December 1994/January 1995, no. 44.

### Boards and Memberships

- ♦ Kentucky Center for Renewable Energy and Environmental Stewardship, Board member, 2009 – 2011.
- ♦ Kentucky Conservation Committee, Board Member, 2008 – 2015. President, 2014 – 2015.
- ♦ Kentucky Solar Energy Society, Founding Member, Board Member and Chair, 2008 – 2009, Board Member, 2019 - present.