SOUTHERN INDIANA GAS AND ELECTRIC COMPANY
d/b/a VECTREN ENERGY DELIVERY OF INDIANA, INC.

IURC CAUSE NO. 44645

DIRECT TESTIMONY ON REMAND

OF

M. SAMI KHAWAJA, PH.D.
CHIEF ECONOMIST
THE CADMUS GROUP

ON

EVALUATION, MEASUREMENT, AND VERIFICATION,
MEASURE LIFE, AND LOST REVENUES

SPONSORING PETITIONER'S EXHIBIT NO. 12 & ATTACHMENT MSK-1

DIRECTTESTIMONY OF

M. SAMI KHAWAJA, PH.D.

I. INTRODUCTION AND SUMMARY OF CONCLUSIONS

Q. Please state your name and business address.

A. My name is M. Sami Khawaja and my business address is 720 SW Washington, Portland, OR 97205.

Q. By whom are you employed and in what capacity?

A. I am employed by The Cadmus Group ("Cadmus"), an energy efficiency evaluation firm, as Chief Economist.

Q. Please describe your educational background and professional experience.

A. I hold a doctorate degree in Systems Science/Economics. I have been conducting impact evaluations for energy efficiency programs for nearly 35 years, and am an expert in evaluation methods. My skills encompass statistical sampling design, program theory and planning, implementation, and evaluation. During my more than three-decade career, I have led over 100 energy efficiency evaluation projects.

I am a co-author to the following documents:

- International Performance Measurement and Verification Protocol
- National Action Plan for Energy Efficiency Program Impact Evaluation Guide
- Electric Power Research Institute Impact Evaluation Guide
- U.S. Department of Energy Uniform Methods Project

I have provided expert testimony to Public Utilities Commissions in five states, including Ohio and Michigan, and have published work in *Contemporary Policy Issues, Energy Services Journal, The Journal of Applied Mathematics and Decision Sciences, Water Policy, Quirk's Market Research, Electricity Journal, Energy Magazine,* and *The American Journal of Agricultural Economics.* I have over 50 conference presentation and papers. I have conducted over 50 training workshops on evaluation methods all over the US and internationally.

Cadmus was a member of the TECMarket Works team selected by the statewide Demand Side Management Coordination Commission ("DSMCC") that performed evaluation services for Energizing Indiana. I participated in those activities. In addition, Cadmus was selected by the Vectren Oversight Board to perform evaluation services for gas and electric EE programs at Southern Indiana Gas and Electric Company d/b/a Vectren Energy Delivery of Indiana, Inc., ("Vectren South") and Indiana Gas Company, Inc. d/b/a Vectren Energy Delivery of Indiana, Inc. ("Vectren North"). In addition, the Vectren Energy Delivery of Ohio, Inc. ("VEDO") Collaborative selected Cadmus to perform evaluation services in Ohio for VEDO's gas programs. So, I am familiar with the gas and electric EE efforts at Vectren South, Vectren North and VEDO.

Q. Have you previously testified before the Indiana Utility Regulatory Commission ("IURC" or "Commission")?

A. I have not.

Q. What is the purpose of your direct testimony in this proceeding?

A. Vectren South, under the direction of the Vectren Oversight Board ("Oversight Board"), has retained Cadmus to perform evaluation services for its EE programs for the last approximately eight (8) years. As a result, Vectren South requested that I provide support for the reliability of saving estimates derived from evaluation, measurement and verification ("EM&V") activities. In addition, the Citizens Action Coalition of Indiana, Inc. ("CAC") suggested that a three (3) year cap should be placed on the recovery of lost revenue. I discuss the reasons a cap unrelated to the life of the measure is arbitrary. I also discuss the reason Vectren South's proposal to cap lost revenues based upon the weighted average measure life and a 10% reduction in savings add a level of customer safeguards that assure reasonable recovery of lost revenues.

Q. Are you sponsoring any attachments in this proceeding?

A. Yes. I am sponsoring the following attachment:

- Petitioner's Exhibit No. 12, Attachment MSK-1, which provides supplemental information regarding evaluation tools and techniques.

Q. Were your testimony and exhibits in this proceeding prepared by you or with your participation?

A. Yes.

Q. Would you please summarize your conclusions?

A. My conclusions are:

- The EM&V tools used in the Vectren South evaluation are rigorous and meet or exceed all industry standards.

- Utilities lose revenue for the duration of the effective useful lives (EUL) of the installed measures.

- The EUL values used by Vectren South are conservative for an overall weighted average measure life of 9 (rounded from 8.5) years. Applying widely used industry EULs would have raised the weighted average life to 9.5 years. The proposed use of the lower end confidence level estimates of savings by imposing a weighted average measure life cap of 9, then including the 10% further savings reduction, would equate to a 7.7 measure life cap, making it significantly more conservative. In other words, the use of conservative values for EULs, combined with the lower values of estimated savings (such as the probability of the actual savings exceeding the proposed values is 95%), yields a statistically conservative estimate of net lifetime energy savings.

- The uncertainty of the savings and the lost revenue estimation for future years exceeds that of recent years. The increased uncertainty in future years is brought about mainly due to measure removal or degradation of savings. The impact of both is likely exaggerated and the additional safeguards proposed by Vectren South are sufficient to compensate for the increased uncertainty. For example, the degradation of performance applies to the baseline equipment as well as the efficient equipment (perhaps to higher extent making the savings estimate more conservative).

II. EVALUATION MEASUREMENT & VERIFICATION IN THE CALCULATION OF LOST REVENUE

Q. Please describe the EM&V process utilized for Vectren South.

A. The evaluation covers three areas of investigation: Impact Evaluation, Process Evaluation, and Market Effects. My testimony discusses impact evaluation specifically. The impact evaluation can take many forms, from a general engineering desk review to a rigorous billing analysis using a control and treatment (program participant) group. To minimize uncertainty, as performed in Vectren South's most recent evaluation, one-fourth of the total savings were estimated via a randomized control trial analysis of billing data (the gold standard within the EM&V industry). Furthermore, the sampling methods utilized by Vectren South's evaluator for verification are rigorous and typically exceed industry-accepted statistical confidence and precision standards. The realization rate, which is a comparison between reported (claimed) and actual (evaluated) savings, adjusted for installation rate, for Vectren South has typically been high (95% in Vectren South's 2015 evaluation and 93% based on 2016 preliminary evaluation results) and therefore has shown successful performance.

Q. Is the EM&V process a rigorous and reliable source for determining energy savings?

A. Yes. A range of EM&V approaches and techniques are used to estimate electricity and gas savings for various energy efficiency programs. These methods have largely originated from the need for state regulators to assess the success of ratepayer funded programs. Regulators support evaluation activities because of their interest in documenting total savings, assessing the cost-effectiveness of efficiency compared to generation alternatives. The industry has been developing and improving these methods over the last 40 years. As a result, most of the EM&V methods have been tested and subjected to considerable scrutiny. The industry has responded by developing very rigorous protocols over the years. Most EM&V professionals adhere to these rigorous protocols. The intent of EM&V is to estimate the counterfactual, or what would have happened absent the program. There is no way to connect a meter and measure energy

not consumed. Instead, energy savings must be estimated using such approaches as field measurements, modeling, energy bill analysis, user surveys, etc. Not all methods are equally rigorous. The level of rigor employed is determined primarily by two factors: 1) the contribution and importance of the program; and 2) the uncertainty of the major inputs.

Evaluators perform many different types of analysis to estimate energy savings for energy efficiency programs, including: custom engineering estimates, REM/Rate analysis, billing analysis, engineering desk reviews, demand elasticity modeling, leveraged analysis and regression modeling. The rigorous and reliable impact evaluation produces a statistically valid estimate of actual savings. Descriptions of these various evaluation activities can be found in Petitioner's Exhibit No. 12, Attachment MSK-1.

Q. Discuss the confidence and precision of statistical sampling as it relates to the EM&V process.

A. Confidence and precision energy program evaluation is typically based on estimating energy impacts using a representative sample of program participants to determine how measures are installed and used. The results of these efforts are then used to estimate savings for the program. For Vectren South, program evaluations are in line with the industry standard of obtaining estimates with a confidence level of 90% with a relative precision of ±10%.

Statistical sampling seeks to minimize bias in energy savings estimates, while increasing the precision of these estimates. Bias arises when either the sampling design or the measurement approach leads to estimates that do not equal the true target value (e.g., average savings of population of LEDs distributed). In other words, bias is a negative property to be avoided. A confidence interval is a range of values that is believed—with some stated level of confidence—to contain the true population metric. The confidence level is the probability that the interval contains the target quantity. Precision provides convenient shorthand for expressing the interval believed to contain the estimator (e.g., if the estimate is 1,000 kWh, and the relative precision level is 10%, then the interval is 1,000 ±100 kWh. Stated another way, we are 90% confident that the true unobserved

population value is between 900 and 1,100 kWh). The purpose, then, of statistical sampling in the EM&V process is to mitigate risks of inaccurate energy savings estimates, while increasing the reliability of the evaluation results.

Q. Does the accuracy of estimating energy savings from EE programs impact only lost revenue calculations?

A. No. Measuring the savings is also relevant to determining the cost effectiveness of the measure or program. Additionally, the reliability of EE as a resource is dependent on rigorous EM&V. Utilities integrated resource planning process will be negatively impacted without reliable EM&V methods.

Q. Is it appropriate to recover lost revenues for the life of measure?

A. Yes. Lost revenues are an estimation of the amount of lost sales attributable to energy efficiency programs, as measured by evaluation, measurement and verification. Lost revenue (lost kWh times fixed portion of retail rate) recovery is appropriate for the life of measure because as long as the measure is installed and is saving energy, the utility is losing revenue. Of course, measures may be removed for many reasons. EUL estimates account for measure failure. Measure removal is still a risk, but the safeguard suggested by Vectren South is sufficient to compensate for the lost savings.

Q. What concerns do you have with a three (3) or four (4) year measure life cap?

A. Utilities should be allowed reasonable opportunity to recover their program cost and lost revenues. Otherwise, demand side and supply side options are not comparable from financial perspective (the playing fields are not level). Failure to recover these costs will reduce utility earnings. Also, a three or four-year cap will incent utilities to pursue measures with short lives at the expense of more deep reaching long lasting measures (e.g. insulation).

Most importantly, it is extremely likely that lost revenues are far in excess of those claimed due to the significant amount of market effects caused by utility programs.

Q. Please describe what you mean by market effects.

A. We define a "market effect" as a change in the structure or functioning of a market or the behavior of participants in a market that is reflective of an increase in the adoption of energy-efficient products, services, or practices and is causally related to market interventions. Very often these market interventions are the activities of DSM programs. One goal of Vectren South DSM programs is to transform energy use such that energy is used more efficiently than it has been in the past, that current gains in energy efficiency are retained in the future, and that market actors (i.e., customers, trade allies) value energy efficiency more highly in their future decision-making than they have in the past.

There are two key aspects to assessing market effects. The first is to describe and understand a market to understand how it may be changed and to establish a baseline against which changes can be measured. Surveys conducted as part of Vectren South's DSM program evaluations regularly monitor and track these changes. Program managers can use this same market assessment information to identify and improve existing program strategies. The second aspect, also monitored with surveys, is to understand how the interventions have influenced the market in order to refine and improve interventions, to identify situations in which interventions are no longer needed, and to determine what new or continuing interventions and strategies may be needed to maintain and improve upon the desired outcomes. Market effects have occurred when awareness levels have increased, energy efficient products stocking has increased, trade allies and contractors have been trained and are pushing energy efficient options, among other metrics.

Q. Is it appropriate to cap lost revenue based on weighted average measure life of a plan?

A. Yes. Lost revenue will take place for the duration of the measure life. That is the time upon which recovery should be based. It is important to appreciate that EUL is not an actual end of life metric for a measure. It is simply the median of life. In fact, as such, 50% of all measures will fail before that date. But, 50% will also live long after the EUL. The survival rate of measures is not linear. Most of the 50% that will fail by the EUL will actually be operational for the great majority of the EUL. During that time period,

revenues are lost almost consistently. For a time period after the EUL, revenues will continue to be lost for some period of time. As such, EUL is a conservative estimate of the length of revenue lost period. The most practical and feasible methods to determine EULs and persistence is to use benchmarking sources such as Technical Reference Manuals (TRM's), which in turn rely on combinations of manufacturer's claims, laboratory research, field studies, and other primary research often conducted by national labs with federal grants (e.g., Lawrence Berkeley National Laboratory). This primary research can be fed back into TRMs that states and utilities can utilize to inform the next DSM program year or cycle. The EULs currently used by Vectren South are conservative. In the first quarter of 2017, Vectren South's independent, third-party evaluator, Cadmus, benchmarked a sample size of approximately 50% of all measures included in the 2016-2017 Plan. This analysis indicated 96% of the evaluated measure lives used in Vectren South's 2016-2017 DSM filing are closely aligned with the latest evaluation results. However, 25% of Vectren South's measure EULs were found to be conservatively low.

The EM&V impacts were estimated at 90% confidence and ±10% precision. I would recommend going to the low end of the confidence interval and use those estimated savings to calculate the weighted average measure life. This approach will, in essence, conservatively use values that have a 95% chance of being at that level or higher. This will reduce the weighted average measure life calculation by 10%.

Q. Do you believe that the estimate of lost revenues by its nature becomes less precise, less accurate and less certain over time?

A. Estimates of anything are more certain in the immediate than in the distant future. That is a given. However, with the safe guards proposed above, (lower end of the confidence interval and lower EULs than industry norm) certainty of achieving those savings (or higher) is significantly increased. Change in expected savings due to changed operating hours or changes in operations are not valid reasons in my mind, as the change can go in either direction. Degradation in savings, also known as savings persistence, is also not a valid argument as the baseline equipment would also have degraded leaving the difference between the installed efficient equipment and baseline equipment (i.e., the

savings) unchanged. In fact, one can argue that the baseline equipment would have witnessed higher degradation and savings would have increased.

Q. Can you summarize your testimony regarding the use of evaluation, and effective useful life of measures, in the calculation of lost revenues?

A. In my view, Vectren South's use of evaluation results, combined with the EUL of program measures, is a conservative basis for the calculation of lost revenues.

First, the EUL values used are conservative (Vectren South estimate of weighted average life is 9 (rounded from 8.5) years while the same estimate based on industry values is 9.5 years).

Second, Vectren South's evaluation process for estimating net energy savings utilizes at minimum a 90% confidence interval (industry accepted standard). Vectren South supports a 10% degradation of annual savings within its lost revenue calculation. This reflects using the lower end of the confidence interval which is also statistically conservative. This equates to a weighted average life of 7.7 years.

Finally, it is extremely likely that lost revenues are far in excess of those claimed due to the significant amount of market effects caused by utility DSM programs.

Q. Does this conclude your direct testimony?

A. Yes.

VERIFICATION

I, M. Sami Khawaja, PH.D, Chief Economist at The Cadmus Group, affirm under the penalties of perjury that the statements and representations in the foregoing Direct Testimony are true to the best of my knowledge, information and belief.

M. Sami Khawaja
Dated: June 13, 2017

DESCRIPTION OF EVALUATION ACTIVITIES

Custom Engineering Estimates

Custom commercial/industrial programs often have measures that are specific to each customer. For such types of measures, customer engineering estimates are required, as is conducted for Vectren South's C&I Custom Program. Some type of initial estimate will typically be developed by the program implementation contractor. Impact evaluation may utilize the program estimate and focus on attribution questions, or may develop a revised estimate based on further on-site data collection and analysis. For on-site data collection, custom project-defined parameters are monitored. Parameters of interest include hours of operation, duty cycle (percent of time running in each time increment), instantaneous demand, cumulative energy consumption, flow rates (for pumps and chillers), indoor and outdoor temperatures, and volumes of throughput for manufacturing operations.

REM/Rate Analysis

This analysis entails modeling several homes (with computer programs such as DOE-2) to develop a relationship between Home Energy Rating System (HERS) score and home size. The evaluator then compares this baseline to homes that received program incentives. Simulation models such as REM/Rate are essentially a very detailed engineering estimation approach. This approach is being used to evaluate Vectren South's Residential New Construction Program.

Billing analysis

Billing analysis examines changes in whole-premise energy consumption by analyzing monthly consumption histories based on billing records. In the case of the billing analysis conducted for Vectren South, control groups are identified by matching each program home's consumption with similar consumption of homes in a control group (the approach used for the Residential Behavior Savings Program). The change in usage is then calculated over time, accounting for effects of naturally occurring efficiency and non-program impacts. The randomized control trials employed for the company is considered the gold standard in the industry.

Engineering desk review and Standardized Engineering Estimates

For programs that do not require a regression or billing analysis, the evaluator conducts engineering desk reviews. The analysis reviews all calculation and formula inputs for deriving energy and demand savings. The evaluator uses utility program tracking data, data assumptions from TRMs, industry studies and research papers, and applicable measure engineering estimates to ensure that each calculation is accurate to the specific territory in question. These reviews are the basis for evaluations for Vectren South's C&I programs.

In conjunction with engineering desk reviews, standardized engineering estimates calculate savings based on assumed equipment and usage parameters, such as efficiency, kW/ton, and hours of operation. For prescriptive measures, such estimates are typically part of program assumptions and are included in the program tracking data base. Where these estimates have not been developed by the program, they may be developed as part of the impact evaluation. In cases where many similar measures are installed and the engineering parameters are well known, standardized engineering estimates may be the basis for impact estimates, with most of the evaluation effort going to program attribution (net-to-gross analysis).

Demand Elasticity modeling (price response model)

This form of analysis uses sales data from a tracking database, as well as marketing materials, to create a model that predicts the demand for efficient light bulb sales in the absence of the program. The evaluator takes aggregated sales data and dissects it into observable time frames, usually a week to a month, and matches sales data against the price of the measure at that point in time. Essentially, the model compares responsiveness of consumer demand of specific products when price changes occur. This impact approach is often used for "upstream" lighting programs, and is being used for Vectren South's Residential Lighting Program. Elasticity models are a common approach in many economic studies within and outside of the EM&V world.

Leveraged Analysis

A key aspect of Vectren South's technical approach to impact evaluation is to use leveraged analysis of sample data wherever practical. A leveraged analysis builds a relationship between sample observations and other information known not only for the

sample but also for the program population the sample represents. The relationship determined from the sample is then applied to the population to extend the sample results. This type of leveraging approach is useful whenever the information available for the broader group has a good relationship to the information of interest available only for the sample.

Regression modeling

Another type of leveraged analysis is regression modeling. The sample is used to develop a regression model predicting energy savings (or another key quantity of interest such as demand reductions) as a function of known characteristics. The fitted model is then applied to the general population, or to a larger sample for which the characteristics are known. This impact approach is used by Vectren South for evaluating the Appliance Recycling Program. Another type of regression model (day matching based on temperature) is being used for the Smart Thermostat Pilot Program.