

A Reasoned Analysis for a New Distributed-Generation Pricing Mechanism for Michigan Regulated Electric Utilities

Preliminary Study

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Robert G. Ozar P.E.
Assistant Director, Electric Reliability Division
Michigan Public Service Commission

Outline

- 1. Introduction**
2. Foundations
3. Modeling overview
4. Onsite-usage analysis
5. Cost-of-Service implications of DG study results
6. Economic & payback analysis



Legislative Directives to the Michigan Public Service Commission

PA 341 Sec. 6 (a) (13)

...**the commission** shall conduct a study on an appropriate tariff reflecting an equitable cost of service for utility revenue requirements for customers who participate in a net metering program or distributed generation program under the clean and renewable energy and waste reduction act...

...**the commission** shall approve such a tariff for inclusion in the rates of all customers participating in a net metering or distributed generation program...

Hierarchy of Legislative Directives

The commission shall conduct a study:



- on an appropriate tariff
- reflecting an equitable cost of service
- for utility revenue requirements

for customers who participate in a net metering program or distributed generation program

“tariff”

DG Pricing
Mechanism

Primary Objective

To develop a new approach to replace Net Energy Metering* for renewable generation under 150 kW, and for methane digesters up to 550 kW

- That allows for **traditional cost-of-service** methods to allocate costs, and thus determine a fair cost-of-service
- That has **billing determinants that strongly connect to actual grid usage**, and thus provides **accurate and transparent price signals**:
 - Inducing optimal DG system operations
 - That fairly monetizes the value of customer participation in **demand response, load control, and energy efficiency** actions, and thus equitably contributes toward the purchase of advanced technologies that allow such activities
- Retains DG as a reasonable/economic option for customers

* Subject to PA 342, Sec. 183

Secondary Objectives

- To determine if it is necessary to create **specific DG rate classes** for “solar, solar/battery, or other renewable energy systems” for allocating costs in a COSS
- To determine a **valuation method** for customer-sited generation that is injected into the grid (excess generation)
- To determine whether **credit for generation-capacity** should be reflected:
 - ***on a class basis*** [i.e. as an offset to coincident demand (inflow) in the COSS];
or
 - ***on an individual customer basis***, [i.e. as bill credits for DG capacity available to the grid (per kWh or kW credit)]

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Distributed Generation (DG) Program Regulatory Principles

All DG pricing mechanisms are variations of three foundational approaches:

- **(1) Grid-based balancing service**
- **(2) Retail customer as Small Power Producer (SPP)**
- **(3) Actual power inflows and outflows as billing determinants**

DG Mechanisms

- **Balancing services**
 - **True net-metering** operates as an uncompensated (free) kWh balancing service [grid as battery]
 - **Modified net-metering** is a billing or pricing-period balancing-service in which net excess generation is converted to a \$ credit (applied to future monthly bills)
- **Retail customer as Small Power Producer** (generation is separately metered)
 - **[True feed-in tariff]** Generation is interconnected upstream of the utility billing meter
 - **[Buy-all Sell-all]** Generation is interconnected downstream of the utility billing meter (at the customer's service panel)
- **Inflows and outflows as billing determinants**
 - **[Inflow & Outflow Mechanism]** Power inflows are retail purchases, power outflows credited as if generated by a SPP

Net Energy Metering Pricing Model

Uses net of [Inflow – Outflow] to calculate the customer bill:



Customer Charge + (kWh)_[(Inflow-Outflow)+CF] × $\left(\frac{\$}{\text{kWh}}\right)$ Full Retail Rate *If (I – O) + CarryForward > 0*

or = *Customer Charge*

If (I – O) + CarryForward ≤ 0

Buy-all Sell-all Pricing Model

Uses **Consumption** and **Generation** to calculate the customer bill:

$$\begin{aligned} & \text{Customer Charge} + (\text{kWh})_{\text{Consumption}} \times \left(\frac{\$}{\text{kWh}} \right)_{\text{Full Retail Rate}} - [(\text{kWh})_{\text{Generation}} \\ & \times \left(\frac{\$}{\text{kWh}} \right)_{\text{Value of Energy}} - \text{Capacity Credit}_{\text{Generation}} \end{aligned}$$

Based on Nameplate Capacity:
e.g.
 $\text{ELCC} \times \text{Capacity}_{\text{Nameplate}}$

Traditional DG Pricing Mechanisms were Designed to Promote Market Adoption of Nascent Renewable Technologies

- **Net Energy Metering (NEM):** *understates* cost-of-service
 - By definition true NEM applies the standard retail-rate to a customer's **net purchases** and that precludes customer bills from reflecting COS
- **Buy-all Sell-all (BASA):** *overstates* COS
 - Uses billing determinants that conflict with actual power flows
 - High “feed in” or “value of solar” credits needed to provide economic payback

DG Pricing-Mechanism Conundrum

Billing determinants that deviate substantially from the physical service provided make it exceptionally difficult to:

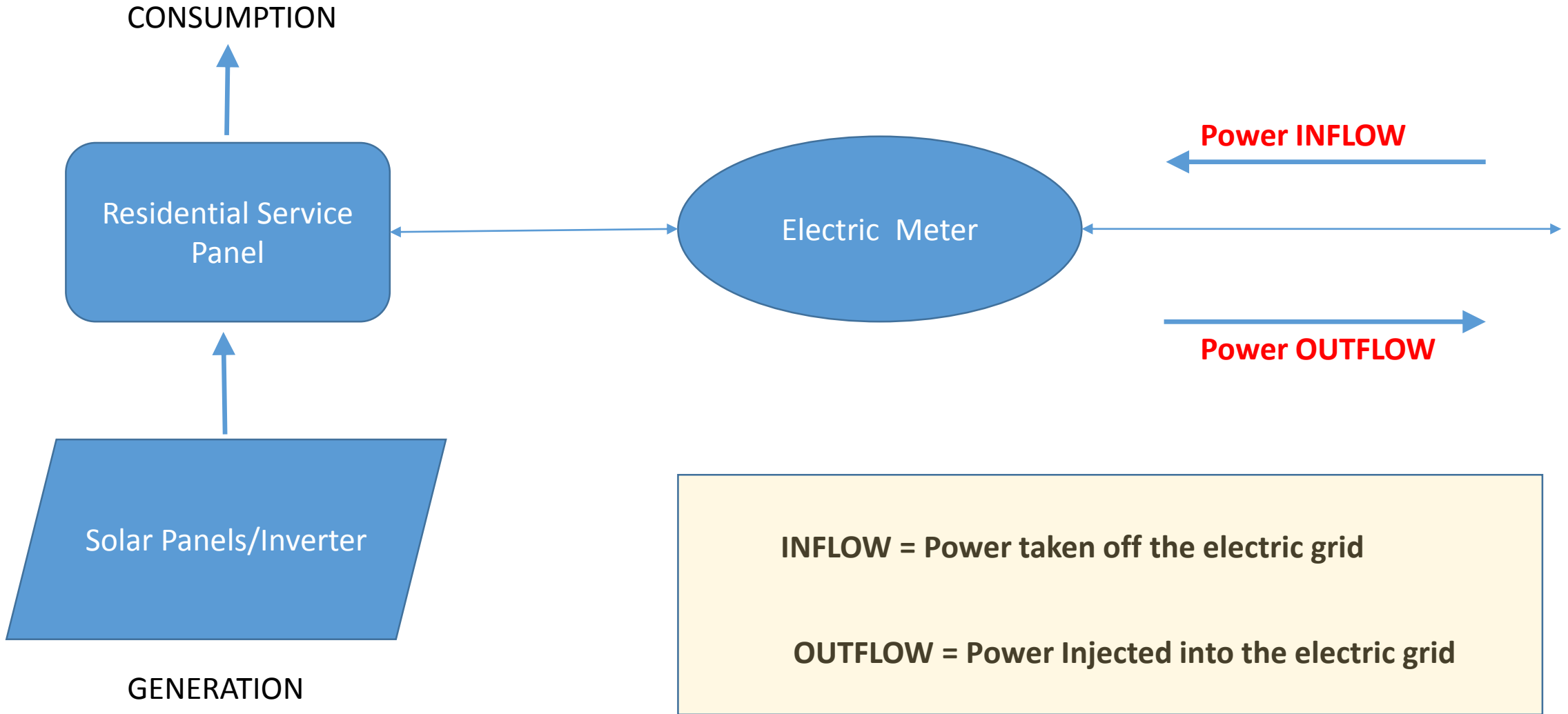
- (1) recover a “fair” cost of service; and
- (2) induce efficient operational and economic behavior

Core Issue:

Solution - Inflow & Outflow Mechanism

- **Supports traditional cost causation analysis**
 - Easiest method to implement *cost-of-service* based rates
 - Allows for dynamic pricing, dynamic credits, value of energy or avoided-cost credits, and demand charges (distribution and power supply)
- **Customer bills are highly correlated with actual power flows** at the customer's interconnection with the distribution grid
 - Can send clear and accurate pricing signals to customers
- **Flexible platform is “future proof”** with respect to changing DG technologies and regulatory objectives

What is INFLOW and OUTFLOW?



Inflow & Outflow Pricing Model

[Simple commodity based rate-design]

Uses **Inflow** and **Outflow** to calculate the customer bill:

$$\text{Customer Charge} + (\text{kWh})_{\text{Inflow}} \times \left(\frac{\$}{\text{kWh}} \right)_{\text{Full Retail Rate}} - [(\text{kWh})_{\text{Outflow}} \times \left(\frac{\$}{\text{kWh}} \right)_{\text{Value of Energy \& Capacity}}]$$

Starting Point: Same Retail Rate as Full Requirements Customers

Inflow & Outflow Pricing Model

[Commodity and demand based rate-design]

Uses **Inflow** and **Outflow** to calculate the customer bill:

$$\begin{aligned} & \text{Customer Charge} + \\ & (kWh)_{\text{Inflow}} \times \left(\frac{\$}{kWh} \right)_{\text{Distribution \& Power Supply}} + (kW)_{\text{Inflow}} \times \left(\frac{\$}{kW} \right)_{\text{Distribution \& Power Supply}} \\ & - [(kWh)_{\text{Outflow}} \times \left(\frac{\$}{kWh} \right)_{\text{Value of Energy}}] - \text{Capacity Credit}_{\text{Outflow}} \end{aligned}$$

Based on Outflow, not Nameplate Capacity:

e.g.

$$ELCC \times Capacity_{\text{Nameplate}} \times Outflow_{\text{Capacity Factor}}$$

I & O Mechanism Requirements

- **Billing meter must be capable of measuring power flows in both directions**
 - Extensive smart-meter data allows for progressively more accurate COSS allocators in future general rate proceedings
 - Reasonable to base implementation on net-metered hourly demand [i.e. net inflow or net outflow]
- Ideal implementation based on independent calculation of **integrated** inflows and **integrated** outflows
 - On an instantaneous basis, there is only a power inflow or outflow
 - In any given hour a customer can have both inflows and outflows
 - Not the same as net-metered hourly demand
 - Consideration for future fine-tuning of I&O mechanism

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Model Structure

- Excel Model (hourly)
- Model input – residential consumption & solar PV generation

DOE/NREL System Advisor Model (SAM)

Residential Hourly Load Distribution

[Lansing Capital City Airport TMY3]

NREL PV watts Model

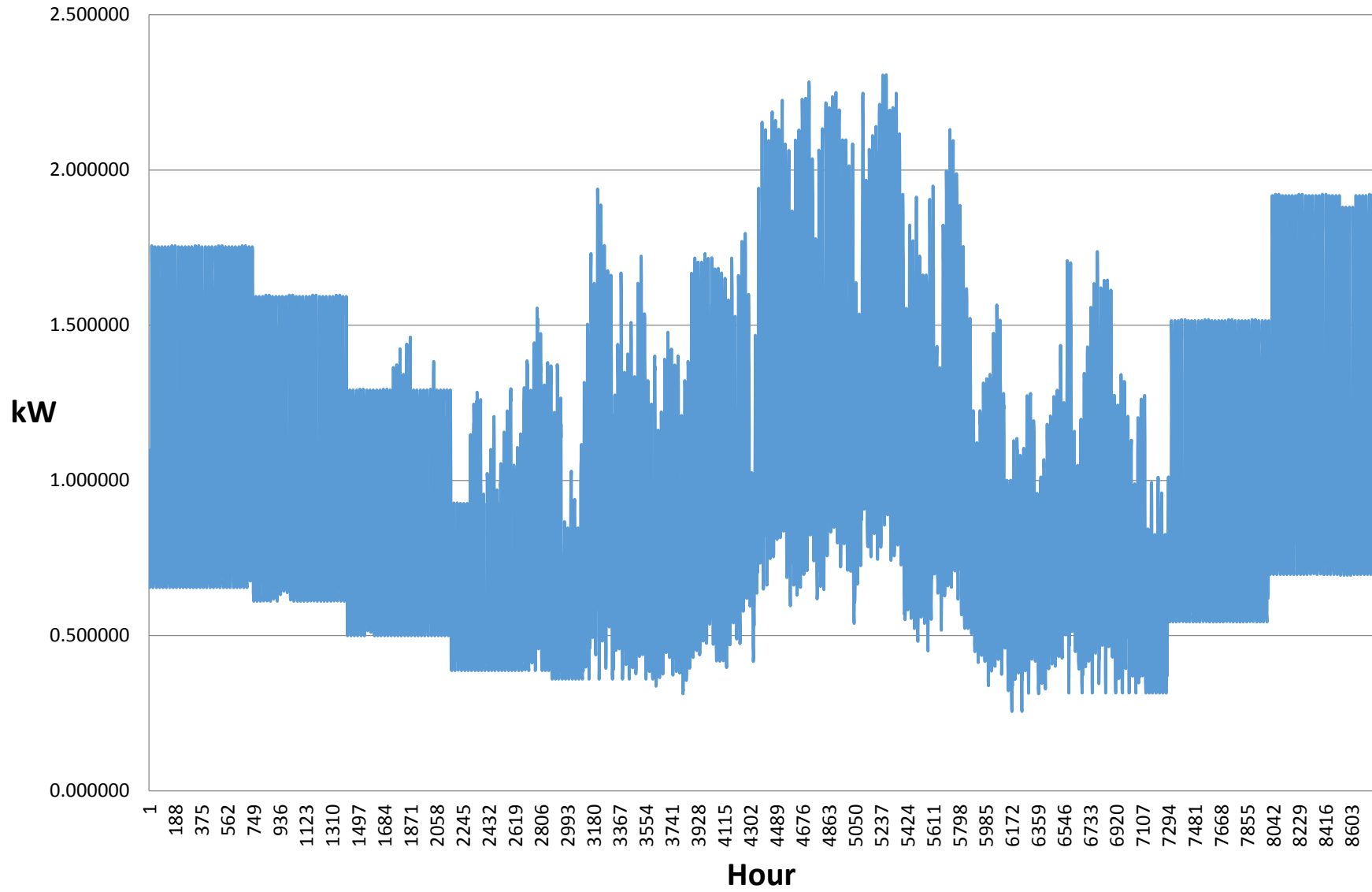
(8760 hour) Solar Output kW (AC)

Fixed Tilt @ 20deg, Lansing MI

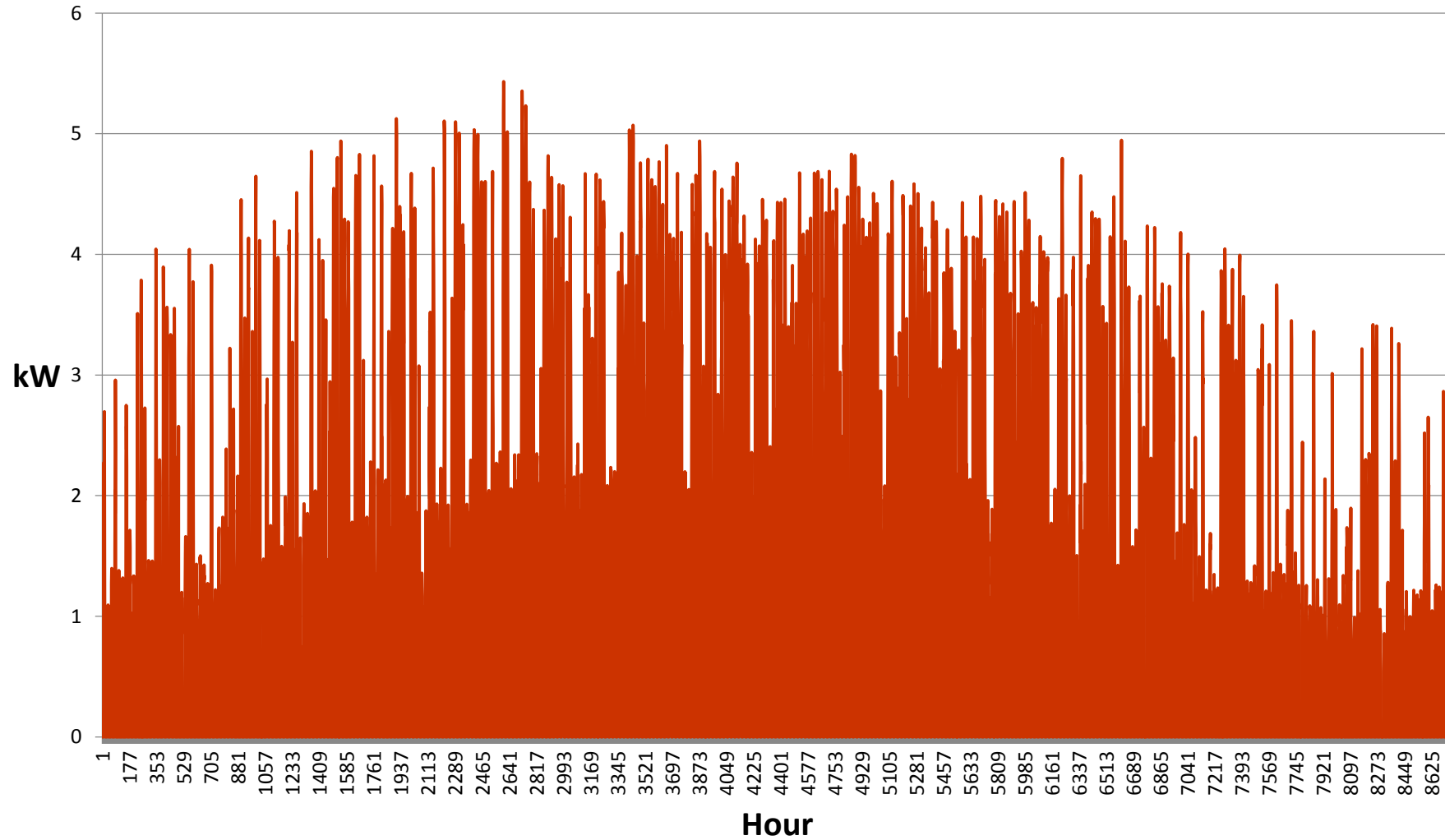
- SAM output calibrated to Consumers Energy's projected 2016 test-year residential annual sales level of 7,844 kWh [U-17990]
- Monthly sales distribution calibrated to match CE's 3-year average residential 4CP (best match uses historical 2010 residential monthly sales distribution)
- **Model Output - power inflow, power outflow, onsite usage, battery charge, and battery discharge**

Average Residential Usage - Hourly kW/Customer

Annual Load - 7,844 kWh



NREL PVWatts Calculator
Hourly Solar Output (AC) kW
System Capacity 6.28 kW (DC)
Fixed Tilt @ 20deg, Lansing MI



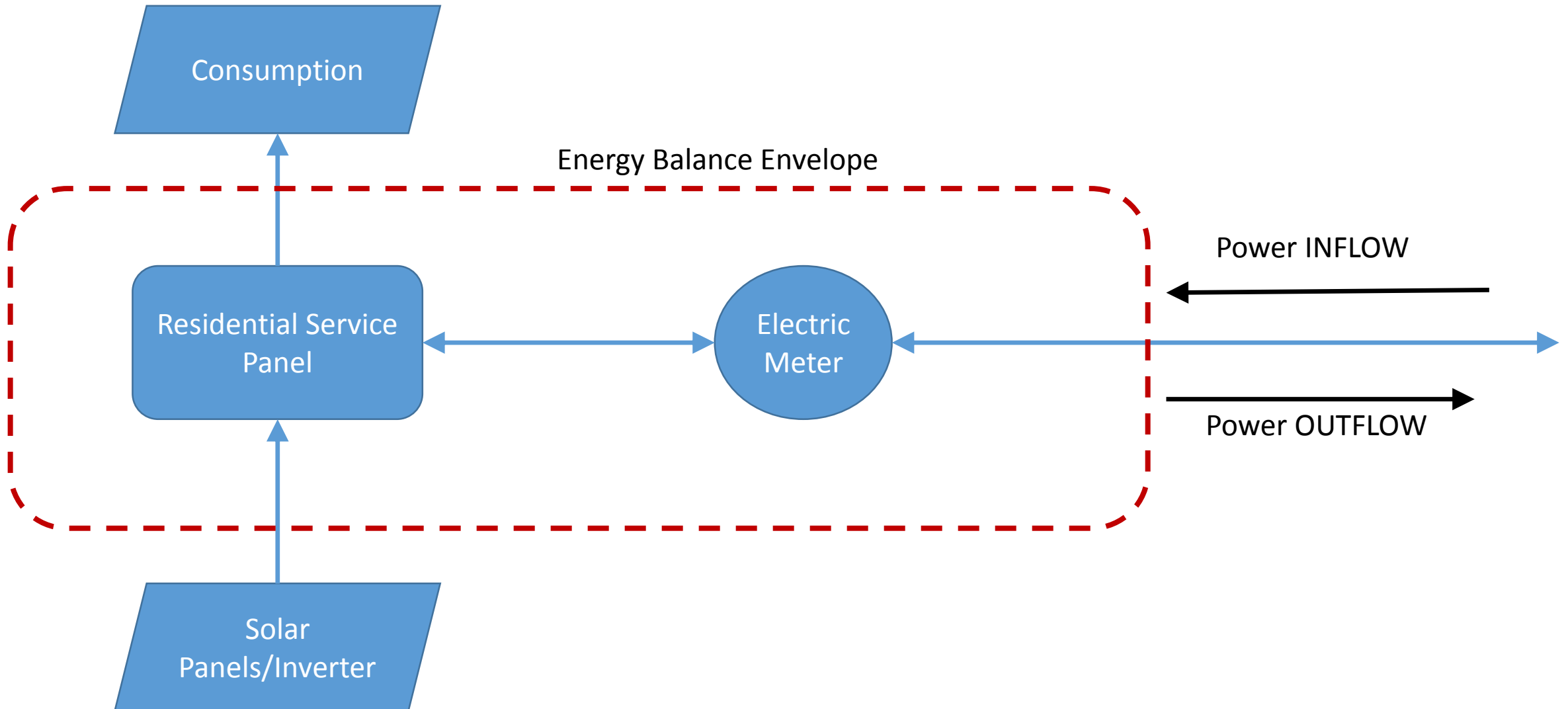
Modeling Mathematics

- The derivation of the mathematical relationships between generation and consumption, and power inflows and outflows, starts with an energy balance:

$$\text{[Energy In = Energy Out]}$$

Equation (1)

Distributed Generation Customer Energy-Balance



Energy Balance

- Inserting all energy flows intersecting the energy balance envelope [dashed line] into Equation (1), yields an exact relationship between the model's key input variables, generation and consumption, and the desired grid parameters, inflow and outflow; i.e.

- **[Generation + Inflow = Consumption + Outflow] Equation (2)**

- Or alternately stated;

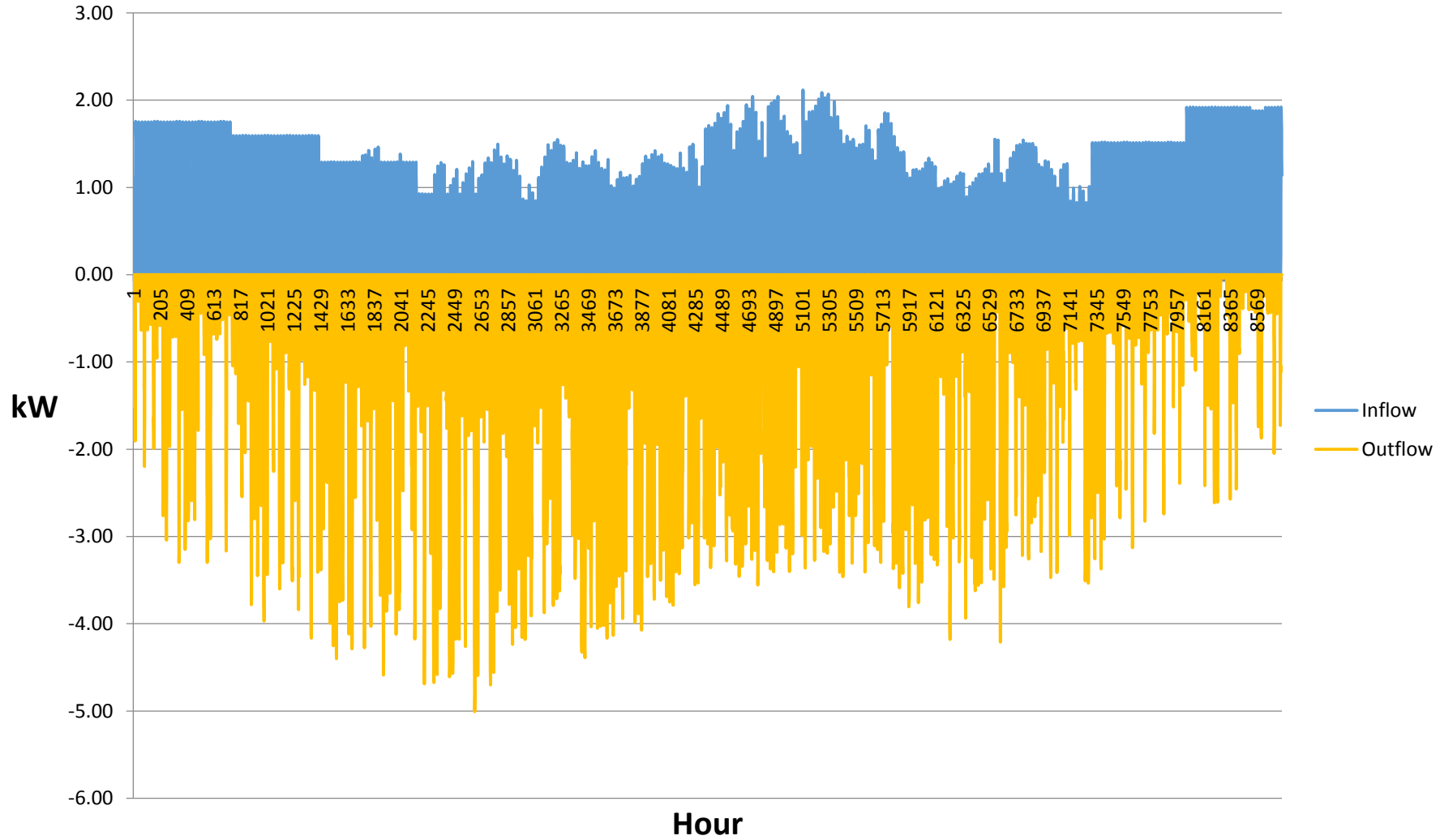
- **[Inflow – Outflow] = [Consumption – Generation] Equation (3)**

Simplifying Assumption

- Consumption and generation data-output by the SAM and PVWatts[®] models are limited to hourly values.
- A **net positive (or negative)** value of [Consumption – Generation] over the course of an hour represents a practical estimate of the **integrated hourly inflow (or outflow)** for that hour.

In this manner, a stream of 8760 (hourly) inflows and outflows are developed from consumption and generation data.

**Residential Distributed Generation Customer
Hourly Inflow & Outflow (kW)
January -December
Solar PV Capacity 6.28 kW (AC)**



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Onsite Usage of Distributed Generation

Because onsite-usage can be quantified by reference to smart-metered power flows, it is the key to unlocking past barriers to implementation of cost-of-service based DG tariffs.

Calculation of Generation Used Onsite

Rearranging the energy balance (Eq. 3) yields two identities:

$$\mathbf{[Generation - Outflow] = [Consumption - Inflow]} \quad \mathbf{Equation (4)}$$

These mathematical identities are recognized as representing the “onsite-usage” portion of the generation output.

$$\mathbf{Onsite\ usage = [Generation - Outflow]} \quad \mathbf{Equation (5)}$$

And:

$$\mathbf{Onsite\ usage = [Consumption - Inflow]} \quad \mathbf{Equation (6)}$$

Inflow/Outflow as a Function of System Properties

The *physical electrical system* suggests that Equations (5) and (6) be rearranged to a form in which inflow and outflow are the dependent variables:

$$\text{Inflow} = [\text{Consumption} - \text{Onsite Usage}]$$

Equation (9)

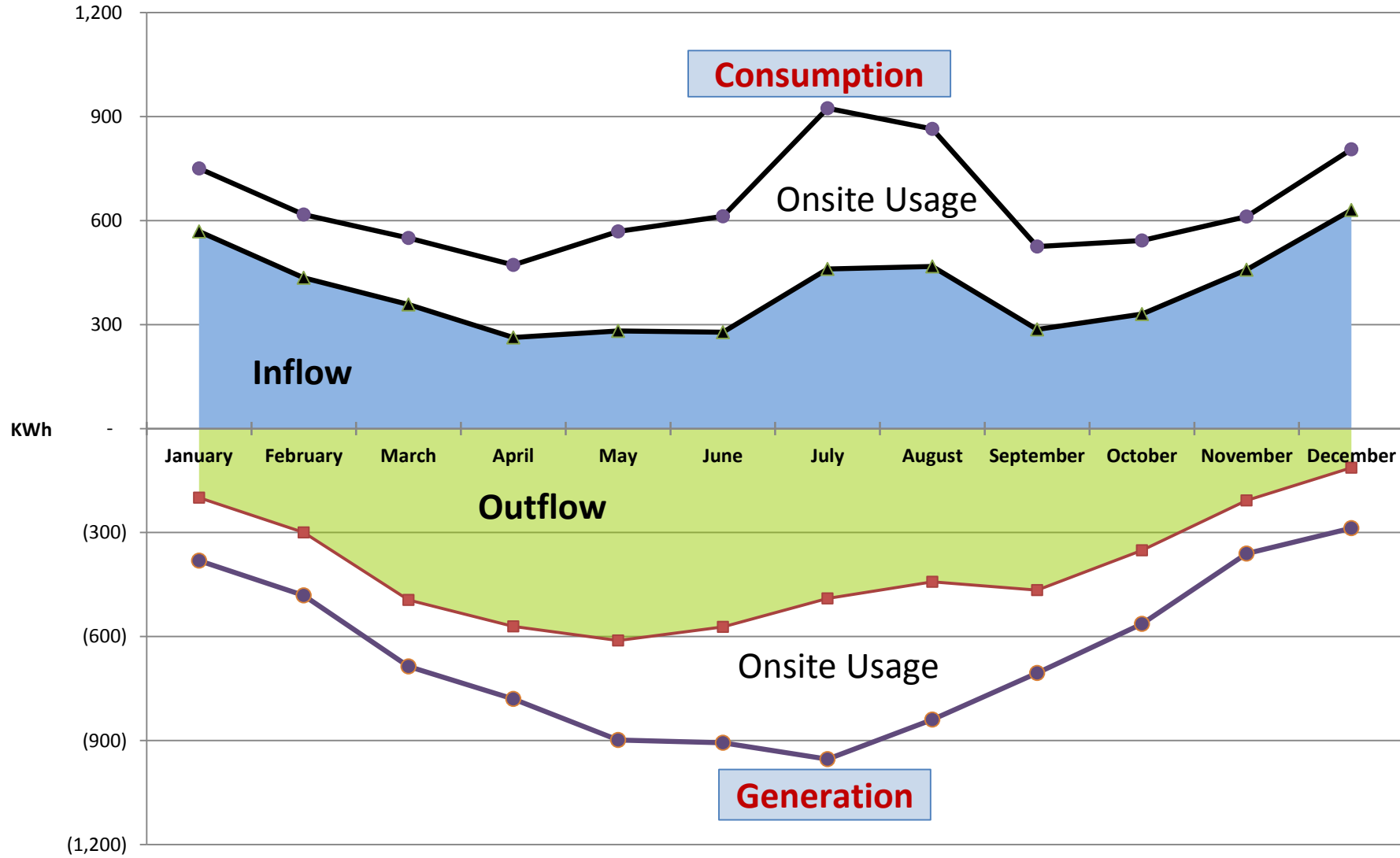
And:

$$\text{Outflow} = [\text{Generation} - \text{Onsite Usage}]$$

Equation (10)

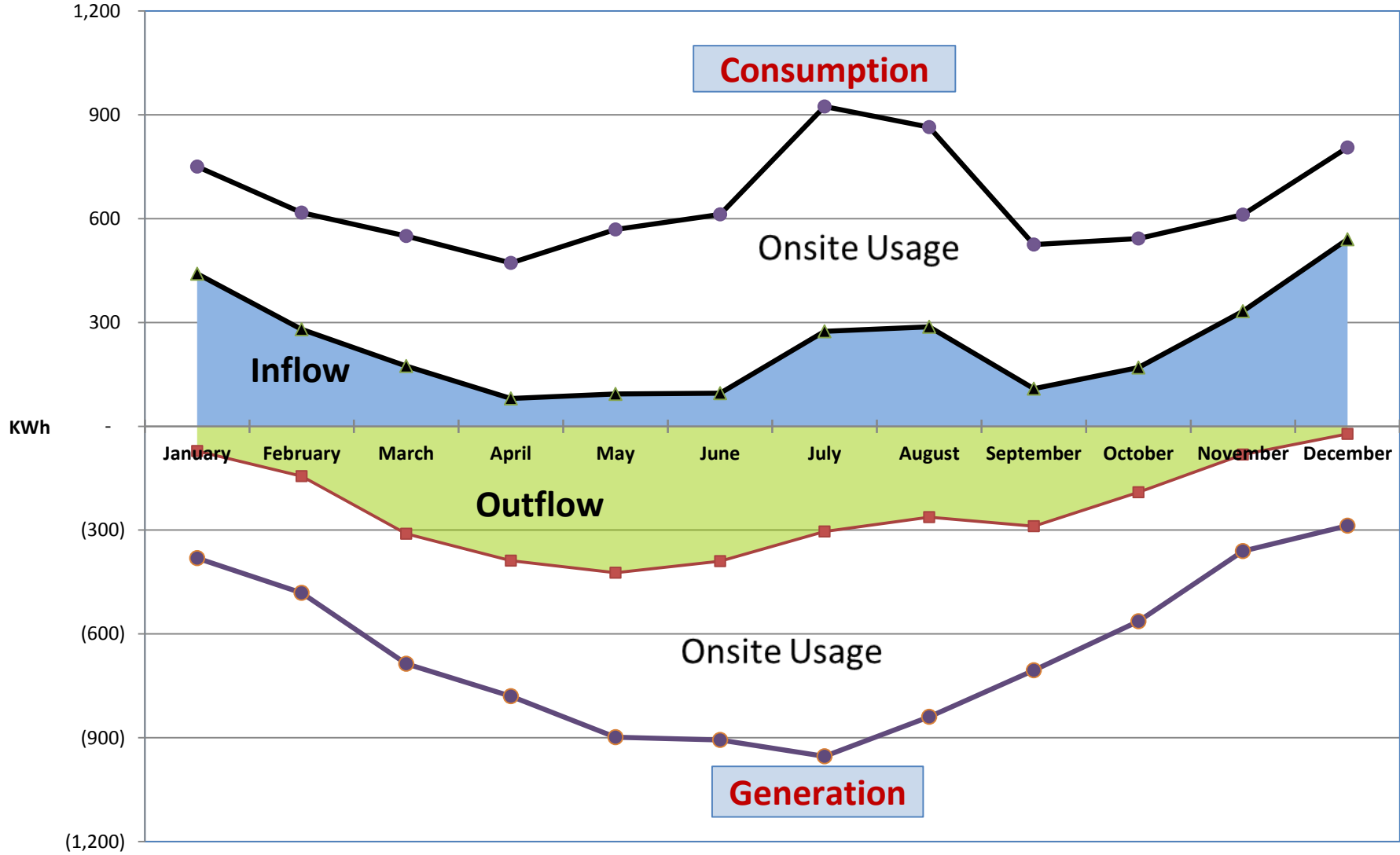
Residential Distributed Generation Comparison of Power Flow Parameters

6.28 kW Solar PV [100% of Annual Consumption]: 8760 hour analysis



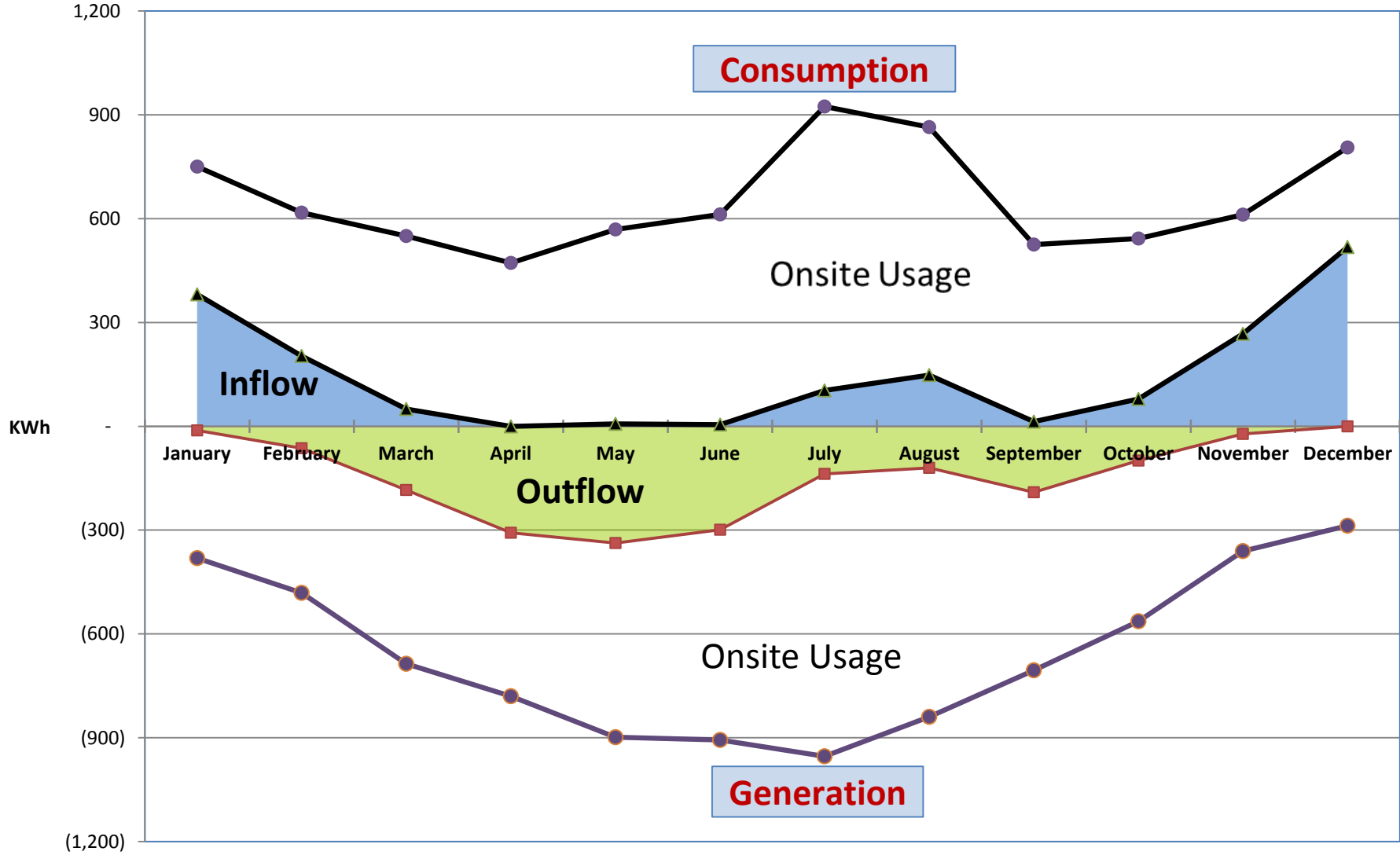
Residential Distributed Generation Comparison of Power Flow Parameters

6.28 kW Solar PV + 7 kWh Tesla Powerwall 1: 8760 hour analysis



Residential Distributed Generation Comparison of Power Flow Parameters

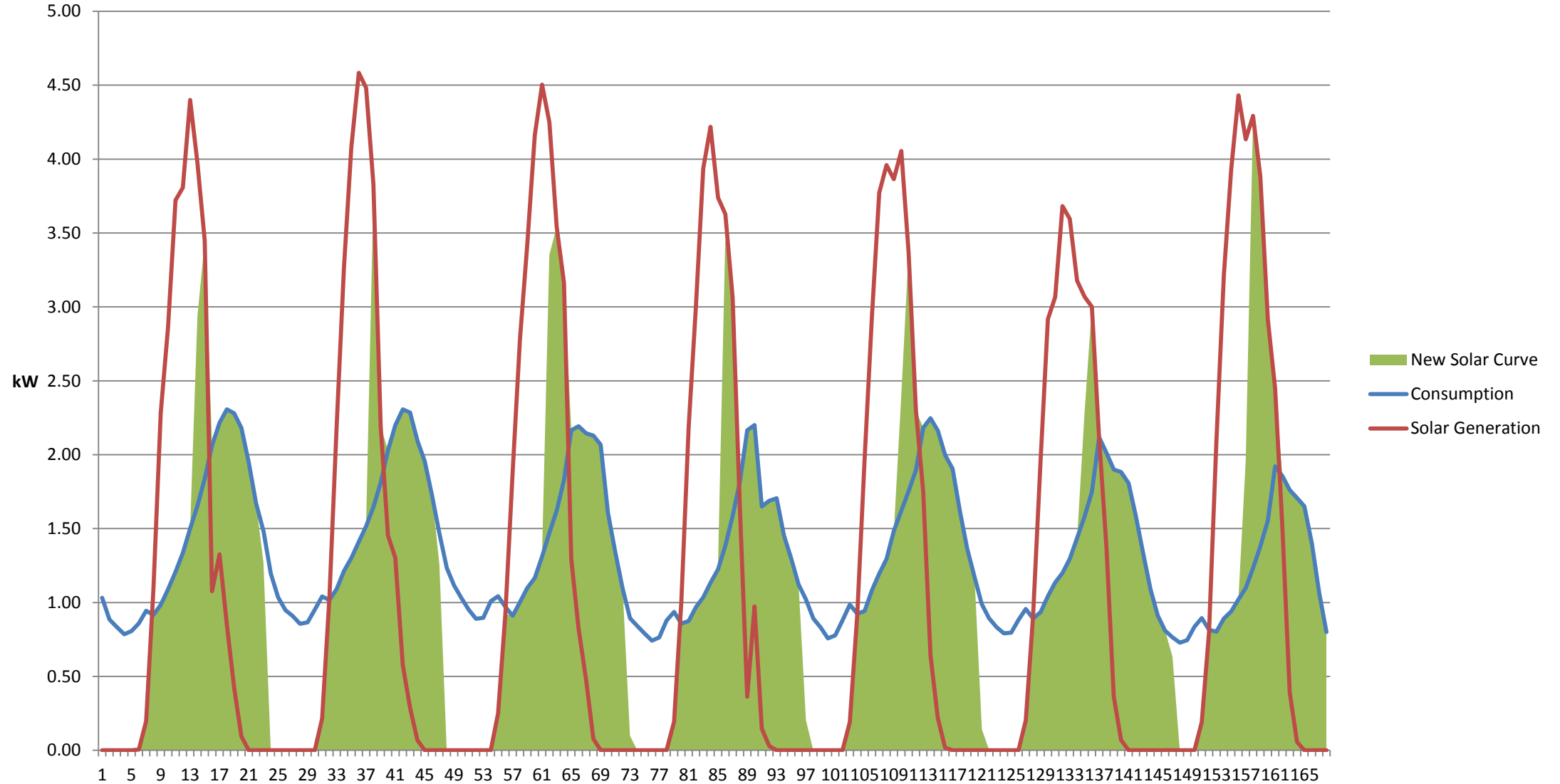
6.28 kW Solar PV + 14 kWh Tesla Powerwall 2 : 8760 hour analysis



Time-shifting of Solar Output

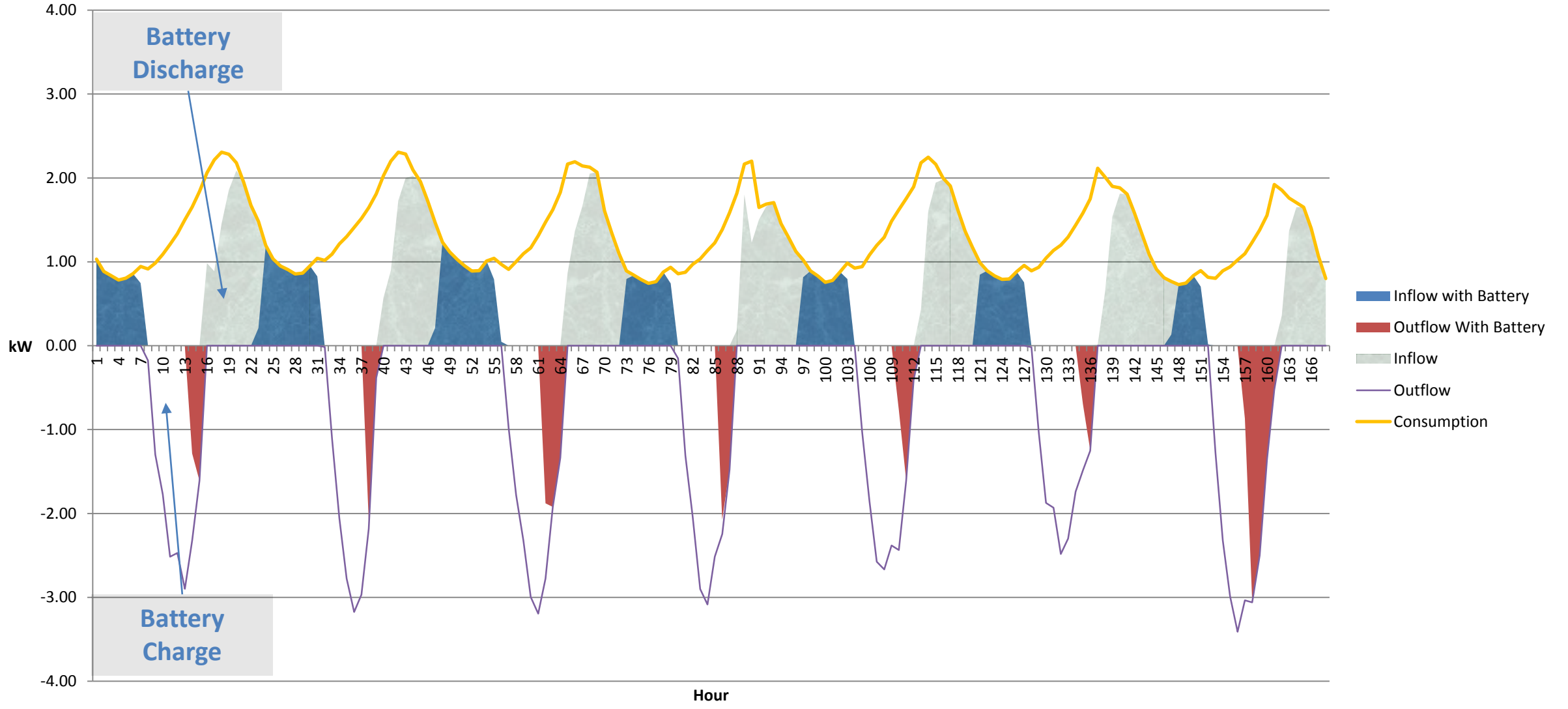
August 7-13 [hourly]

6.28 kW (DC) Residential Solar PV + 14 kWh (DC) Tesla Powerwall2



Residential Hourly Peak-Demand Reduction August 7-13 (Hourly)

6.28 kW (DC) Residential Solar PV + 14 kWh Tesla Powerwall 2



Observations

- **Optimal operation of grid-interconnected DG systems occurs when onsite-usage is maximized [for a given level of PV Capacity]**
 - If the level of generation physically used on-site could be increased, then to that extent, more efficient operation of the DG system is achieved
 - The timing of onsite usage is also a factor leading toward operational efficiency, e.g. peak demand reduction
 - I&O with battery storage mitigates the issue of two-way flows on radial distribution circuits with high penetration of customer sited solar PV

Conclusions

- **If the economic payback to a customer under a particular regulatory mechanism is indifferent, or nearly indifferent, to changes in the level (and timing) of onsite-usage, then such mechanism is inherently flawed**
 - Net Energy Metering (NEM) is indifferent to changes in the level/timing of generation used onsite
 - Buy-all Sell all (BASA) is indifferent to changes in the level/timing of generation used onsite

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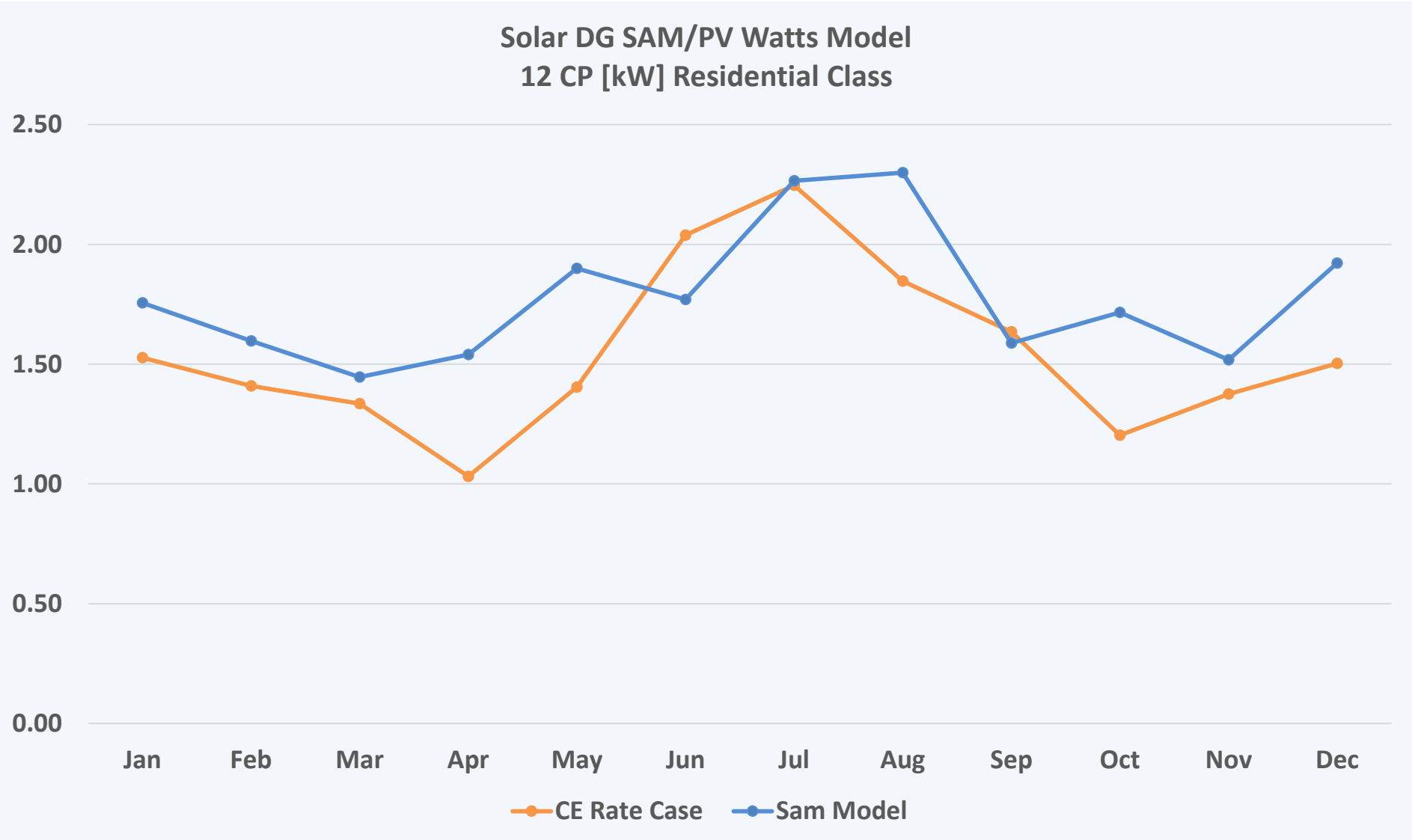
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Findings related to Cost-of-Service

- Load diversity (i.e. power inflows) within the sub-group of residential DG customers can be significant
 - Residential DG peak-demand (inflow) is strongly correlated with the level of solar PV capacity vis-à-vis a customer's annual load
 - Residential DG peak demand can be reduced by onsite energy storage operated to re-dispatch solar output (load following)

Good Correlation between Model and Rate Case Coincident Peaks (Consumers Energy U-17990)

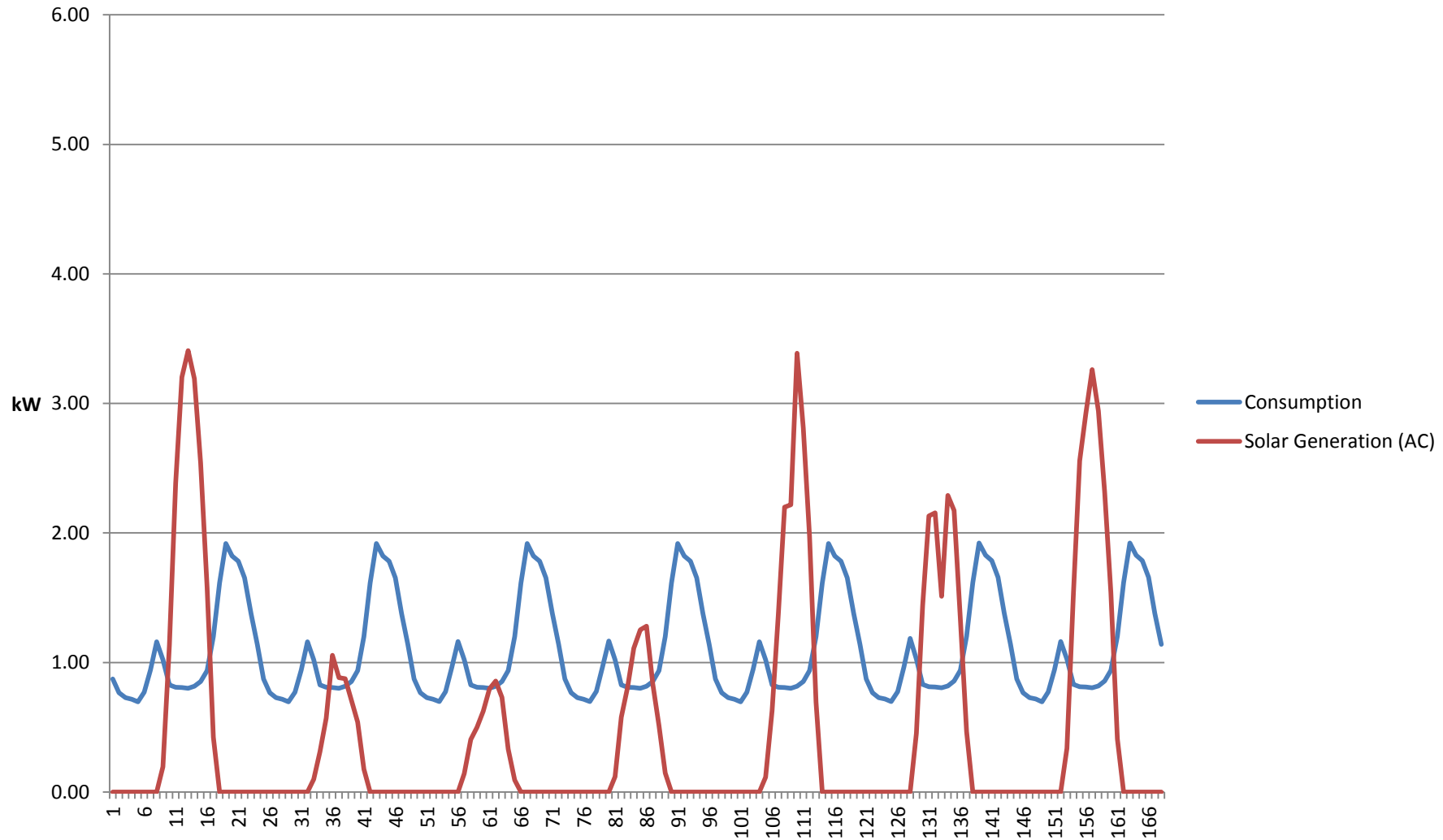


Comparison of 8760 Hour Model To Approved Residential 4CP [CE U-17990] Solar PV System Capacity [100% of Annual Consumption]

CE Rate Case U-17990		Model Solar DG	
4 CP	Residential RS +RT kW/Cust	Residential kW/Cust	Inflow kW/Cust
Jun	2.04	1.77	0.07
Jul	2.25	2.27	1.02
Aug	1.85	2.30	1.73
Sep	1.64	1.59	0.16
Total	7.8	7.9	3.0

With
Solar PV

**Residential Distributed Generation Customer
Consumption and Generation
December 11 - 17 [hourly]
6.28 kw (AC) Solar PV [100% of Annual Consumption]**



Modeling Observations and Conclusion Regarding the COSS Segregation of Solar DG Customers

- Customers having **small to moderate levels** of PV capacity (relative to their annual consumption) have monthly **peak-demand profiles** that are similar to the full requirements customers
 - Like a smaller-than-average customer
- Customers having **high levels of PV capacity** have lower summer coincident peaks – but nearly identical winter coincident peaks as full requirements customers

Conclusion: COSS segregation of solar PV DG customers into a separate rate-class is not necessary

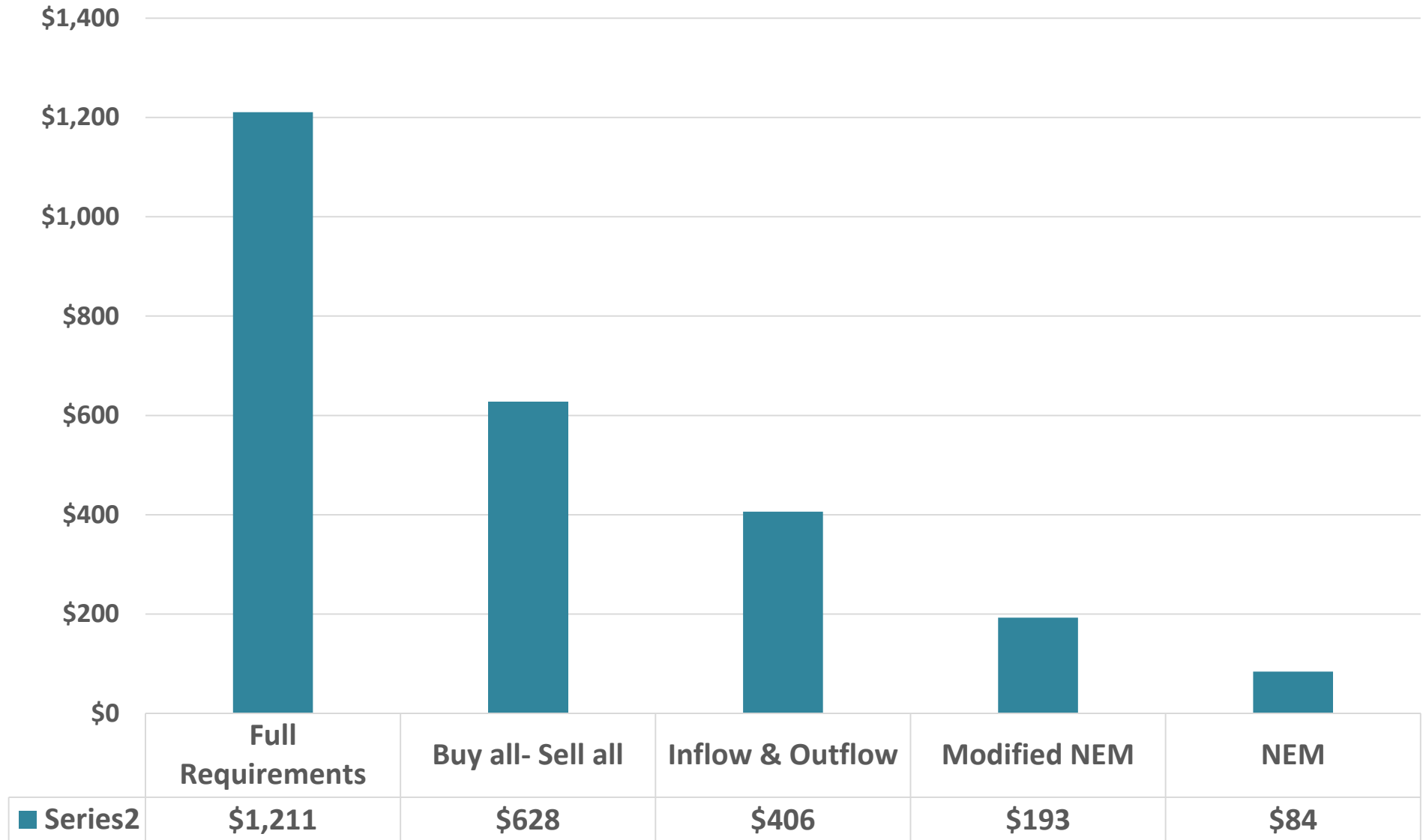
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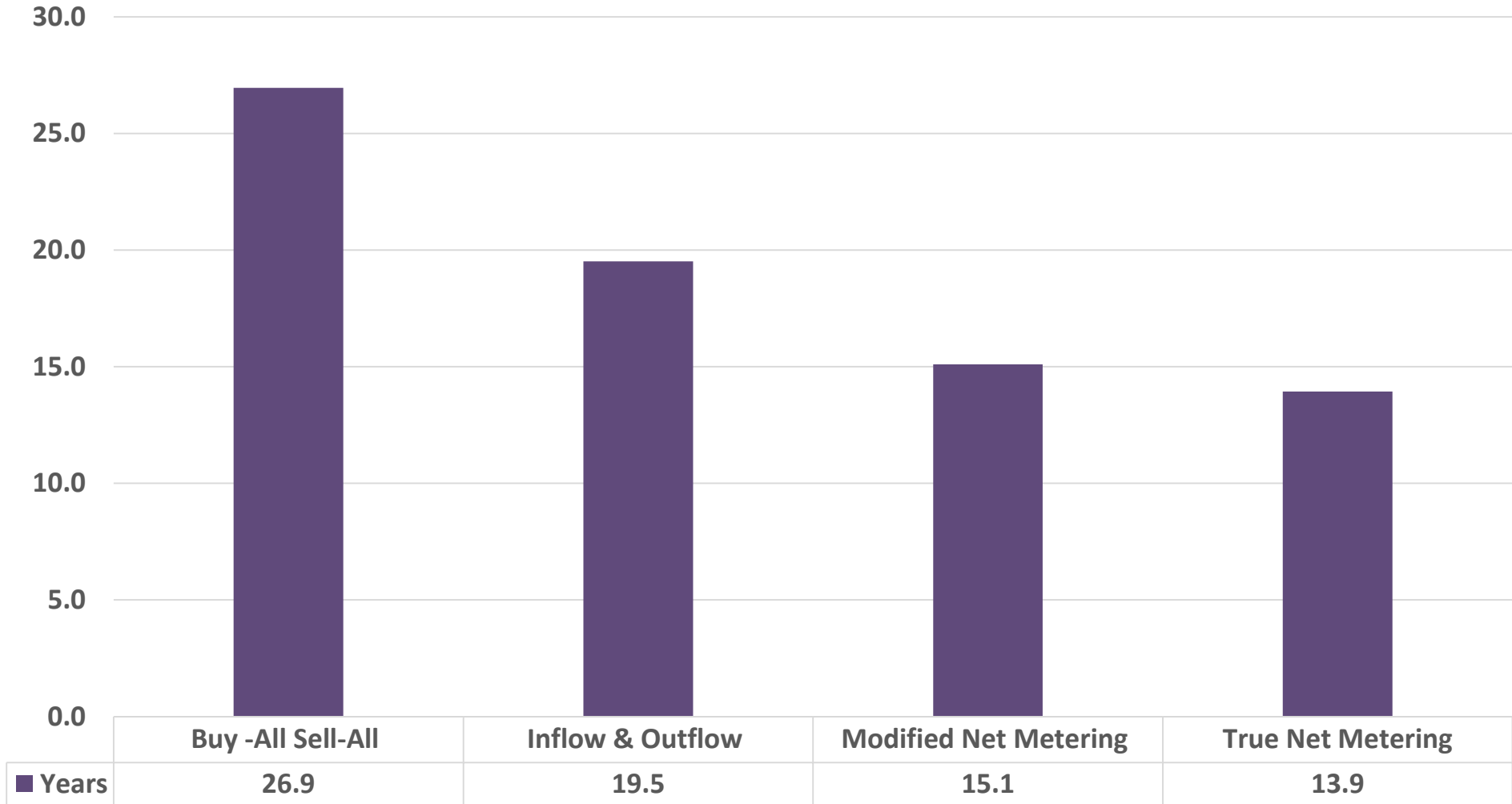


Residential Annual Bill

Standard Pricing; Generation Valuation @ 7.43 cents per kWh
6.28 kW Solar PV @ 100% of Annual Consumption



Simple Payback
Installed Cost \$15,700 \$2.50/Watt (Excludes ITC)
6.28 kW Solar PV [100% of Annual Consumption]
Standard Residential Rate/7.43 cents/kWh Credit



Valuation of Solar PV Outflow

Effective Outflow Capacity Method

6.28 kW (AC) Solar PV [100% of Annual Purchases]	7,844 kWh
Credit -LMP Monthly Average MISO REAL TIME	0.035
Energy Loss Factor	0.079
Value of Energy \$/kWh	0.038002172
Cost of New Entry (CONE) \$/kW-yr	\$ 94.80
100% of CONE \$/kW-Yr	\$ 94.80
Nameplate Capacity kW (DC)	6.28
Outflow Capacity factor [Outflow/Generation]	61.4%
Effective Load Carrying Capacity (ELCC)	44%
Effective Capacity kW (AC)	1.70
Capacity Credit - \$/Yr	\$160.93
Capacity Loss Factor	0.079
Capacity Credit [\$/Yr]	\$ 174.74
Annual Outflow kWh	4818
Capacity Value \$/kWh	\$ 0.036
Value of Generation \$/kWh	\$ 0.0743

1.26 kW Solar PV [20% of Annual Purchases]	1,569 kWh
Credit -LMP Monthly Average MISO REAL TIME	0.035
Energy Loss Factor	0.079
Value of Energy \$/kWh	0.038002172
Cost of New Entry (CONE) \$/kW-yr	\$ 94.80
100% of CONE \$/kW-Yr	\$ 94.80
Nameplate Capacity kW (DC)	1.26
Outflow Capacity Factor [Outflow/Generation]	6.5%
Effective Load Carrying Capacity (ELCC)	44%
Effective Capacity kW (AC)	0.04
Capacity Credit - \$/Yr	\$3.39
Capacity Loss Factor	0.079
Capacity Credit [\$Yr]	\$ 3.68
Annual Outflow kWh	101
Capacity Value \$/kWh	\$ 0.036
Value of Generation \$/kWh	\$ 0.0743

Conclusions and Recommendations

1. The Inflow & Outflow Mechanism should be adopted as the replacement mechanism for NEM as it provides the best option for achieving:
 1. Clear and accurate pricing signals encouraging optimal operation of DG systems and rational economic behavior of customers
 2. Retail rates based on Cost-of-Service (COS)
2. Modeling *suggests* that initial deployment of the I&O mechanism should have **combined COSS allocations** with the underlying full requirements tariffs [i.e. no separate DG rate classes].
3. **Dynamic pricing** provides enhanced transparency of price signals and thus could be required as a condition for customer enrollment in any future I&O tariff.
4. The feasibility of *load control* and *energy waste reduction* program **incentives** should be investigated as a tool to further develop this energy resource.
5. Outflow credits should be based on the *effective outflow-capacity method* or the Commission's approved PURPA rate; [standard rate for all program participants].
6. Tariffs should be **simple** and readily understandable.

Thank You!

Email [Robert G. Ozar
ozarr@Michigan.gov](mailto:ozarr@Michigan.gov)

LinkedIn <https://www.linkedin.com/in/robert-ozar-46224a78>