Thermodynamics and Heat Transfer LE5 Part 2
Nguyen Xuan Binh 887799

Problem 1: Describes all the performance models in the System Advisor Model (SAM) (10 points)

Performance models in SAM measure how well the power's system outputs energy by using simulations.

- **Photovoltaic Systems**

SAM models grid-connected photovoltaic systems that consist of a photovoltaic array and inverter. The array can be made up of flat-plate or concentrating photovoltaic (CPV) modules with one-axis, two-axis, or no tracking.

<u>Detailed Photovoltaic</u>
The detailed photovoltaic model calculates a grid-connected photovoltaic system's electrical output using separate module and inverter models
Use the detailed photovoltaic model when you have information about the equipment that will be used in the system.
<u>PVWatts Model</u>
The PVWatts model is an implementation of NREL's popular online photovoltaic calculator. It models a grid-connected photovoltaic system using a few basic inputs to describe the system's nameplate capacity, array orientation and mounting type, and system losses.
<u>High Concentration PV</u>
The high concentration photovoltaic model is appropriate for grid-connected photovoltaic systems with high concentration photovoltaic (HCPV) modules. The concentrating photovoltaic model uses separate models to represent the module and inverter.

- **Battery Storage**

SAM's electric battery storage model is available with the Detailed Photovoltaic and Generic System models for either front-of-meter or behind-the-meter applications. A simplified version of the battery model is available with the PVWatts model.

<u>Detailed PV-Battery</u>
The detailed PV-Battery model couples a grid-connected photovoltaic system to a battery bank, which can be connected to either the DC side of the photovoltaic inverter, or the AC side of the system.
<u>PVWatts-Battery</u>
The PVWatts-Battery model is a simplified implementation of the PV-Battery model for behind-the-meter applications
<u>Generic System-Battery</u>
The generic PV-Battery model couples a grid-connected power system to a battery bank.
<u>Standalone Battery</u>

The standalone battery model is for a battery bank connected to the grid that charges and discharges from the grid.

Electric TES

The electric thermal energy system model is for a thermal energy system (TES) that uses grid power as a power source to generate heat.

- **Concentrating Solar Power**

The concentrating solar power (CSP) models are for grid-connected thermal power plants that use solar energy to generate steam to drive an electric power generation plant.

Parabolic Trough (Physical Model)

The physical trough model calculates the electricity delivered to the grid by a parabolic trough solar field that delivers thermal energy to a power block for electricity generation, with an optional thermal energy storage system.

Parabolic Trough (Empirical Model)

The empirical trough model models the same type of parabolic trough system as the physical trough model, but uses a set of curve-fit equations derived from regression analysis of data measured from the SEGS projects

Molten Salt Power Tower

A molten salt power tower system (also called central receiver system) consists of a heliostat field, tower and receiver, power block, and optional storage system.

Direct Steam Power Tower

The Direct Steam Power Tower model is not included in versions released after November 2020

Linear Fresnel Molten Salt

A molten salt linear Fresnel system consists of a field of slightly curved or flat Fresnel reflectors that focus light on an absorber in the focal plane above the reflector

Linear Fresnel Direct Steam

A direct steam linear Fresnel system consists of a field of slightly curved or flat Fresnel reflectors that focus light on an absorber in the focal plane above the reflector.

CSP Generic Model

The CSP generic model model allows you to model a system that consists of a solar field, power block with a conventional steam turbine, and optional thermal energy storage system.

- **Industrial Process Heat**

Process Heat Parabolic Trough

The IPH parabolic trough model is a version of the CSP physical parabolic trough model with no power cycle and modifications for process heat applications.

Process Heat Linear Direct Steam

The IPH linear direct steam model is for a linear collector using direct steam with no power cycle and modifications for process heat applications.

- **Marine Energy**

Marine energy systems convert ocean wave or tidal energy to electricity.

Wave Energy

The marine energy wave model is for a system that uses a wave energy converter (WEC) to convert the energy of ocean waves into electricity

Tidal Energy

The marine energy tidal model is for a system that uses a tidal energy converter (TEC) to convert the energy of ocean tides into electricity.

- **Wind**

The wind power model can model a single small or large wind turbine, or a project with two or more large or small wind turbines that sells power to the grid.

- **Fuel Cell - PV - Battery**

The fuel cell-PV-battery model combines the PVWatts, battery, and a fuel cell model for systems that combine a photovoltaic array and fuel cell with an optional battery bank.

- **Solar Water Heating**

SAM's solar water heating model represents a two-tank glycol system with an auxiliary electric heater and storage tank for residential or commercial applications.

- **Geothermal**

Note. SAM's geothermal power model is for electricity-generating systems, not ground source heat pumps or geo-exchange systems.

- **Biomass Combustion**

A biomass combustion system burns a biomass feedstock (with or without supplementary coal) in a combustion system to generate steam that drives an electric power generation plant.

- **Generic System**

The generic system model is a basic representation of a conventional power plant. The Generic technology option makes it possible to compare analyses of renewable energy project to a base case conventional plant using consistent financial assumptions.

Problem 2: Describe the financial models in the System Advisor Model (SAM) (10 points).

The financial model uses the system's output to calculate the project annual cash flows and financial metrics.

The financial models represent two main types of projects:
•Residential and commercial projects that buy and sell electricity at retail rates
•PPA projects that sell electricity at a wholesale rate

- **Residential and Commercial Owner**

- In SAM, residential and commercial projects buy and sell power at retail rates. For residential and commercial projects, SAM calculates the project's levelized cost of energy (LCOE). Commercial projects may qualify for tax deductions under the Modified Accelerated Depreciation Schedule (MACRS) . Residential and commercial projects are typically smaller than 500 kW, although SAM does not restrict system sizes, so it is possible to model any size system using either the residential or commercial financial model.
- SAM's Electricity Rates page provides a range of options for specifying the retail electricity rate structure for a project. The rate structure may include any of the following:
•Flat buy and sell rates (with or without net metering
•Time-of-use energy charges
•Monthly demand charges (either fixed or time-of-use)
•Tiered rates
•Fixed monthly charges
For projects with demand charges and tiered rates, SAM requires electric load data, which is specified on the Electric Load page.

- **Third Party Ownership**

- In a third party ownership project, a photovoltaic system is installed on a residential or commercial property. The property owner, or customer, makes an agreement with a third party who installs, operates, and owns the system. The system reduces the customer's electricity bill, and the customer makes payments to the third party owner for the system, either through a lease agreement or a power purchase agreement.
- The Host model is from the host perspective, and allows you to compare a lease agreement with a power purchase agreement.
- The Host / Developer model is from the developer perspective to determine a power price that covers the developer's costs.

- **Community Solar**

A community solar project earns revenue from payments made to the system owner by subscribers to the project. The project owner builds, owns, and operates the power system, and has sufficient tax liability to fully utilize all tax benefits.

- **Power Purchase Agreement (PPA)**

- PPA projects sell all of the electricity generated by the power system at a price negotiated through a power purchase agreement (PPA) to meet a set of equity returns requirements. A PPA project may involve one or two parties.
- SAM provides options for calculating a power purchase price given a target internal rate of return, or for calculating the rate of return given a power purchase price.
- The power price can be made to vary annually over the analysis period using either a fixed annual escalation rate, or by assigning a separate price to each year.

<u>Single Owner</u>
In the Single Owner model, the project owner builds, owns, and operates the power system and has sufficient tax liability to fully utilize all tax benefits. The owner may be either the original developer or a third-party tax investor that purchases the project from the developer.

<u>Partnership Flip with and without Debt</u>
The partnership flip with debt (Leveraged Partnership Flip) and partnership flip without debt (All Equity Partnership Flip) models are for two-party projects that involve equity investments by a project developer and a third party tax investor.

<u>Sale Leaseback</u>
The Sale Leaseback model is another two-party structure that involves a tax investor purchasing 100% of the project from the developer and then leasing it back to the developer. This structure differs from the partnership flip structures in that the tax investor and the developer do not share the project cash and tax benefits (or liability). Instead, each party has its own separate cash flow and taxable income.

- **Merchant Plant**

The Merchant Plant model is similar to the Single Owner model described above, except that power generated by the system is sold at market prices that can vary on an hourly (or subhourly), daily, or monthly basis over the project life. Revenue can be from energy production, ancillary services and capacity payments, or a combination of the three.

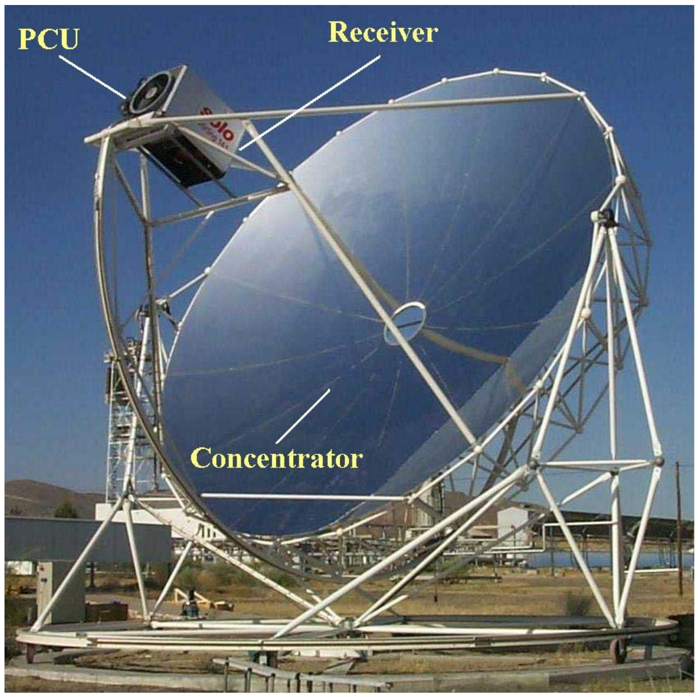
- **LCOE Calculator**

The LCOE calculator uses a simple method to calculate the project's levelized cost of energy (LCOE). You provide the installation cost, operating costs, and a fixed charge rate as input, and the model calculates the LCOE based on the annual energy generated by the system. The calculator can also calculate the fixed charge rate when you provide basic financial parameters.

Problem 3: For one station in the United States: Design a solar dish/Stirling power plant. Total capacity of the power plant is 100 MW (30 points).

Report:

- **A summary of your analysis (one table)**
- **Monthly energy production (one graph)**
- **Resource Beam normal irradiance (W/M$_2$) (monthly profiles, time series and heat map)**
- **System power generated (monthly profiles, time series and heat map)**
- **System total net efficiency (monthly profiles, time series and heat map)**



- In this report, I will design a CSP Dish Stirling power plant
- The location I chose in the United States is Austin, Texas. This is the weather data file

Weather Data Information

The following information describes the data in the highlighted weather file from the Solar Resource library above. This is the file SAM will use when you click Simulate.

Weather file C:\Users\nguye\SAM Downloaded Weather Files\austin_texas\austin_texas_30.264979_-97.746598_psm3_60_2020.

The total capacity of the powerplant is 100 MW

System Properties

Wind Stow Speed	16	m/s
Total Capacity	100000	kW

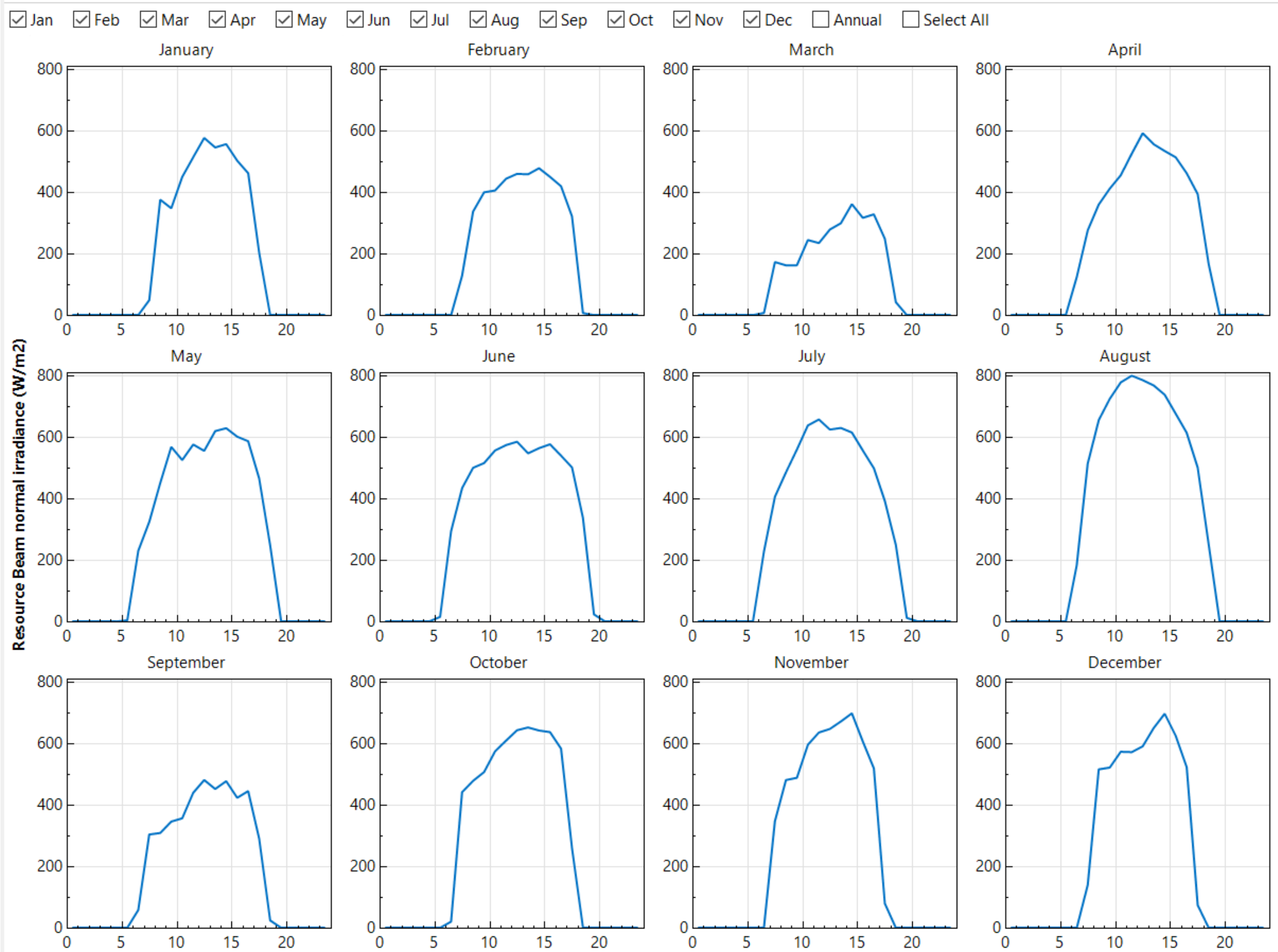
- Summary of my analysis

Solar Field Output	Values	Collector	Value
Field Output		**Mirror Parameters**	
Number of Collectors, North-South	50	Projected Mirror Area	87.7 m2
Number of Collectors, East-West	80	Total Mirror Area	91 m2
Number of Collectors	4000	Reflectance	0.94
Collector Separation North-South	15 m		
Collector Separation East-West	15 m	**Performance**	
Total Solar Field Area	900000 m2	Insolation Cut-in	200 W/m2
		Receiver	Value
System Properties		**Aperture**	
Wind Stow Speed	16m/s	Receiver Aperture Diameter	0.184 m
Total Capacity	100MW		
		Insulation	
Array Shading Parameters		Thickness	0.075m
Ground Slope, North-South	0 deg	Thermal Conductivity	0.06 W/mK
Ground Slope, North-South	0 deg		
Slot Gap WIdth	1 m	**Absorber**	
Slot Gap Height	1 m	Absorber Absorptance	0.9
Stirling Engine	Value	Absorber Surface Area	0.6 m2
Estimated Generation		**Cavity**	
Single Unit Nameplace Capacity	25 kW	Cavity Absorptance	0.6
		Cavity Surface Area	0.6 m2
Engine Parameters		Internal Diameter of Cavity	0.46 m
Heater Head Set Temperature	993 K	Internal Cavity Pressure	101 kPa
Heater Head Lowest Temperature	973 K	Internal Depth of Cavity	0.46 m
engine operating speed	1800rpm	**Parasitics Parameters**	Value
displaced engine volume	0.00038 m3	control system parasitic power	150 W
		cooling system pump speed	1800 rpm
Beale Curve fits coefficients		cooling system fan speed 1	400 rpm
constant coeficient	0.04247	cooling system fan speed 2	550 rpm
1st order coefficient	1.68E-05	cooling system fan speed 3	650 rpm
2nd order coefficient	-5.11E-10	cooling fluid temperature fan speed 2 cut-in	20C
3rd order coefficient	7.07E-15	cooling fluid temperature fan speed 3 cut-in	30C
4th order efficient	-3.59E-20	cooling fluid type	V50%EG
		cooler effectiveness	0.6
pressure cuff fit coefficients		radiator effectiveness	0.6
pressure constant coefficient	0.658769	b_cooler parameter	0.7
pressure first order coefficient	0.00023496	b_radiator parameter	0.7

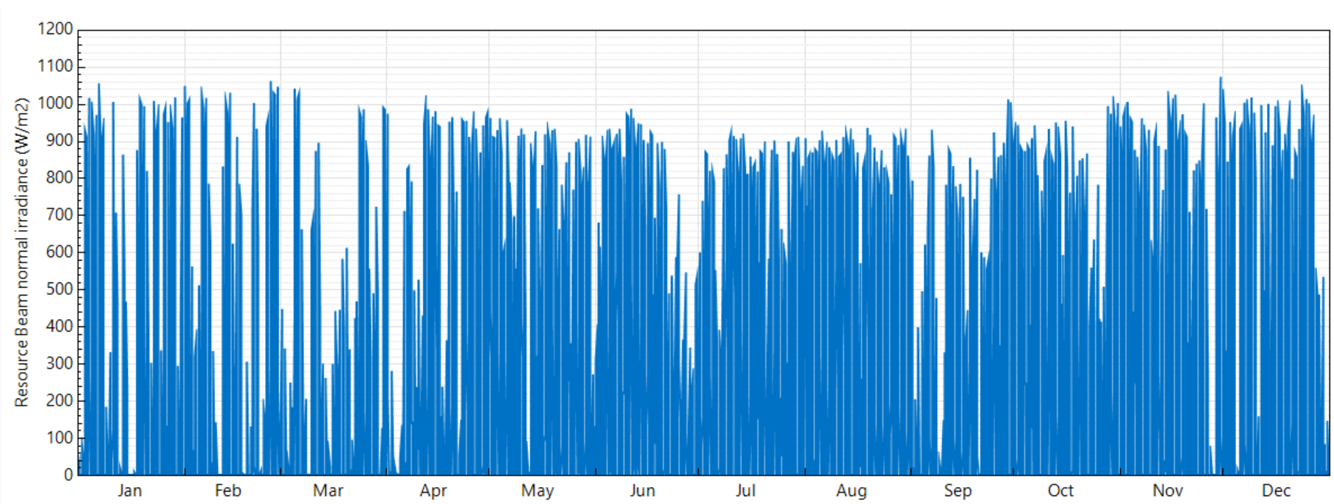
The reported properties of the dish stirling power plant are as follows:

- **Resource Beam normal irradiance (W/M2)**

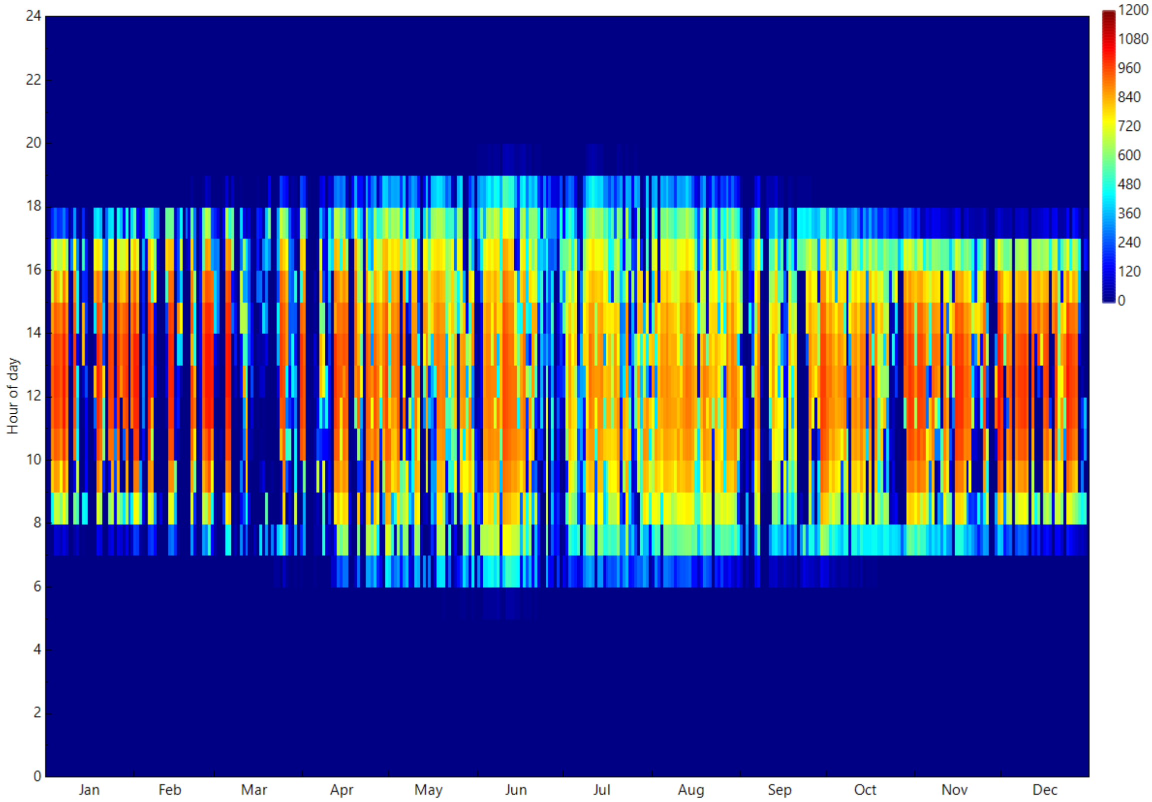
- Monthly profiles



- Time Series

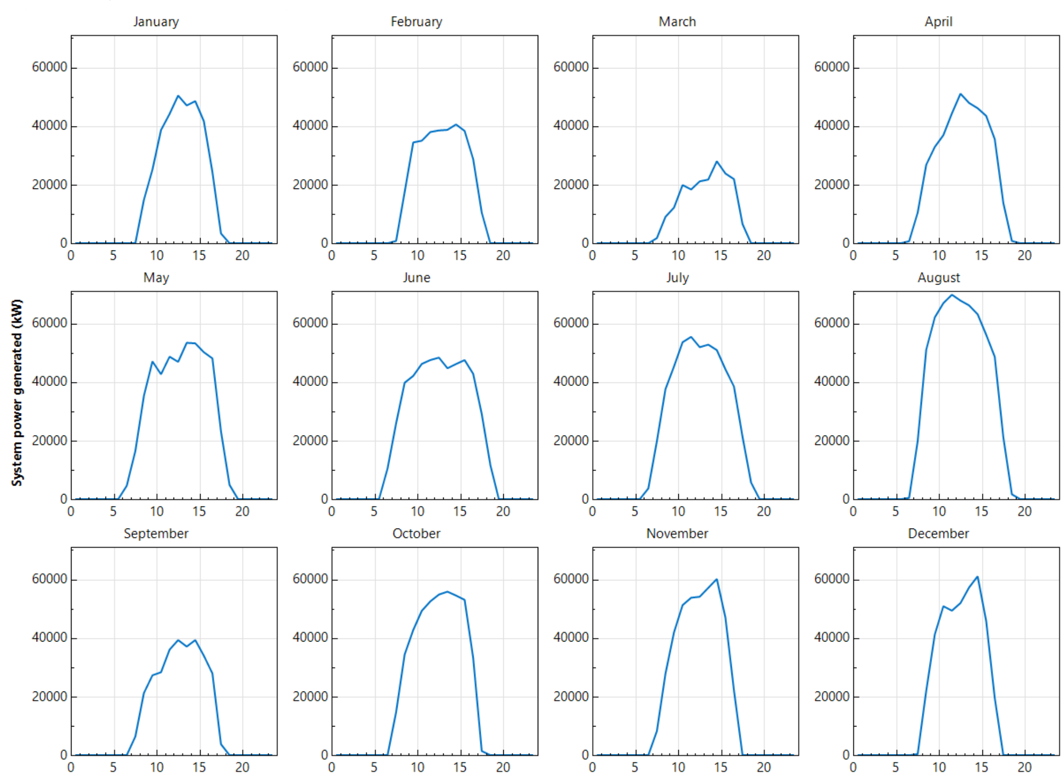


- Heat map

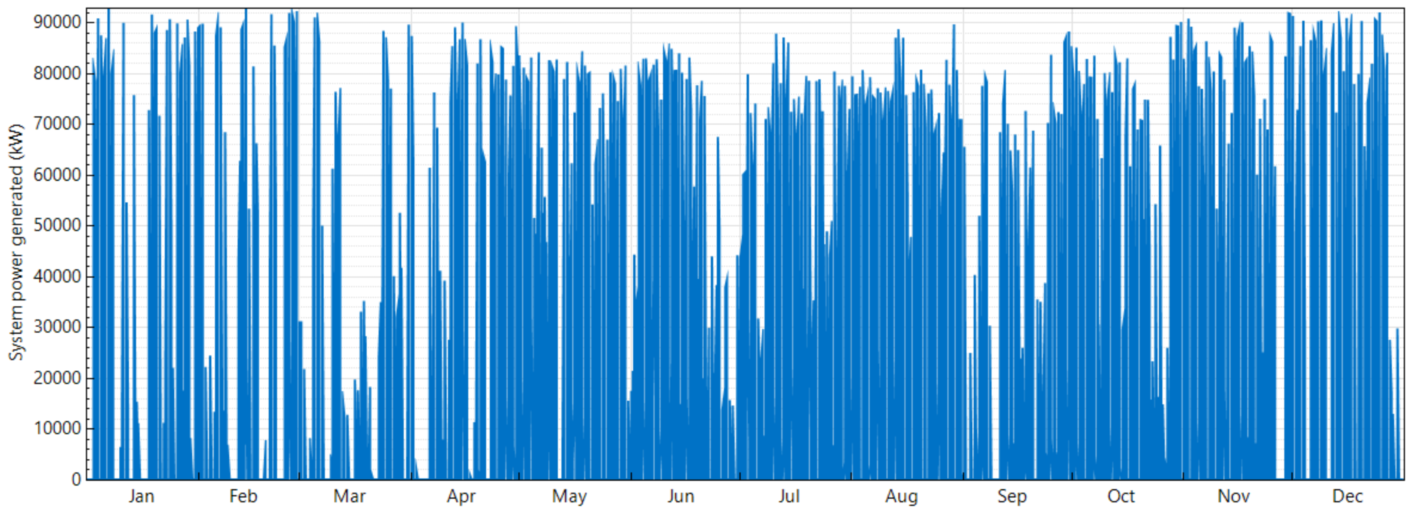


- **System power generated (kW)**

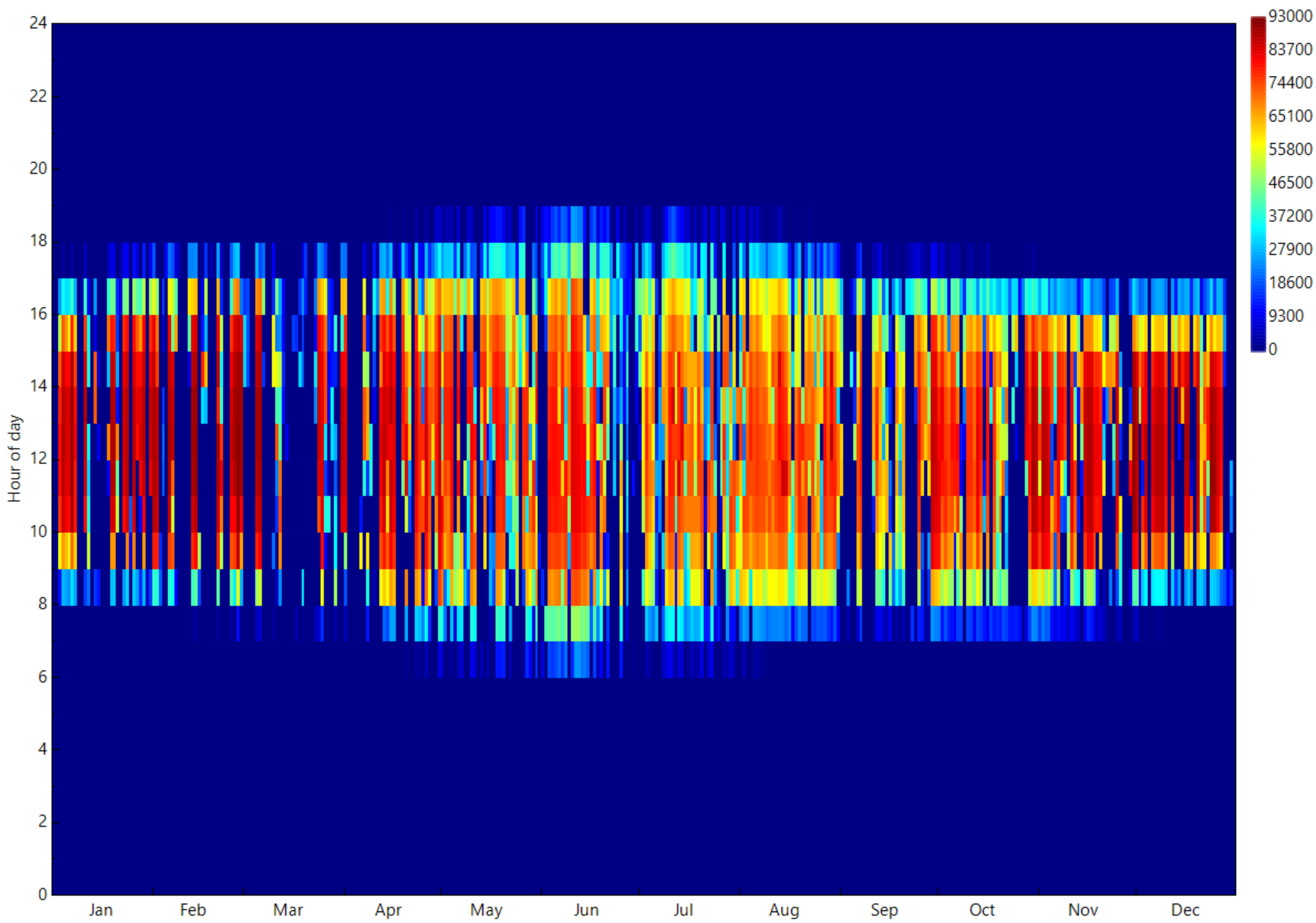
- Monthly profiles



- Time Series

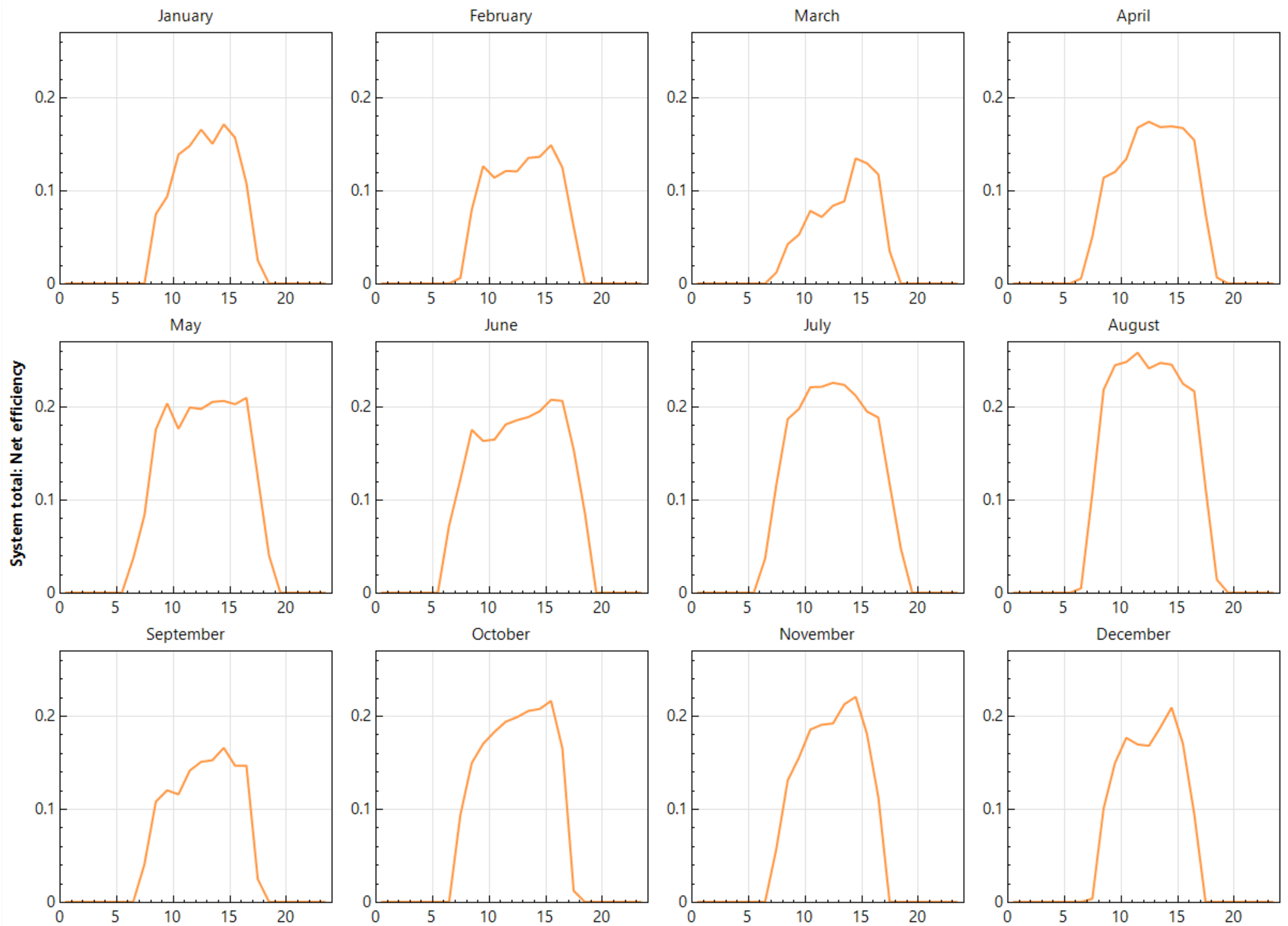


- Heat map

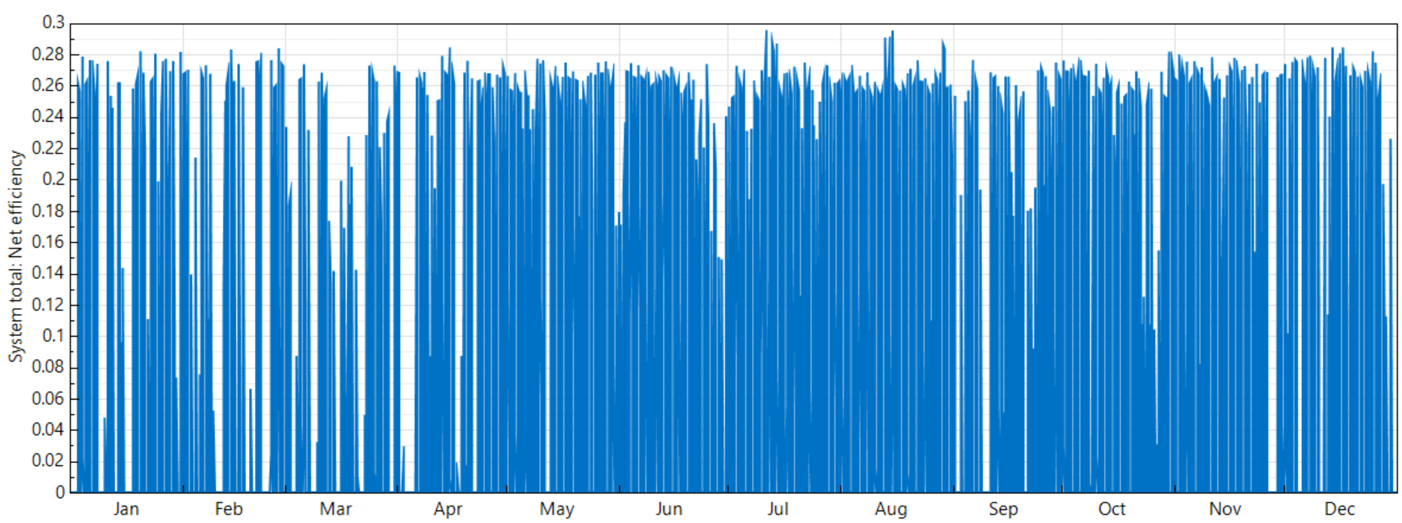


- **System total net efficiency**

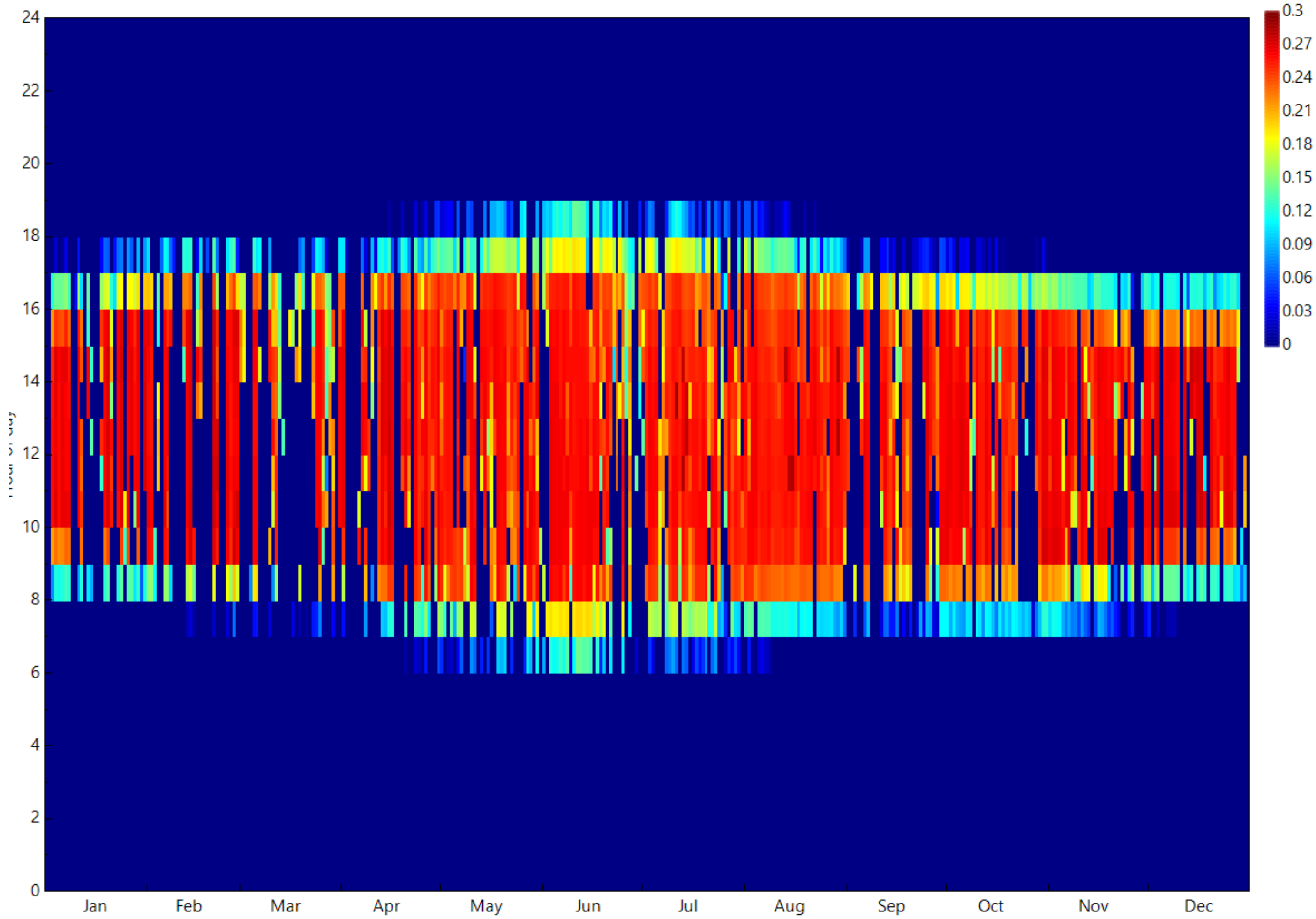
- Monthly profiles



- Time Series



- Heat map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