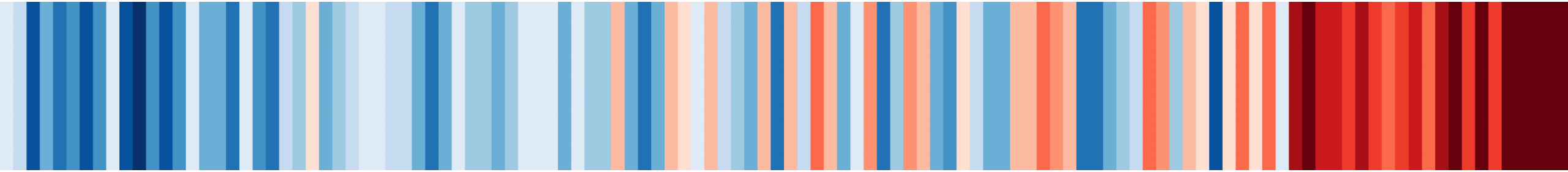
Application of SAM to the K·A·CARE Distributed Generation Portal

Presentation to the SAM Developer Conference

August 2019

Warming Stripes



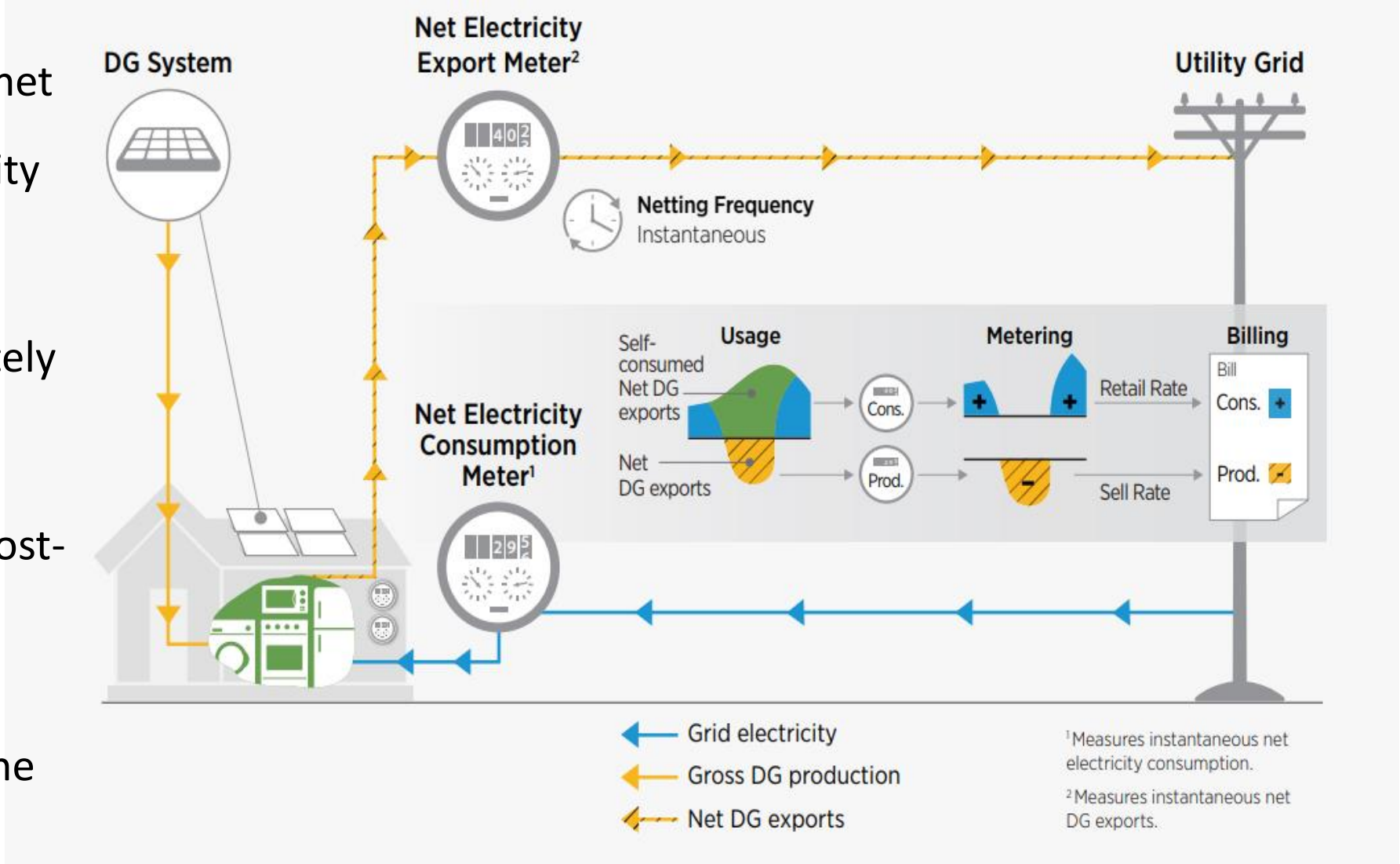
Saudi Arabia average temperatures from 1901-2018

Russ Jones, Abdulhakim Bin Dayl, Hussain Shibli — King Abdullah City for Atomic and Renewable Energy

Mohamed Ali, Waleed Mohamed, Sherif Eldasouki — Link Development

Saudi Arabia is Introducing a Net Billing Program for Distributed PV

- KSA plans to implement net billing to control future price paid for PV electricity as rates change
- Net billing converts exported electricity to a financial credit immediately at the time of export
- If the export credit is not the same as the consumption tariff, the cost-benefit of the PV system must account for the balance between consumption and generation throughout the day



Implementation of the Distributed PV Program is an Intergovernmental Effort

- Under leadership of the Ministry of Energy, Industry, and Minerals (MEIM)
- Key roles by Electricity and Co-Generation Regulatory Authority (ECRA), Saudi Electricity Company (SEC), and King Abdullah City for Atomic and Renewable Energy (K·A·CARE)
- K·A·CARE's roles:
  - Provide consumer-facing information resources, including an independent assessment of benefit to consumers
  - Provide certified training courses for PV designers and installers
  - Provide assessment and advice on PV-related standards for equipment and processes

Shamsi Portal

- “Shamsi” means “My Sun” in Arabic
- The Shamsi portal will support consumers, designers, installers, and permit applicants in the process of designing and installing distributed PV systems

Educative Content

Public awareness and education about solar energy and its benefits

Performance Assessment

Assesses the energy to be produced for a selected location and system configuration

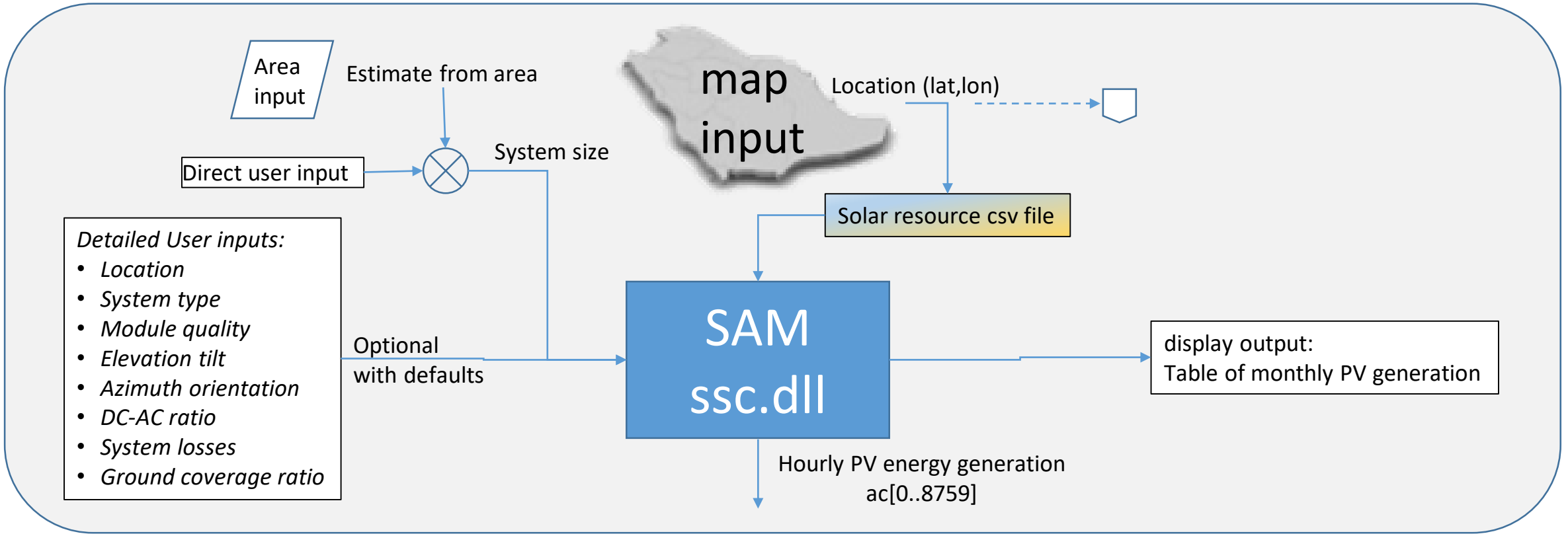
Financial Feasibility

Analyzes financial aspects of solar system based on energy produced and predicts savings and return on investment.

Contractors and Quotations

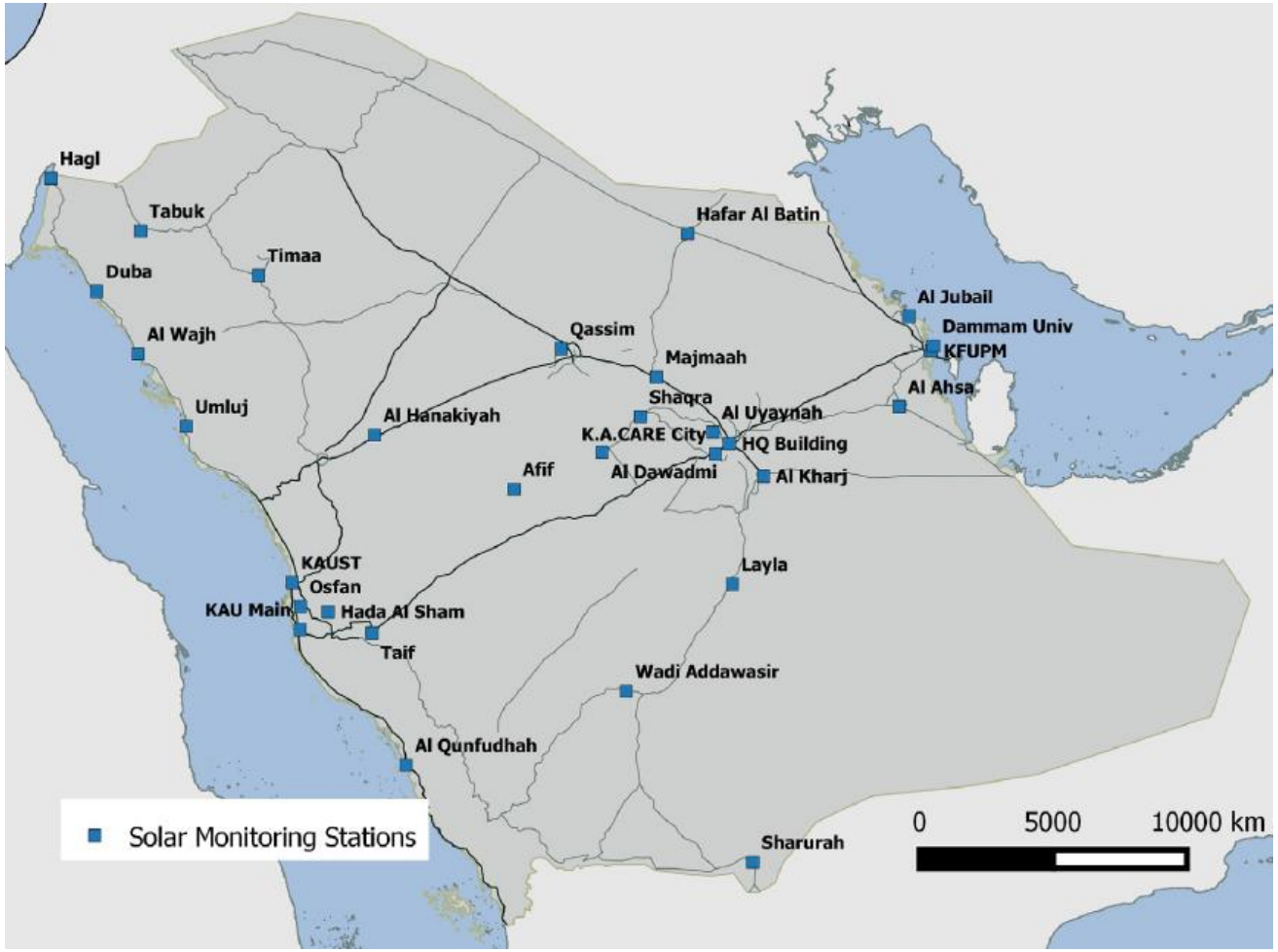
Communication channel to request Quotations from registered contractors

Solar Calculator



The solar calculator is directly using the open-source System Advisor Model (SAM) developed and maintained by the US National Renewable Energy Laboratory (NREL)

K·A·CARE National Renewable Energy data center (NREDC)
Solar monitoring network

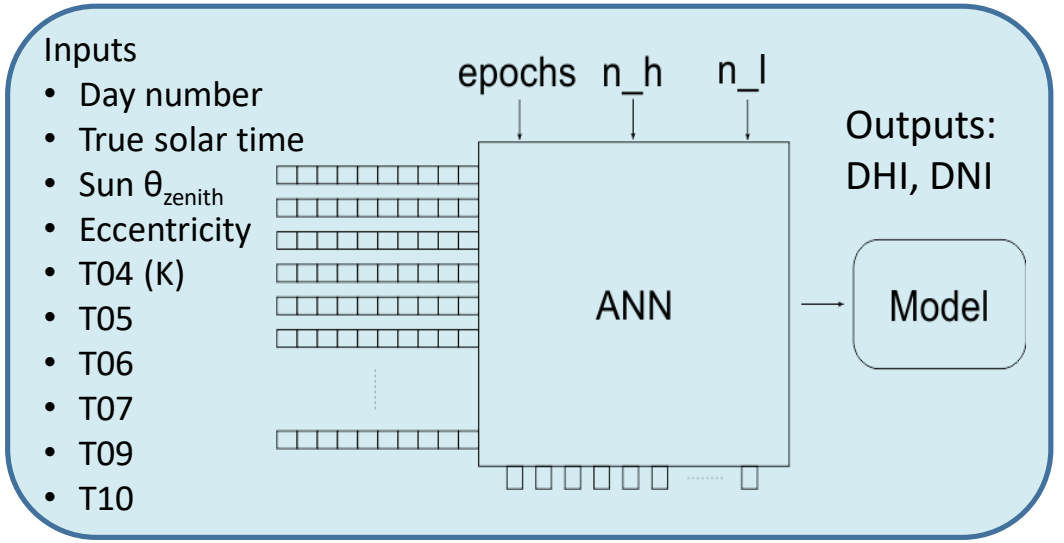


- High accuracy ground measurement network
- Based on the US National Solar Radiation Database (NSRDB) operated by NREL
- Operational since 2013

Solar Irradiance Estimation with Neural Network Algorithm (SIENNA) — Satellite model

SIENNA uses images from the EU Meteosat Second Generation (MSG) Spinning Enhanced Visible and Infrared Imager (SEVIRI)

- The model has a total of 10 inputs (6 thermal channels, 4 solar geometry variables)
- Data (satellite images) are subdivided into cloudy and cloud-free regions
- Four sets of ANNs:
  - DNI cloud-free
  - DNI cloudy
  - DHI cloud-free
  - DHI cloudy
- GHI is calculated by $GHI = DHI + DNI \times \cos(\theta_{zenith})$
- In order to further reduce prediction errors, there are 30 ANNs for each of the 4 sets above
- The final prediction is the median value of the 30 ANN outputs



SIENNA Typical Meteorological Year (TMY) Dataset

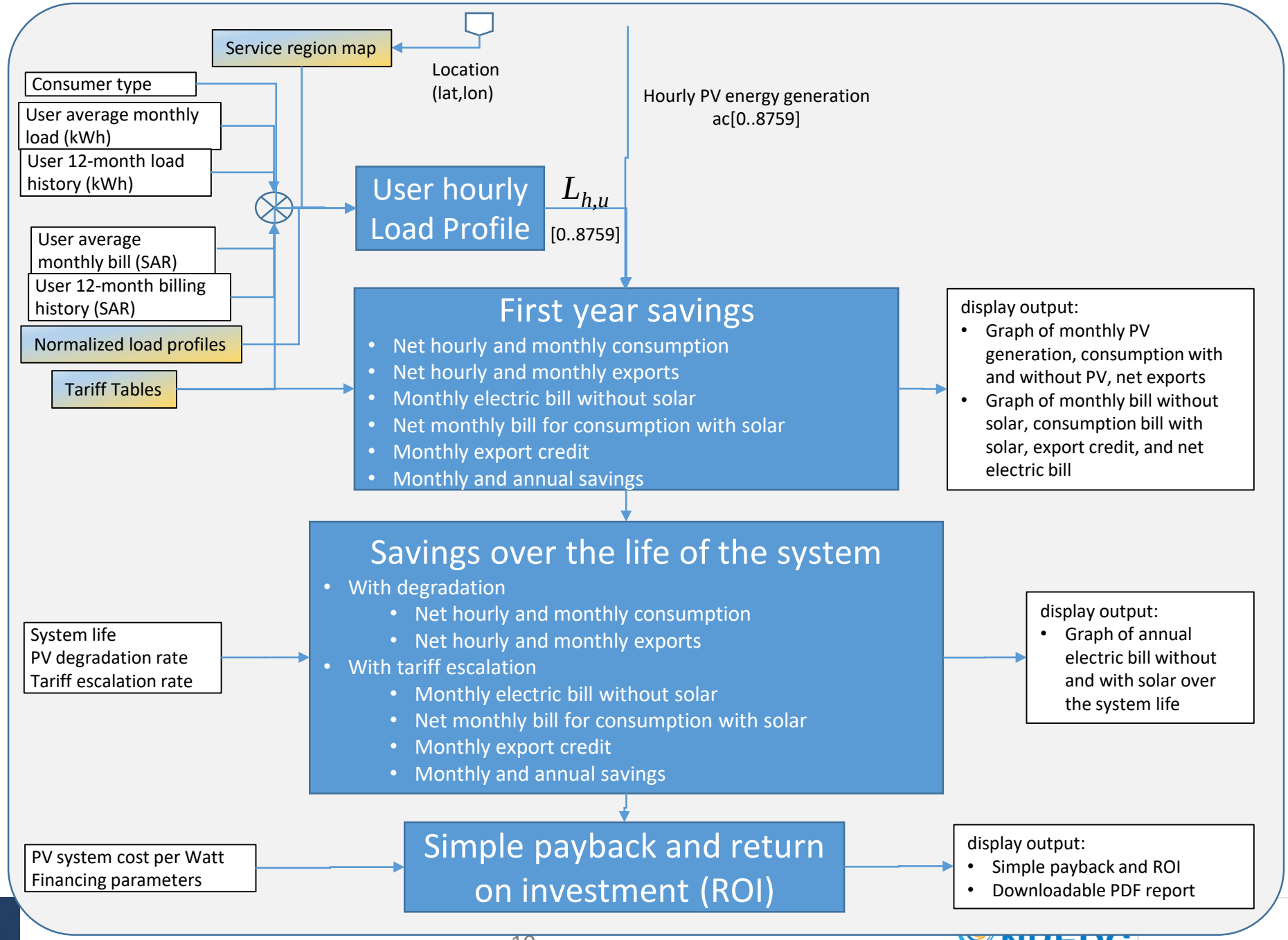
- SIENNA has been used to produce the following data products for KSA stakeholders:
  - Long-term time series (April 2004 to December 2014)
  - 50th percentile TMY
  - 90th percentile TMY
- Both 50th and 90th percentile TMY support technical and financial analyses
- SIENNA satellite model (source for all TMY and time series) is calibrated using the high-accuracy ground data collected by the K·A·CARE NREDC Atlas project.
- The TMY files generated in this project include files for
  - 46 Atlas sites
  - The 148 largest Saudi cities and towns
  - 17,400 locations providing a 0.1° × 0.1° grid over the land mass of Saudi Arabia
- Providing a TMY file within 8 km of any location in the country
- Improved month selection algorithm provides very close match to target irradiance

	Mean error	σ
Annual 50th percentile (P50) GHR	0.036%	0.18%
Annual 50th percentile (P50) DNR	-0.053%	0.27%
Annual 90th percentile (P90) GHR	0.467%	0.39%
Annual 90th percentile (P90) DNR	0.130%	0.36%

Advantages of Using SAM for Solar Calculations

- Calculations are complete and rigorous, accounting for
  - Orientation
  - Tracking
  - Sun position
  - Sky conditions
  - Module temperature derating
  - Shading
  - Inverter efficiency and clipping
- The model has been validated with hundreds of real-life systems.
- The model is actively supported and maintained by NREL, and if improvements are made they can easily be incorporated in our own implementation.
- The model is well-known to all solar professionals and thus does not have to be independently documented and defended by K·A·CARE.

Financial Calculator



Service region map

- The user selects his location on a map input interface
- The selected location is used to automatically determine:
  - Standard solar resource/weather
  - Service region (for load profile seection)
- “Standard” load profiles have been created from an aggregation of load profiles for each consumer class and region (using data from smart meters collected country-wide by SEC):
  - Consumer classes:
    - Agricultural
    - Commercial
    - Government
    - Industrial
    - Private Hospitals & Schools
    - Residential
  - Service regions
    - Central, East, South, West

Software Environment – Development and Production

- First implementation was an Excel spreadsheet, coupled with a stand-alone C program to run PVWatts
  - The Excel example was used as a guide for the web developers
- Developers are using the following tools to implement Shamsi:
  - Visual Studio 2017 with C# for all coding including interface to SAM
    - We used the SAM code generator to get the initial code for the SAM interface
  - SharePoint, HTML, CSS, Javascript
  - WebAPI tool in C# (MVC.NET)
  - Angular CLI for user interface for simple binding of objects to back-end fields
  - SQL Server database (but SAM solar resource files are stored as individual files)
  - Customer Relationship Management (CRM)
- The coding to incorporate SAM into the website has proceeded smoothly

Summary and Conclusion

- Saudi Arabia is implementing its first nation-wide distributed PV regulation
- K·A·CARE is supporting this implementation by providing an online portal for consumers and other stakeholders to assess PV performance and financial benefit
- Use of the SAM API has greatly facilitated our work
  - Enabled an accurate calculation based on PVWatts and K·A·CARE-supplied solar resource data
  - Easy implementation of the interface to the website
- Using SAM will lend credibility and confidence to all stakeholders
- **Thanks to the SAM development team for their outstanding work and support**

Thank you

Solar Calculator Inputs

Parameter name	Value(s)/Type	Default
Location	Latitude and longitude in degrees	None: the user selects the location interactively from a map
System type	0=fixed open rack 1=fixed close mount 2=single axis tracking 3=single axis tracking with backtracking 4=dual axis tracking	0
Module quality	0=standard 1=premium 2=thin film	0
Elevation tilt	float (degrees)	set to latitude of user location
Azimuth orientation	float (degrees clockwise from north)	180
System size	float (kW dc)	4
DC-to-AC ratio	Float	1.2
System losses	Float	14.0
Ground coverage ratio	Float	0.4

- Location and system size are required inputs
- Others are initially concealed, and supplied with defaults
- Balance between simplicity and offering more advanced calculation to informed customers / installers

Financial Calculator Inputs

- Location is passed from the solar calculator
  - Used to lookup service region
- Flexible options for specifying load from consumption history
  - Used with service region to determine hourly load profile
- Other options initially concealed, supplied with defaults

Parameter name	Value(s)/Type	Default
Location	Latitude and longitude in degrees	This location is the same one selected for the solar calculator
Consumer type	One of the following choices: • Residential • Commercial • Government • Health & Education • Industrial • Agricultural	Residential
Electricity consumption	4 optional input sets: • Average monthly consumption • Monthly consumption for 12 months (12 inputs for January .. December) • Average monthly electricity bill • Monthly electricity bill for 12 months (12 inputs for January .. December)	—
Installed cost per Watt of PV system	SAR/W	4.5 (min 1.0, max 20.0)
Fraction financed	Percentage of total system cost	0% (min 0%, max 100%)
Monthly Payment **Number of payments**	Financing details (not shown unless fraction financed > 0%)	0.0966×System cost (10y @ 3%) 120 (min 12, max 300)
System life	Years (int)	25 (min 10, max 50)
Tariff escalation	float	3% per year (min 0%, max 5%)
PV degradation rate	Float	0.75% per year (min 0.5%, max 1.5%)