

Solar on the APS Grid

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NREL Utility-Owned Distributed Generation Models
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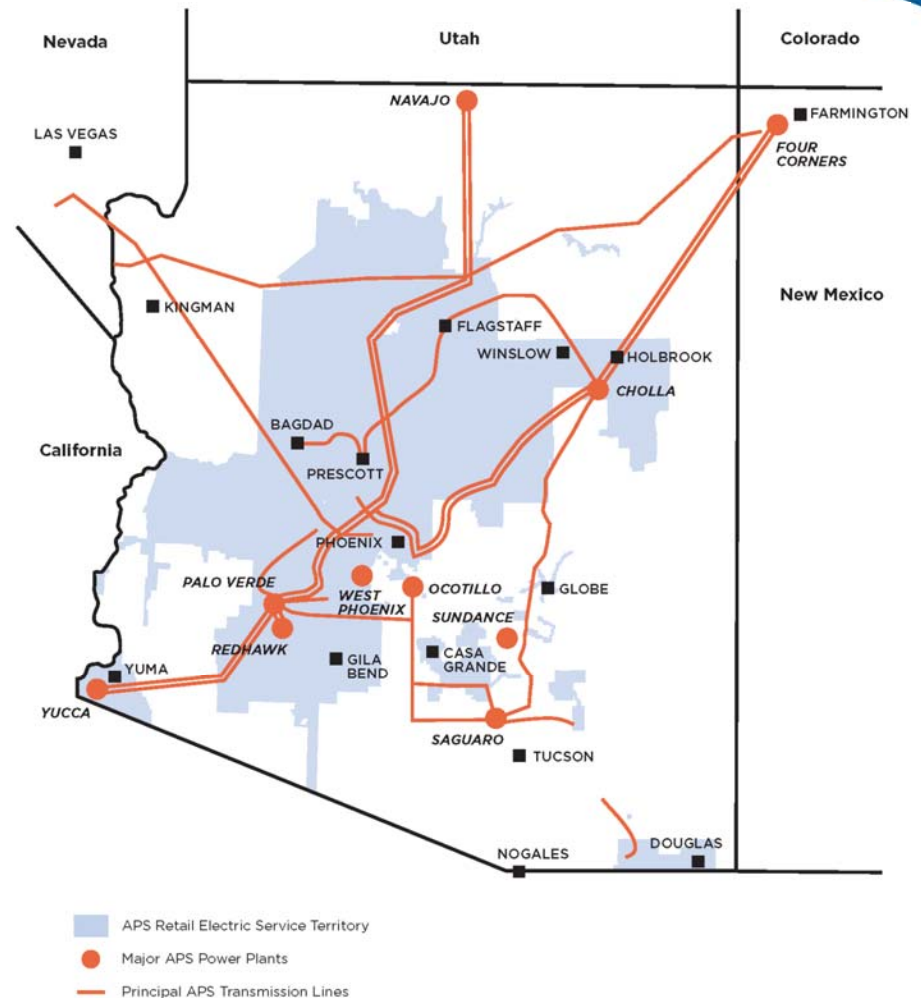


Presentation Overview

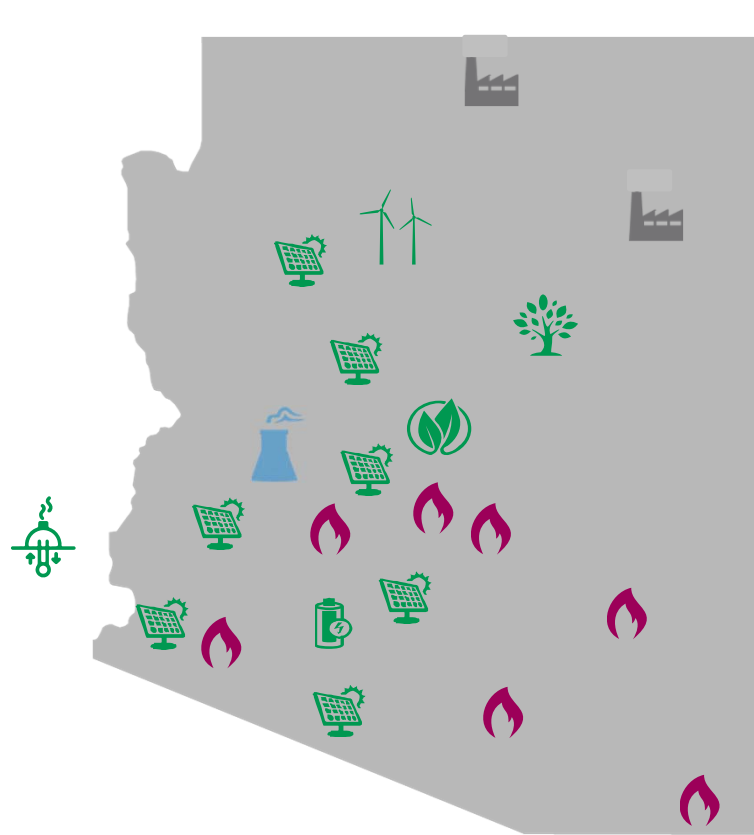
- Arizona Public Service Overview
- Utility Scale Solar
- Residential and Commercial DG
- Solar Partner Program and Lessons Learned

APS Service Territory

- 11 of Arizona's 15 counties
- 34,646 square mile service area
- 1.2 M meters, 2.7 M people
- Over 35,000 transmission and distribution line miles
- 430 substations; 300,000 transformers; over 550,000 poles and structures
- Operating voltages 500, 345, 230, 115, 69, 21, 12.47 kV
- System Peak Load 7,350MW



APS Resource Diversity



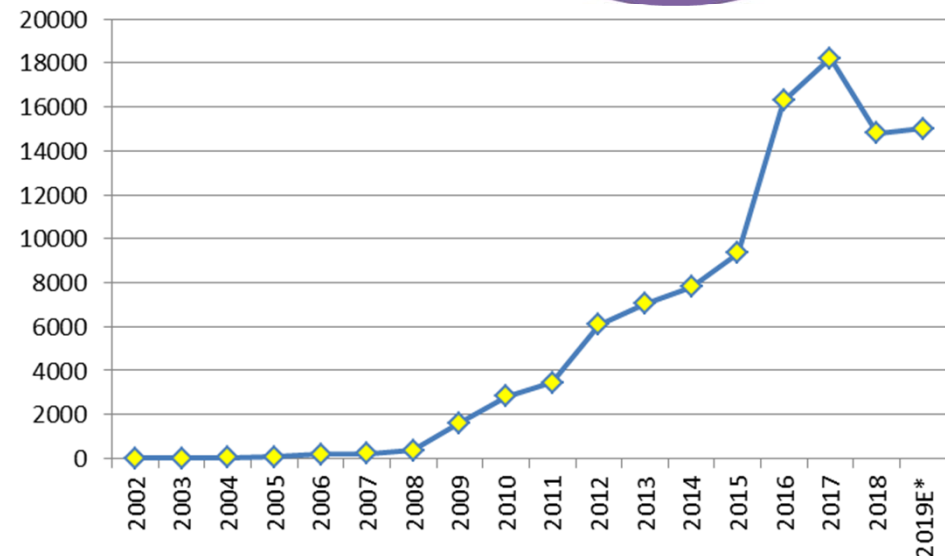
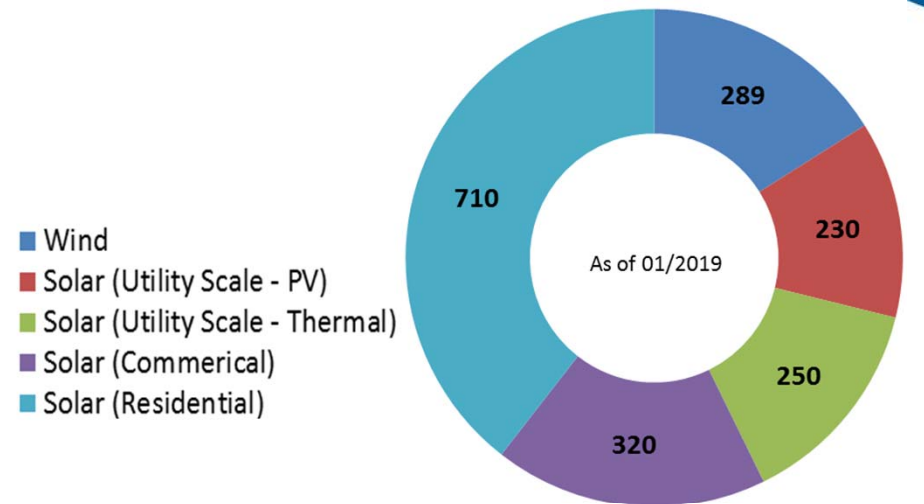
	Capacity Megawatts (MW)
Natural Gas	3,179
Coal	1,672
Renewables	1,475
Nuclear	1,146
Power Contracts	1,554
Energy Efficiency	737
Micro-grids	37
Demand Response	25
	<hr/>
	9,825

 Natural Gas
  Coal
  Nuclear

 Solar PV
  Wind
  CSP w/ storage
  Biogas
  Biomass
  Geothermal

APS Renewable and DER Profile

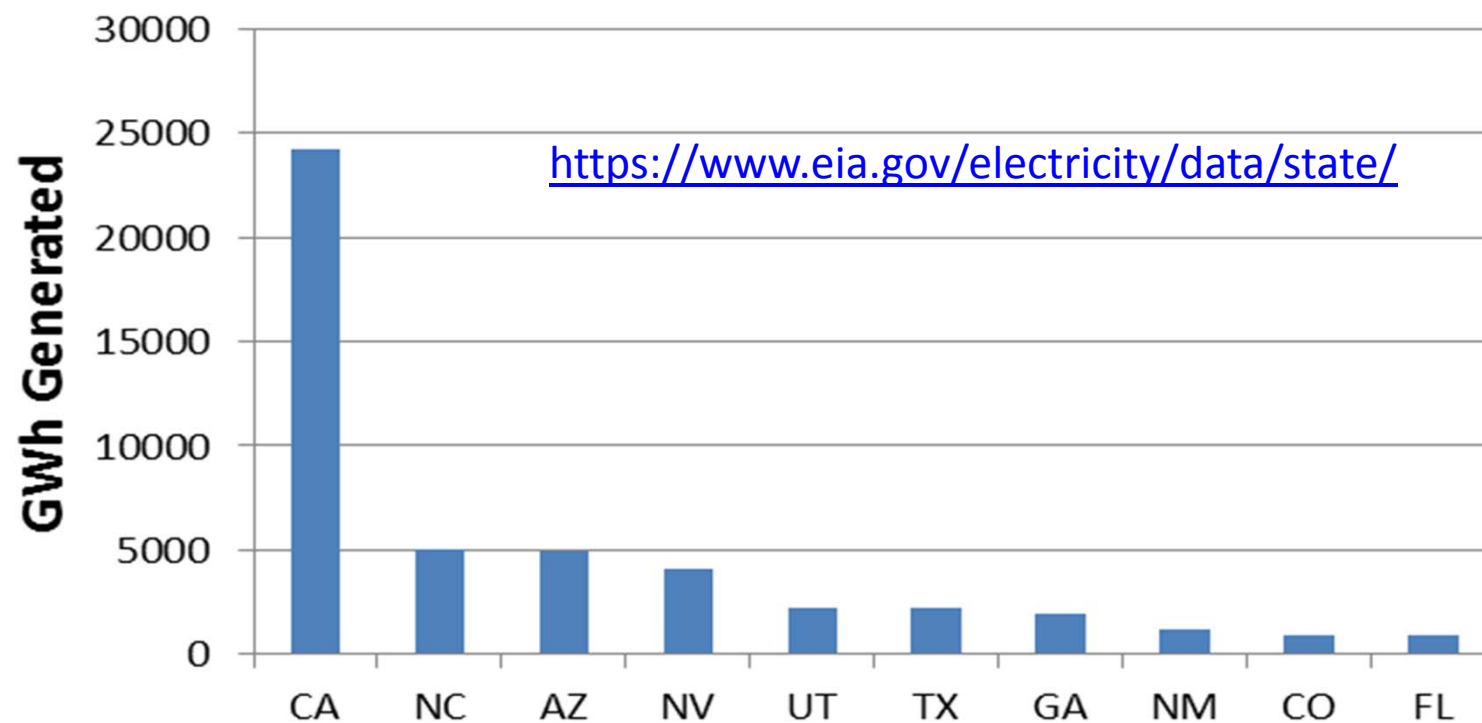
- Renewable profile
 - 769 MW utility scale solar and wind
 - 1030 MW customer owned solar
 - Average 1400 applications/mo.
- Energy storage
 - Solana (solar thermal)
 - 250 MW
 - Battery energy storage
 - 8 MW/12 MWh
- Anticipated DER Forecast
 - 4100 MW* by 2032
 - Most from customer DER



* Based on 2017 IRP data

Where do we rank

(Energy Information Administration – accessed 12/2018)



- Arizona is 3rd nationally for solar PV production
- APS 2nd highest large utility for residential installations per customer
- APS 5th highest solar PV installed capacity of all utilities nationally⁶

Utility Scale Solar at APS

- Luke Air Force Base – 10 MW
 - Desert Star – 11 MW
 - Hyder – 16 MW
 - Cotton Center – 17 MW
 - Paloma – 17 MW
 - Chino Valley – 19 MW
 - Gila Bend – 32 MW
 - Foothills – 35 MW
 - Red Rock – 50 MW
 - Solana – 250 MW
-
- <https://www.aps.com/en/ourcompany/aboutus/solar-commitment/Pages/powering-arizona-with-solar-energy.aspx>

Distributed Solar PV

- Residential
 - Over 90,000 rooftops
 - Over 700 MW
- Commercial
 - Approximately 1,500 systems
 - Over 320 MW
- APS Owned Distributed Solar
 - APS Schools and Governments Program
 - Over 300 sites
 - APS Solar Partner Program (SPP)
 - 1500 residential rooftops
 - APS Solar Innovation Study (SIS)
 - 125 homes
- <https://www.aps.com/en/ourcompany/aboutus/solar-commitment/Pages/bringing-solar-to-our-communities.aspx>

APS Projects

- APS Solar Innovation Study (SIS)
- Punkin Center Battery Storage
 - 2 MW/8 MWh
 - Peak shaving
 - Non wires alternative
- Microgrids
 - Aligned Energy Data Center
 - Yuma Marine Corp Air Station (MCAS)
 - 35 MW, clean diesel generators
- APS Solar Partner Program

Solar Partner Program with EPRI

- Phase 1 - initiated 11/2014
 - 10 MW, 1600 residential customers
 - External Advisory Council
 - Industry, academia, government and research lab
- Rooftop solar PV
 - Residential systems (4-8 kW)
 - West-facing, with advanced inverters
 - 20 year contract - \$30/month bill credit (no usage reduction)
 - APS controls inverters (grid side of meter)
- Centralized communications and control
 - Utility communications, control, and centralized configuration changes
- Phase 2 – initiated 01/2017
 - Feeder energy storage (2 MW / 2 MWh) on 2 feeders
 - Interoperability with VVO and advanced inverters
- Phase 1 [EPRI Report](#) (May 2017)
 - Product ID: 3002011316
- Phase 2 [EPRI Report](#) 11/2018
 - Product ID: 3002014455



APS / EPRI Lessons Learned

Planning & Operations

Feeder demand reduction from aggregated systems (5-8 %)

West-facing coincident to system needs (66 vs 20 %)

No negative VVO impacts

No transformer or customer demand reduction

Advanced Inverters

Respond to commands

Ideal settings vary by feeder (Volt/VAR, PF, unity)

Aggressive voltage settings caused no kW curtailment

Secondary voltage impact dominates

Interoperability & Communications

Need for standards and protocols (nascent industry)

Inverters do not talk at night (solar PV)

Interaction with VVO seen but managed

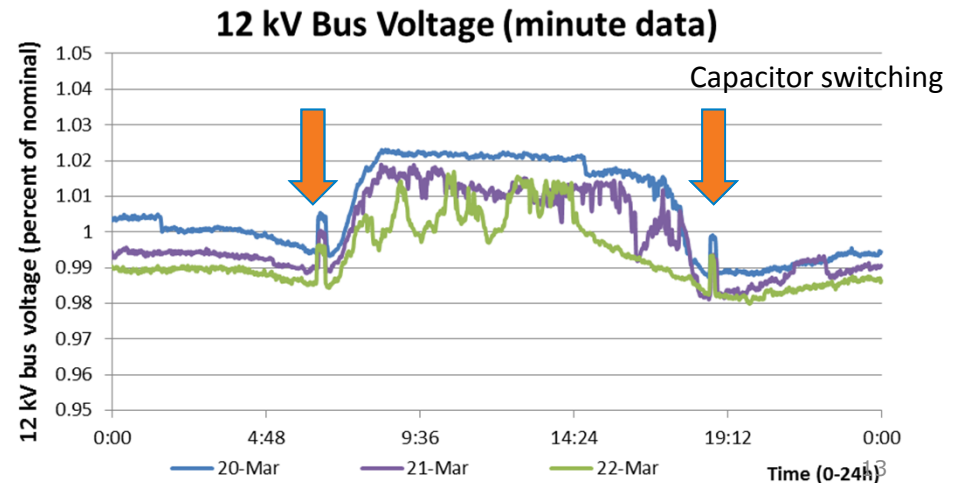
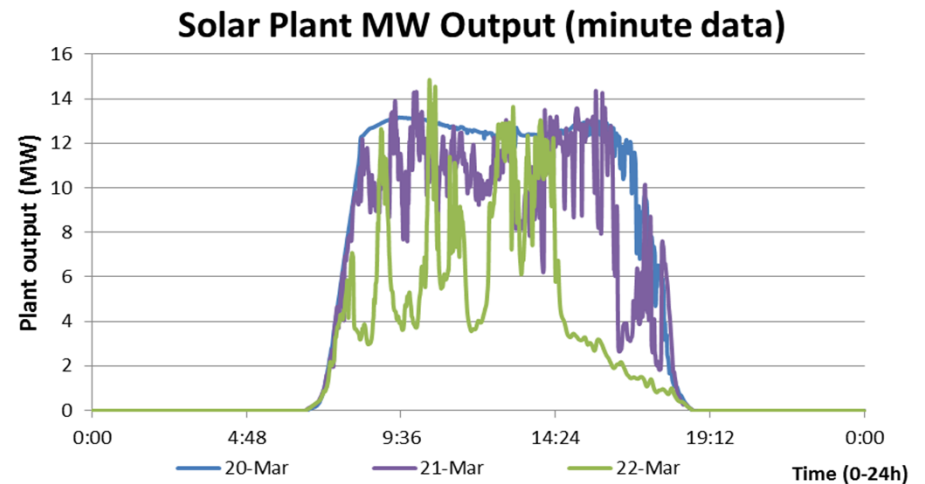
Tradeoffs abound – thoughtful consideration required

Lessons Learned

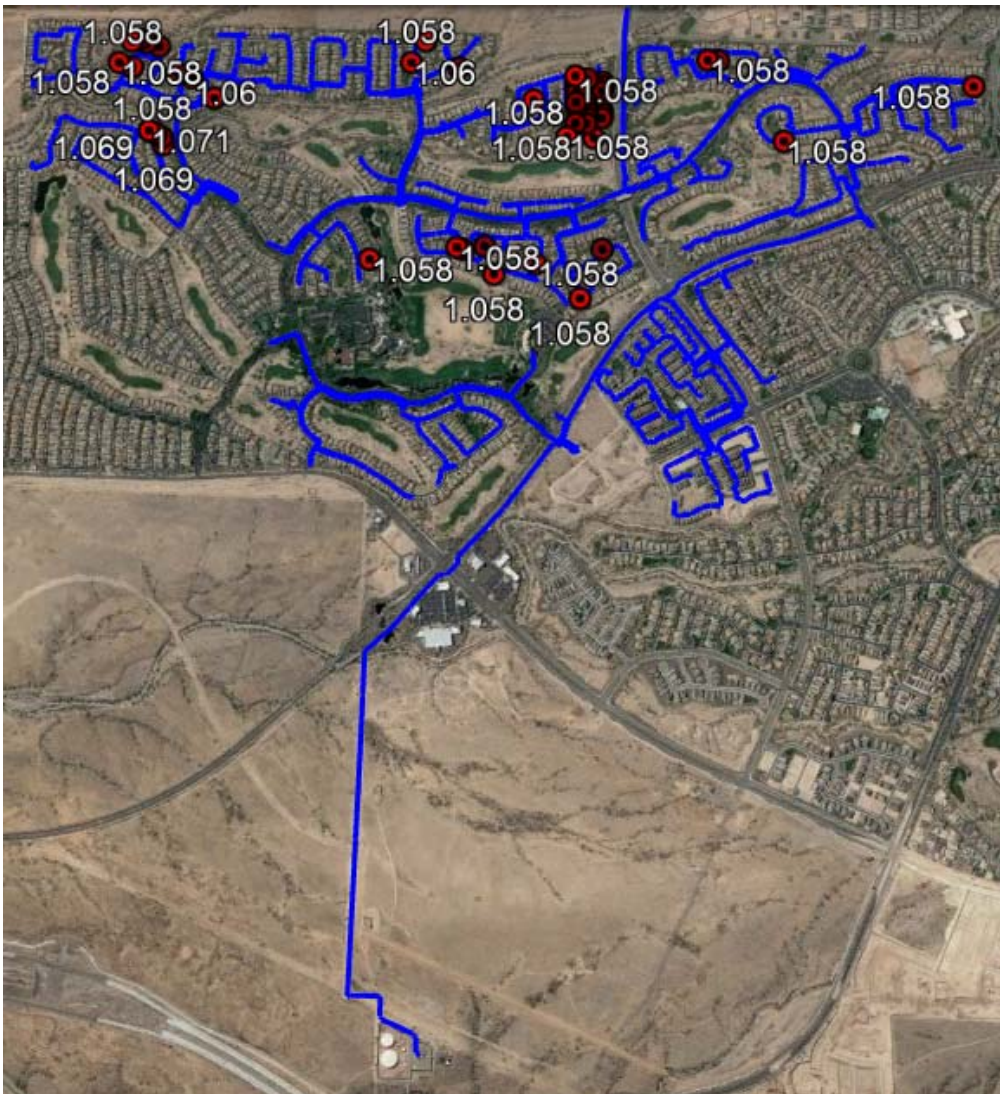


Voltage Variability

- Voltage impact
 - Voltage variability with PV output intermittency
 - Aggregate impacts will be seen at transmission unless mitigated
 - High/Low voltage can damage customer and utility equipment
 - Illustrative Example
 - Three contiguous days with intermittency - low (clear day), moderate and high (cloudy)
 - High voltage variability with PV output variability
 - Existing device (capacitor) operation



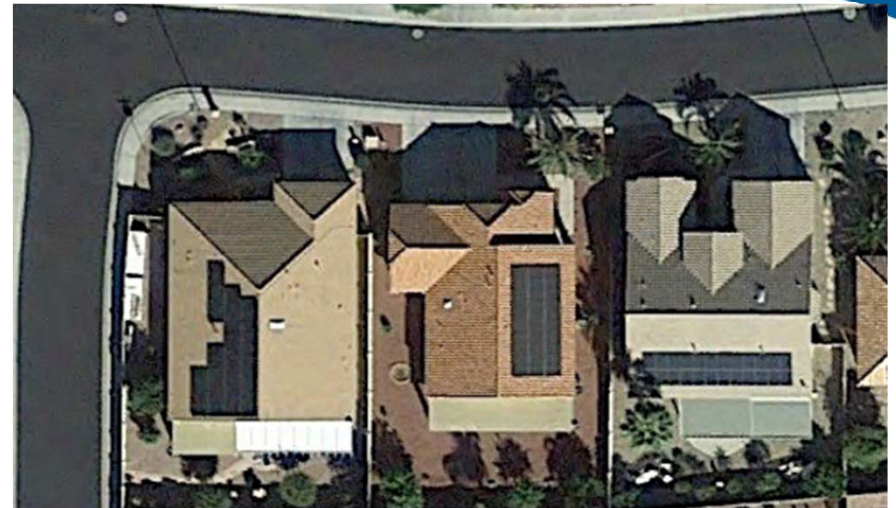
Distribution System Example



- High PV penetration feeder (4.5 MW PV, 10 MW demand peak)
 - ✓ 800 residential PV systems
- Impacts
 - ✓ Voltage rise in areas of high PV concentration
 - ✓ System operations challenges
 - ✓ Line losses
- Studies show a range of impacts
 - ✓ Penetration level not a determinant of PV impacts
 - ✓ Topology (length and wire size) and design are significant factors

Intra-Day Production Spread

- Roof orientation matters
- West-facing systems
 - High coincidence with system needs
 - Dependent on construction
- South and East facing
 - Very early production peaks
 - Non-existent output at load peaks
- Practical deployment
 - Mixed orientations will always exist
 - Different system value



West East South
Normalized values for 6/19/2016

