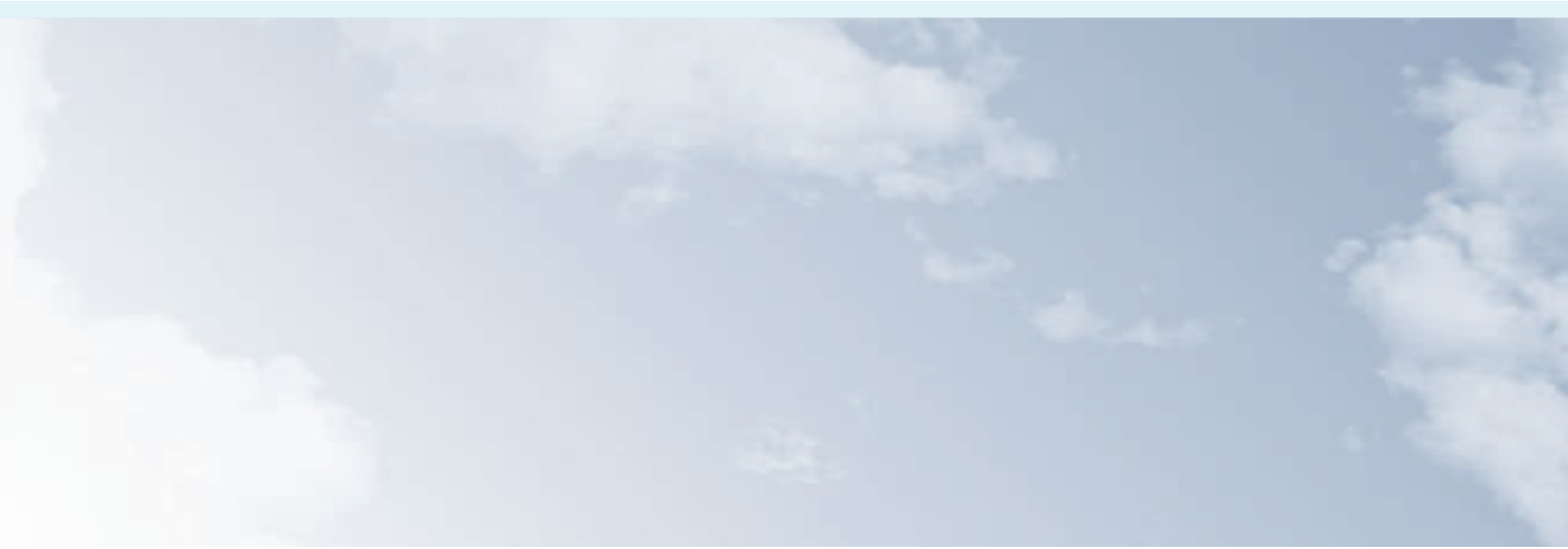
Australian Government
Bureau of Meteorology

Solar resource mapping from geostationary satellite data: Status and needs

Ian Grant, Australian Bureau of Meteorology

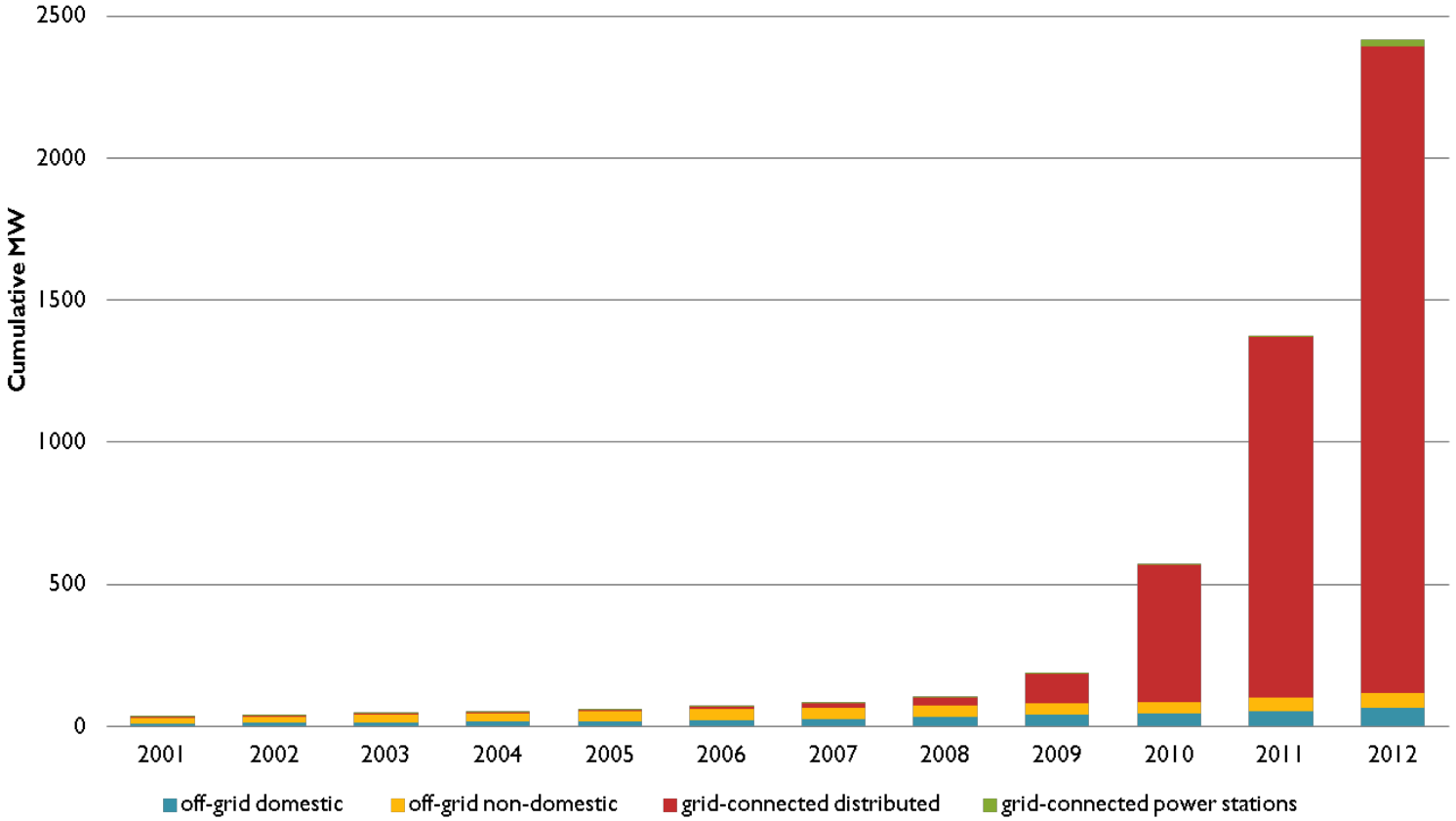


Outline

- Need for solar resource data
- Satellite-derived solar data
  - Contribution
  - Methods
  - Dissemination
- Solar data from advanced geostationary imagers
- Solar forecasting
- International coordination

Solar energy in Australia

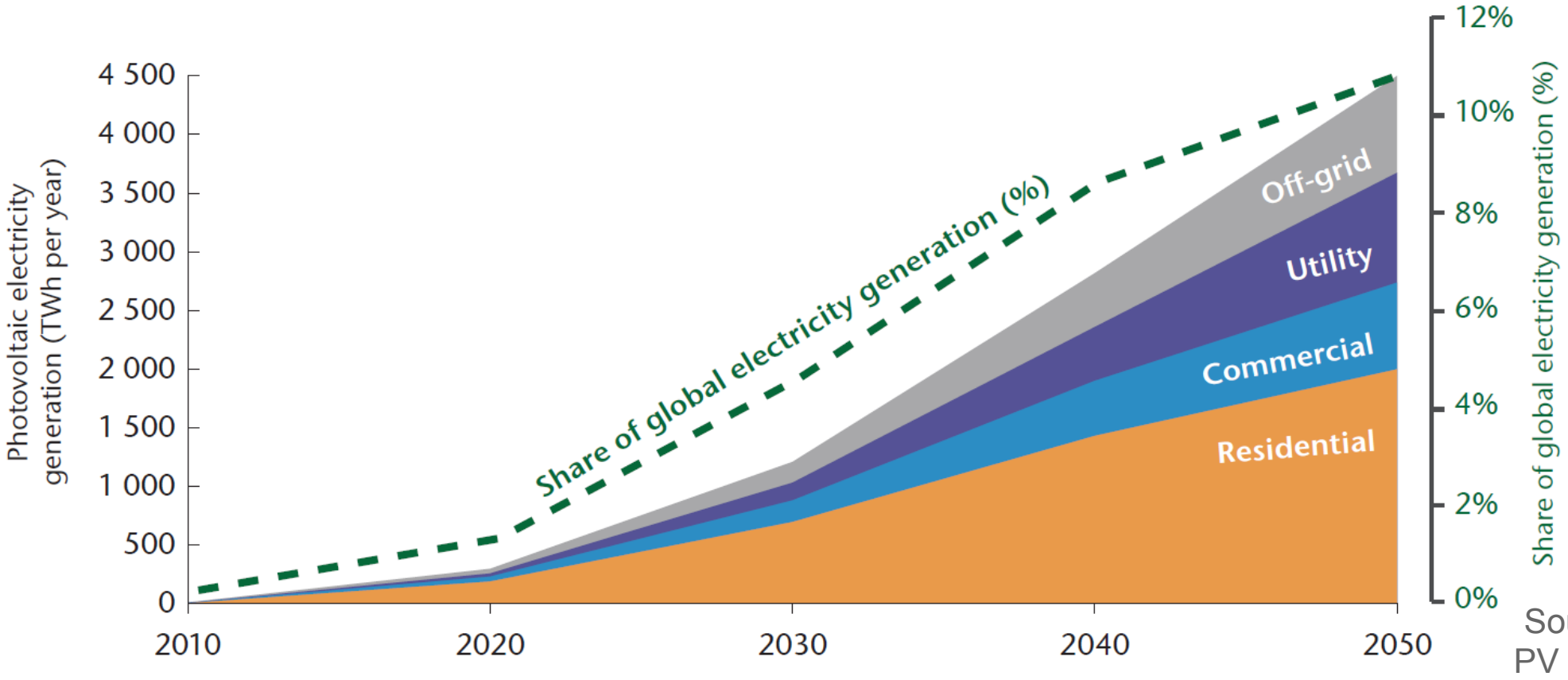
Strong growth in domestic roof-top photovoltaic generation



Source: Austra
PV Associati

Solar energy globally

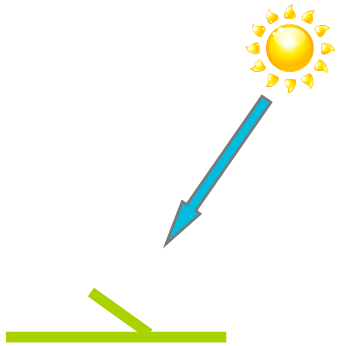
Strong growth expected in solar share of global generation



Source: IEA PV Roadma

Direct and Global solar radiation

Direct solar radiation: The energy only within the Sun's beam



Global solar radiation: The total solar energy falling on a horizontal surface

Solar power station project phases

Site identification

Satellite-derived solar maps + topography, etc. → **Site candidates**

Site qualification

On-site measurement + overlapping satellite time-series → **Bankability**

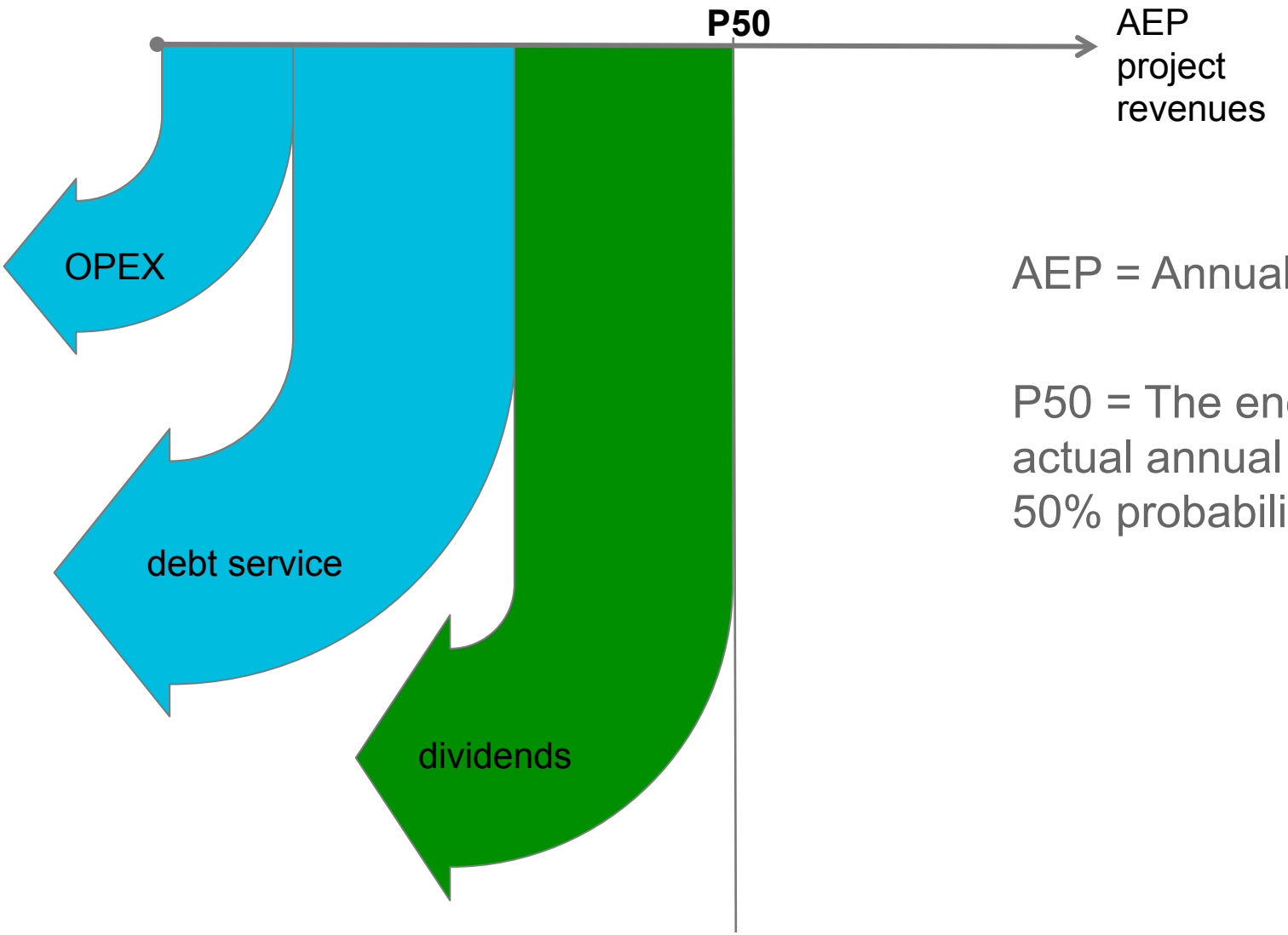
Commercial operation

Solar nowcasting to maximise production

Short-term forecasting to optimise selling → **Project success**

Medium-term forecasting to schedule maintenance

Solar power station cash flow

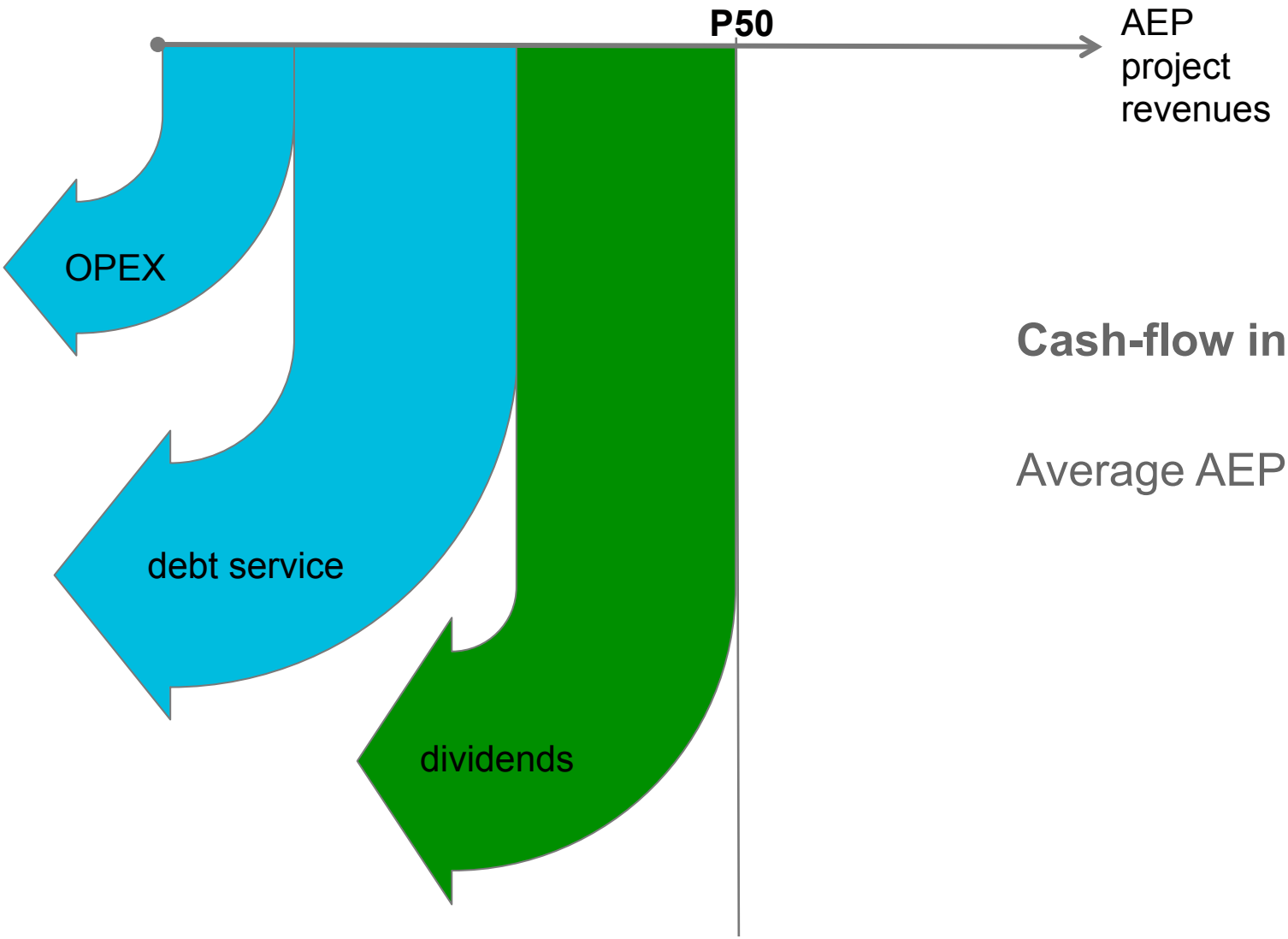


AEP = Annual Energy Production

P50 = The energy amount that a plant's actual annual energy production has a 50% probability of exceeding

Source: Richard Mey
Suntrace GmbH

Solar power station cash flow

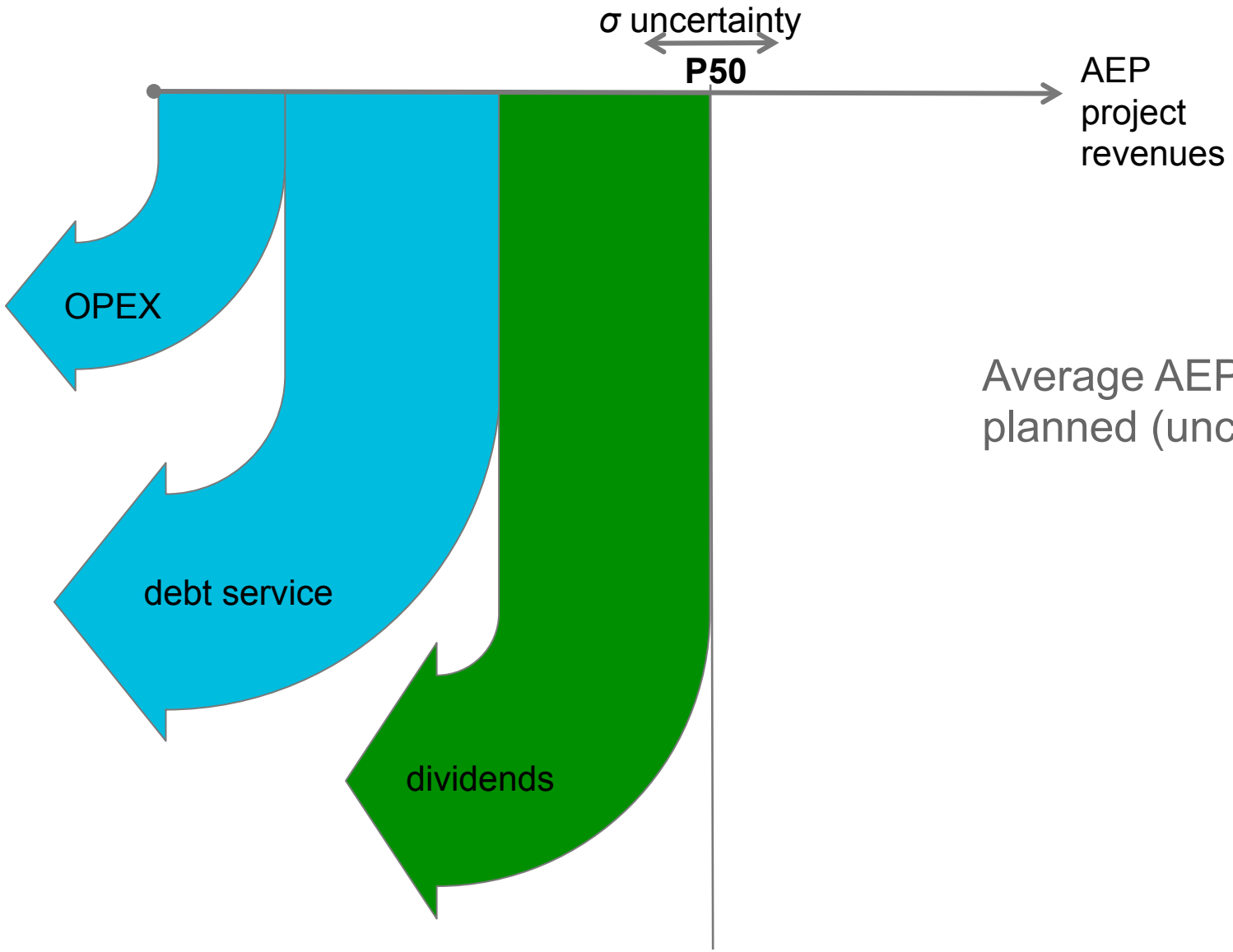


Cash-flow in a P50 year

Average AEP is realised as planned

Source: Richard Mey
Suntrace GmbH

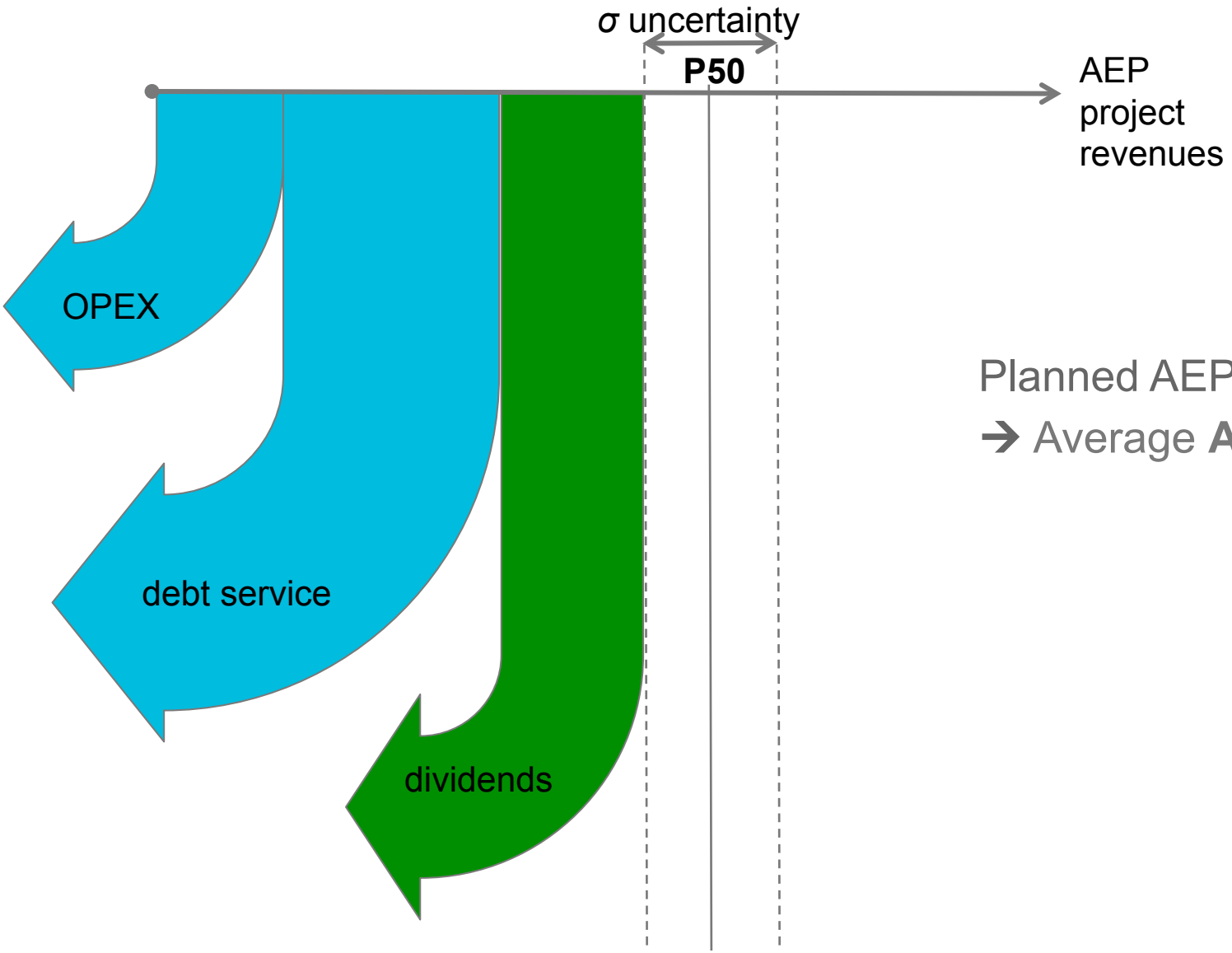
Solar power station cash flow



Average AEP in reality differs from planned (uncertainty)

Source: Richard Mey
Suntrace GmbH

Solar power station cash flow

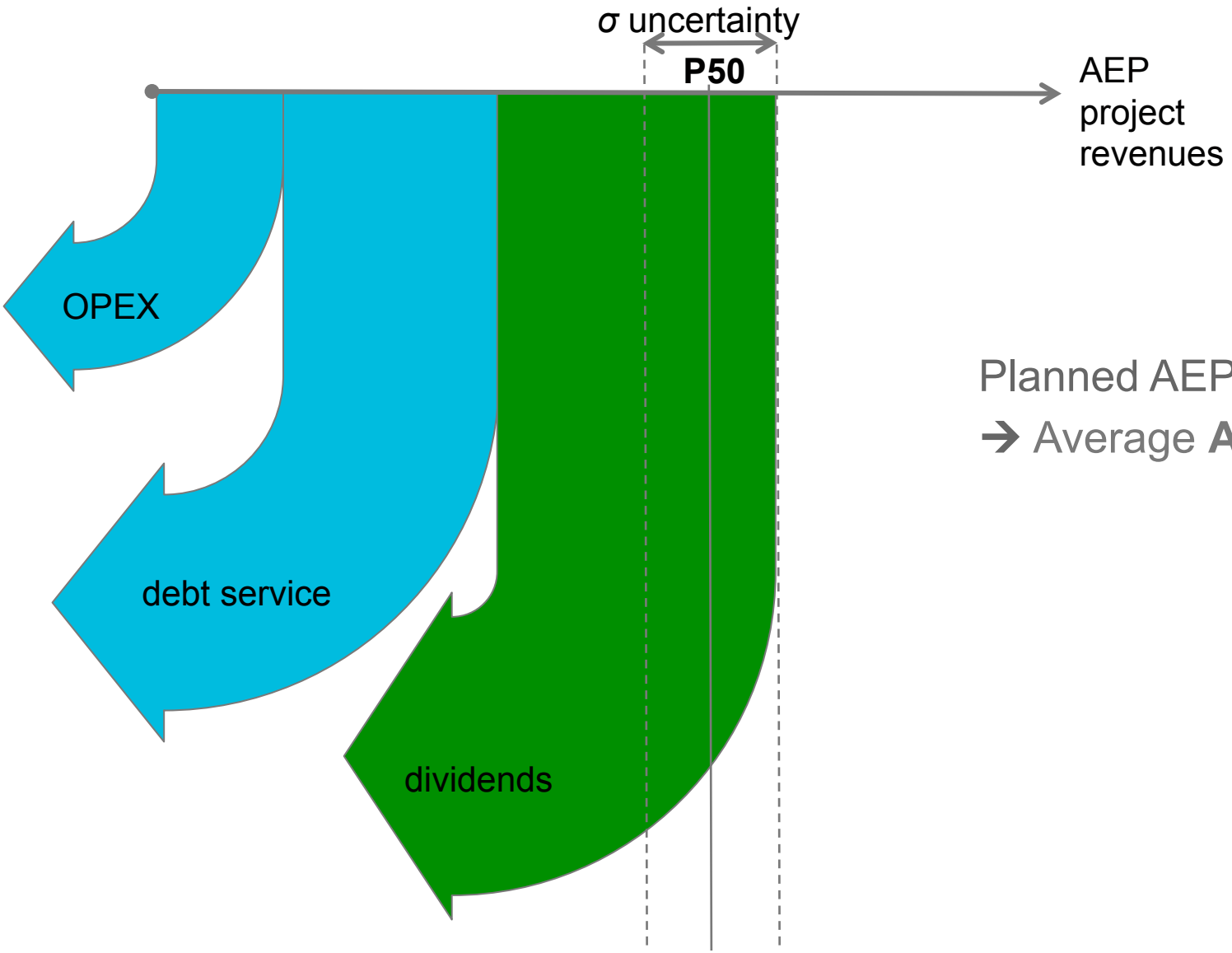


Planned AEP_{P50} was overestimated

→ Average **AEP_{P50} lower by 1 σ**

Source: Richard Mey
Suntrace GmbH

Solar power station cash flow

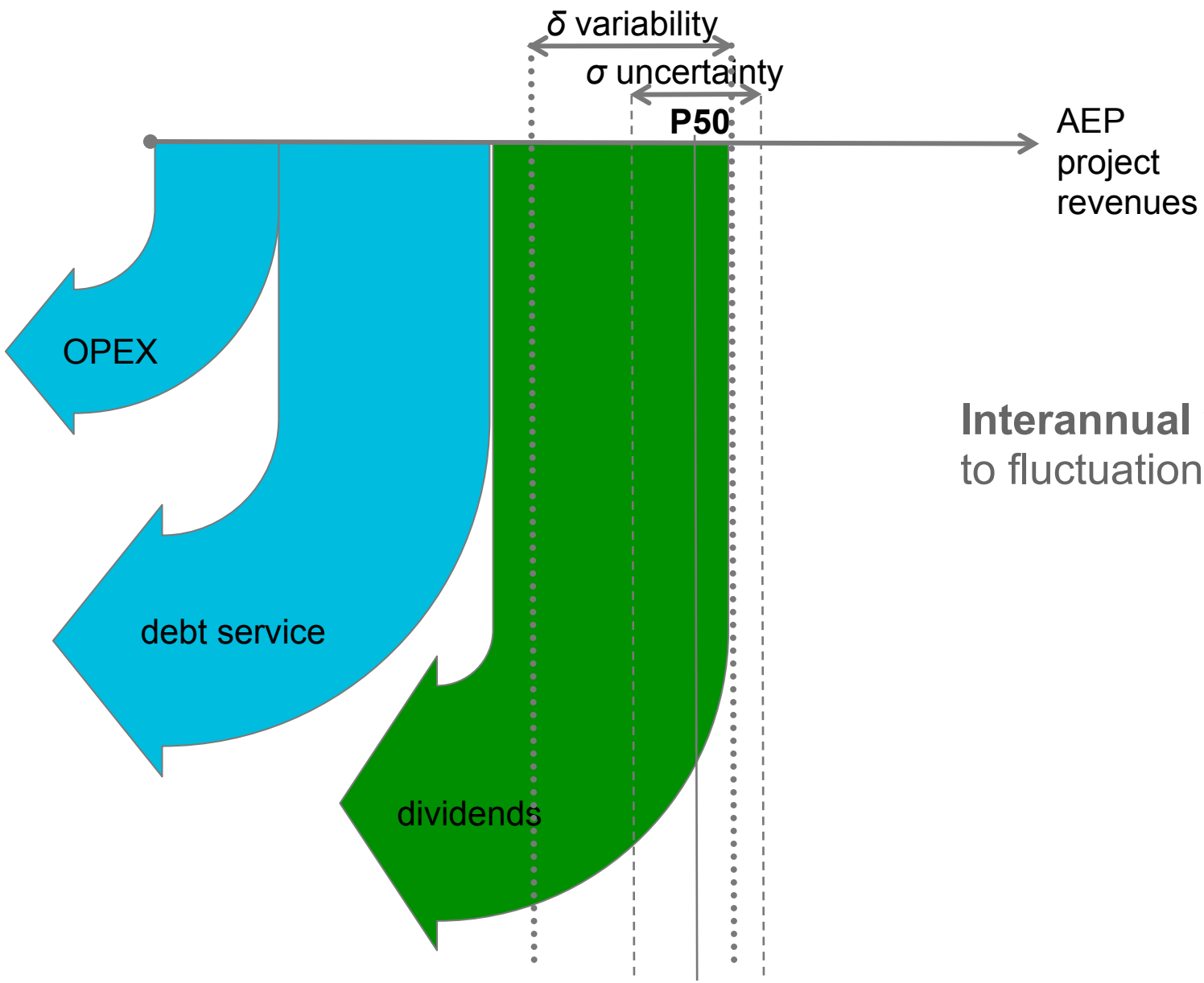


Planned AEP_{P50} was underestimated

→ Average **AEP_{P50} higher by 1 σ**

Source: Richard Mey
Suntrace GmbH

Solar power station cash flow



Interannual variability causes cash flow to fluctuations year-to-year

Source: Richard Mey
Suntrace GmbH

Solar resource data

To achieve high penetration of concentrated solar power (CSP) or photovoltaic (PV) on the grid requires-

- Accurate information about the availability of the solar resource
- Spatial and temporal variability of the solar resource
- Quantified uncertainty of the solar resource estimate

Satellite-based solar resource maps provide complete spatial coverage and long time series

Satellite methods for solar radiation

Amount of solar radiation reaching the surface is controlled by

- Geometry
- Cloud
- Rayleigh scattering
- Water vapour absorption
- Ozone absorption
- Aerosol scattering and absorption
- Surface albedo

Satellite methods for solar radiation

Semi-Empirical Approach

- “Cloud index”: visible-band value scaled to range clear-sky to bright cloud
- Relate “cloud index” to “clearness index” (roughly cloud transmittance)
- Scale clear sky radiative transfer model output by “clearness index”
- Convert global to direct with empirical diffuse fraction model

Physical Approach

- Retrieve cloud and aerosol information from satellites
- Use the information in a radiative transfer model
- Produce both global and direct

Bureau solar radiation from GMS/MTSAT (1)

Physical model

- Parameterises the important radiation processes in atmosphere and cloud
- Retrieves cloud albedo and transmittance, and surface albedo

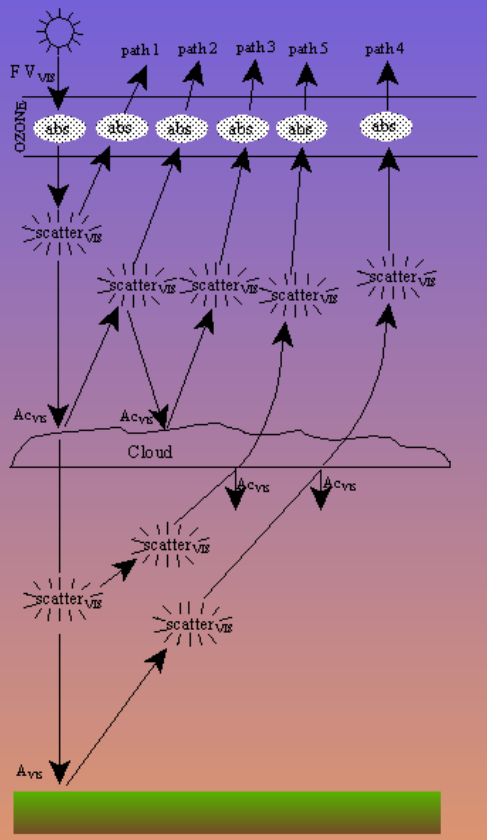
Inputs

- Visible-band image
- Recent clear-sky visible-band surface reflectance
- Total water vapour – from NWP
- Total column ozone – from climatology
- No aerosol

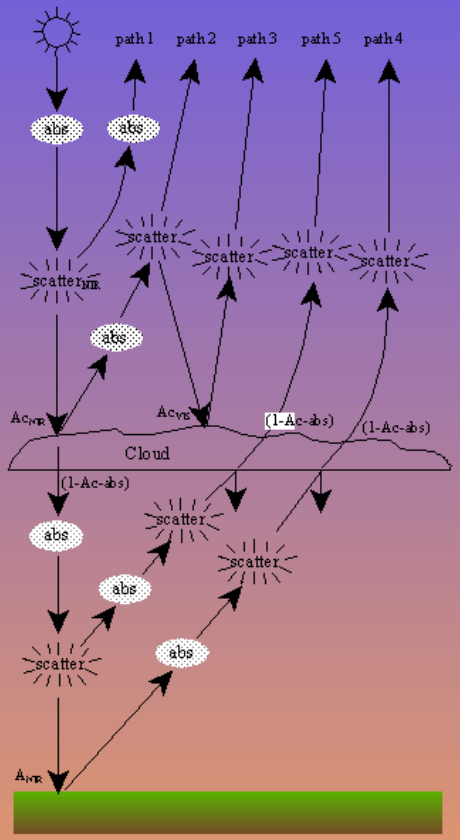
Output

- Global horizontal irradiance – hourly

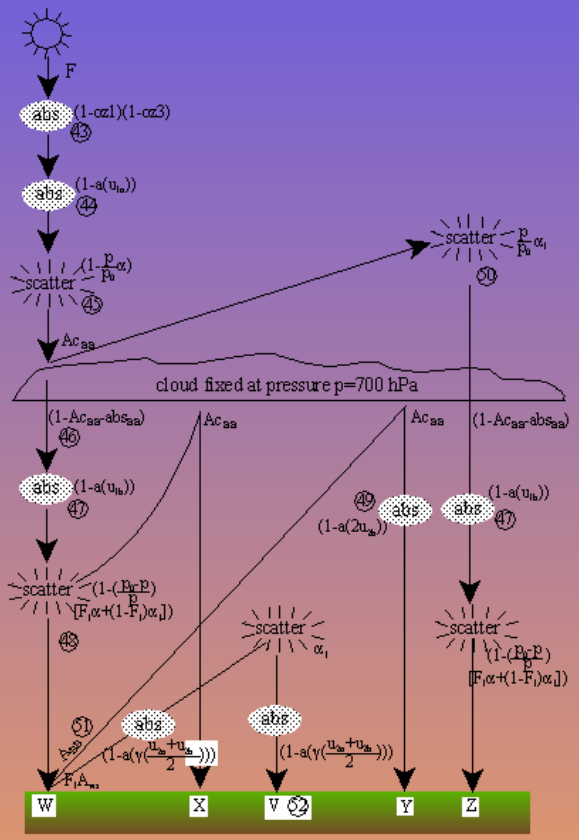
The Solar Radiation Model



GMS-5 Cloudy Sky SW↓ (Satellite) 0.5x - 0.7 µm



GMS-5 Cloudy Sky SW↓ (Satellite) 0.7 - 0.9 µm



GMS-5 Cloudy atmosphere model SW↓ broadband

The Bureau of Meteorology's Solar Radiation Model in its entirety (after Weymouth , 1994)

Bureau solar radiation from GMS/MTSAT (2)

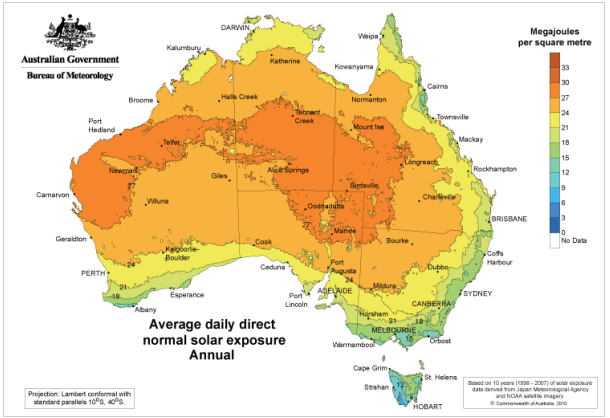
Postprocessing

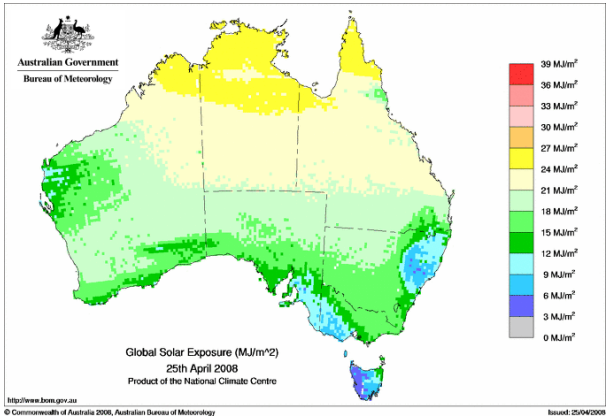
- Empirical diffuse fraction model converts Global radiation → Direct radiation
- Integrate hourly irradiance → daily exposure
- Monthly and annual means and climatologies

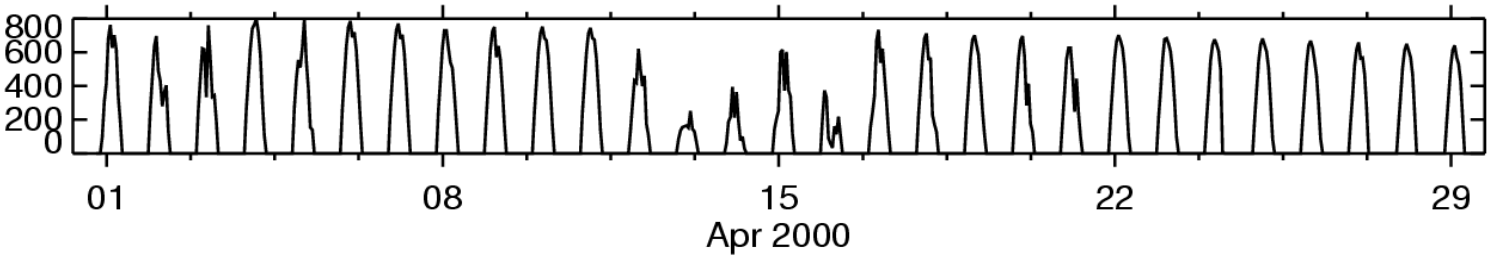
Bureau solar radiation data from GMS/MTSAT

Gridded datasets from GMS and MTSAT series

- 0.05° grid over Australian land since 1990
- Updated daily
- Validation with Bureau surface radiation network
- Time series: Hourly and daily
- Monthly climatologies: Hourly and daily
- Global horizontal and direct beam







Surface solar observations

Quality surface observations are required for

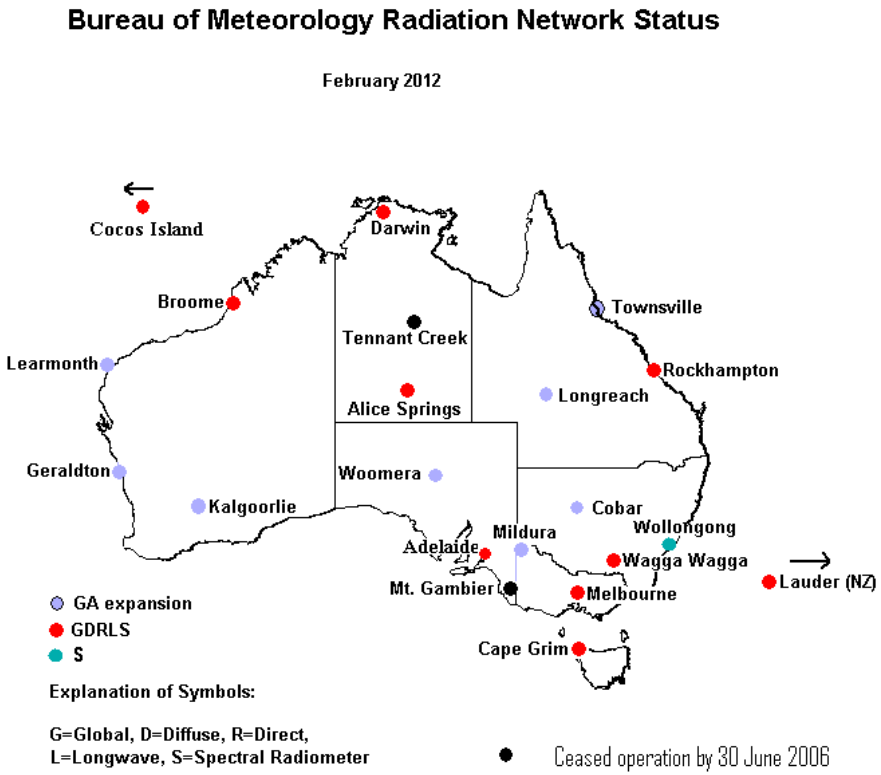
- Validation (uncertainty chracterisation)
- Bias correction

Baseline Surface Radiation Network (BSRN) is gold standard for quality

The Bureau radiation network uses modified BSRN protocols

Bureau surface solar observation network

- 1 second observations
- 1 minute statistics of global, diffuse, DNI and sunshine.



- 31 stations, 17 currently open
- 240 station-years of data

The solar measurements are traceable to the World Radiometric Reference and SI

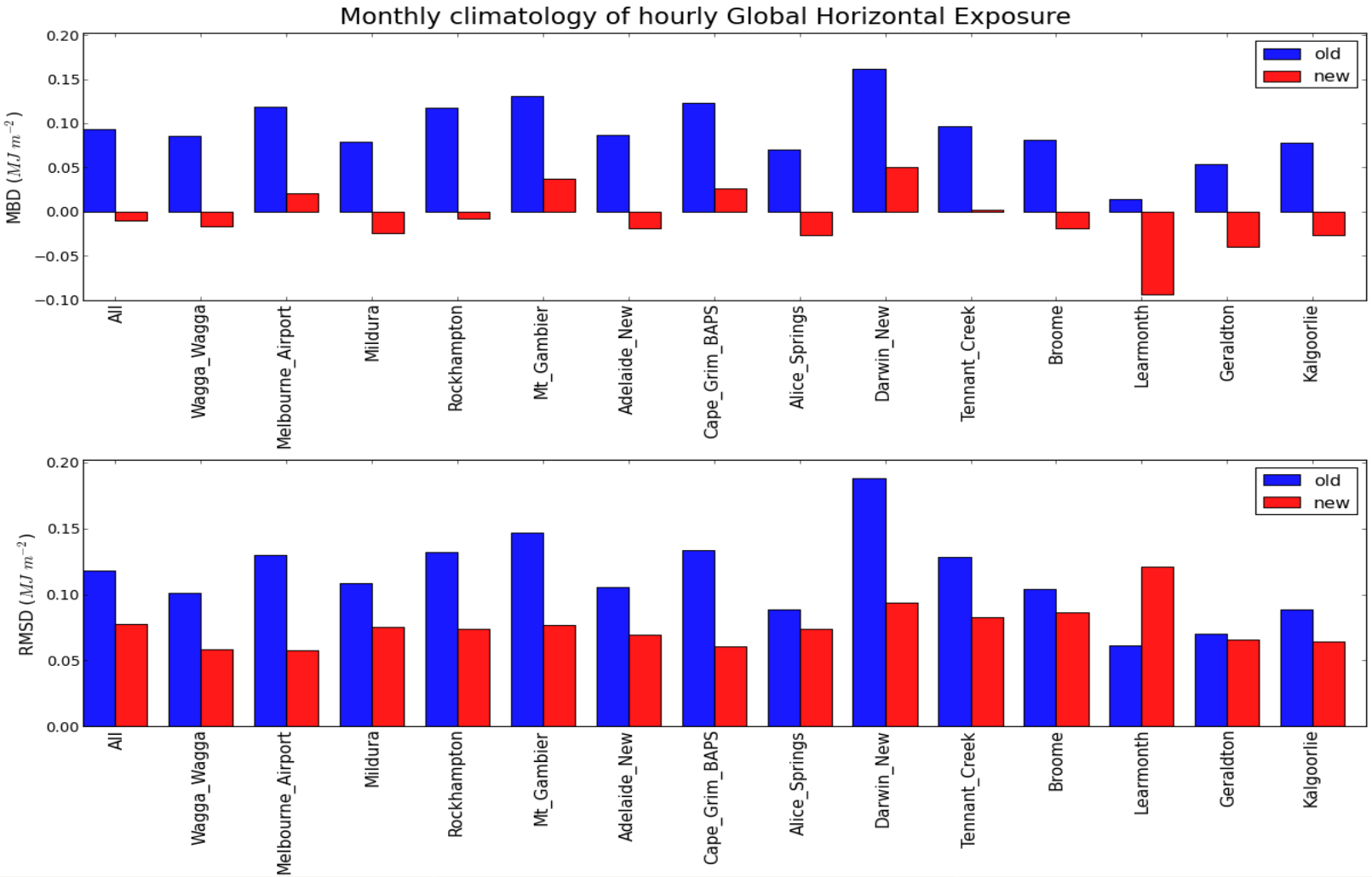
Bias correction with surface data

Before & **after**

Bias correction

Mean Bias Difference

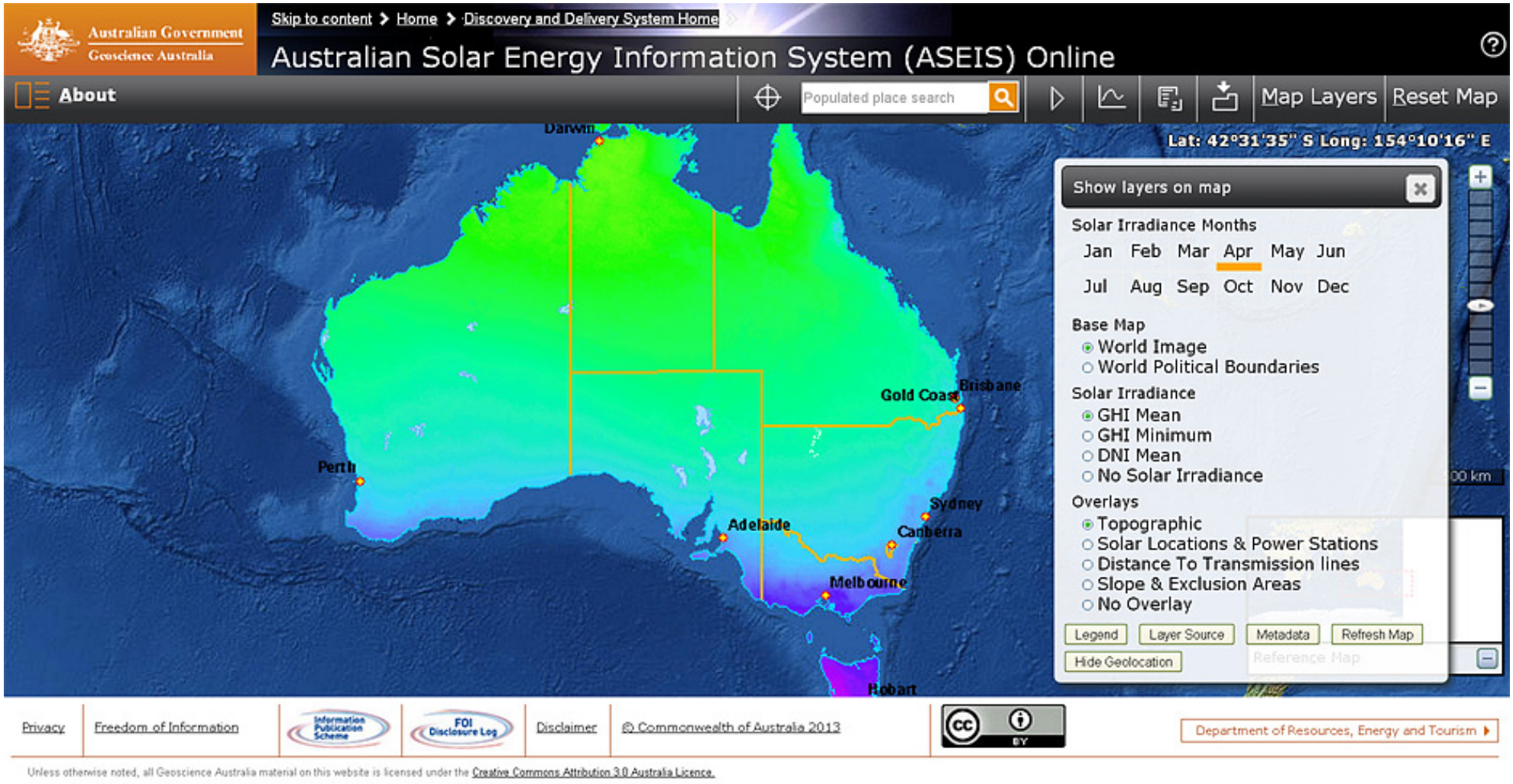
RMS Difference



ASEIS
Australian Solar Energy Information System

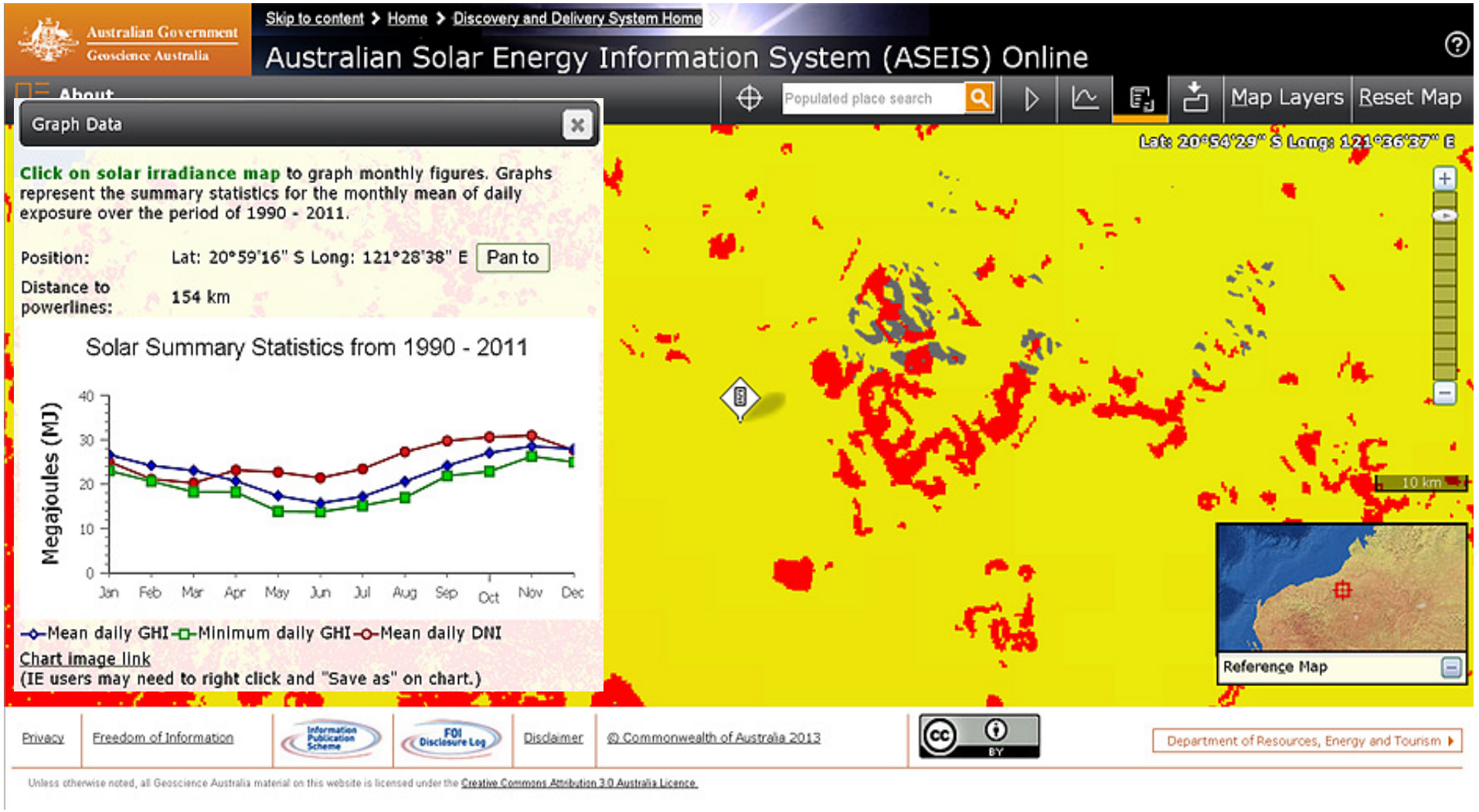
- Improve access to pre-competitive resource & infrastructure data for planning large scale solar power stations – *"Solar prospecting"*
- Collaborative project between Geoscience Australia & Bureau of Meteorology
- Funded by Australian Government through the Solar Flagships program and the Australian Renewable Energy Agency
- Final delivery June 2014
- Three components to improving solar resource data
  - Expand surface network
  - Improve satellite solar data products
  - Improve user support information

ASEIS
Australian Solar Energy Information System



ASEIS

Australian Solar Energy Information System



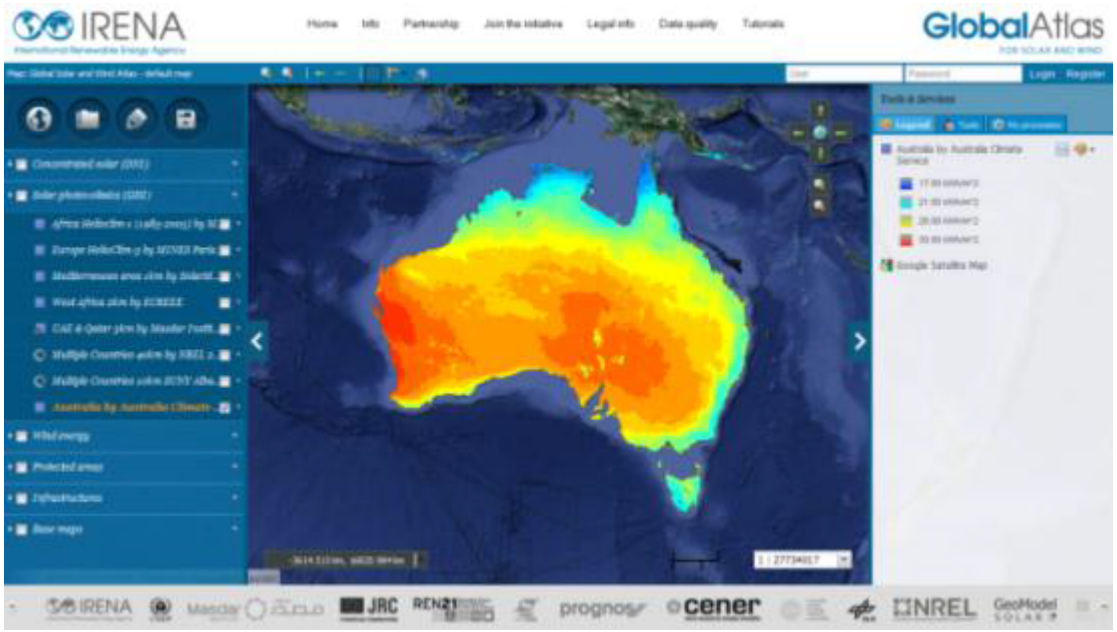
Global access to solar resource data

Global Atlas for Solar and Wind Energy

International Renewable Energy Agency (IRENA)

Global search and discovery site for data related to solar and wind energy

Open architecture with open standards for sharing and viewing geospatial data



Solar radiation now/forecasting

Applications

- Power station and grid operation
- Electricity market operation

Approaches

- Ground-based networks or imagers (minutes)
- Forecasting from satellite observations (0-6 hours)
- Integration of satellite and NWP (0-24 hours)
- NWP and mesoscale models (1-3 days)

AEMO

Australian Energy Market Operator (AEMO)

AEMO releases to the market a new dispatch of scheduled and semi-scheduled generation every 5 minutes – 24 hours a day every day

Generators offer supply: 5 minute interval, 2 hour horizon; 30 minute interval, 8 day horizon

[Bid 48h ahead; then price is fixed but amount (MW) can be revised]

Annually: 200TWh of electricity or $9billion

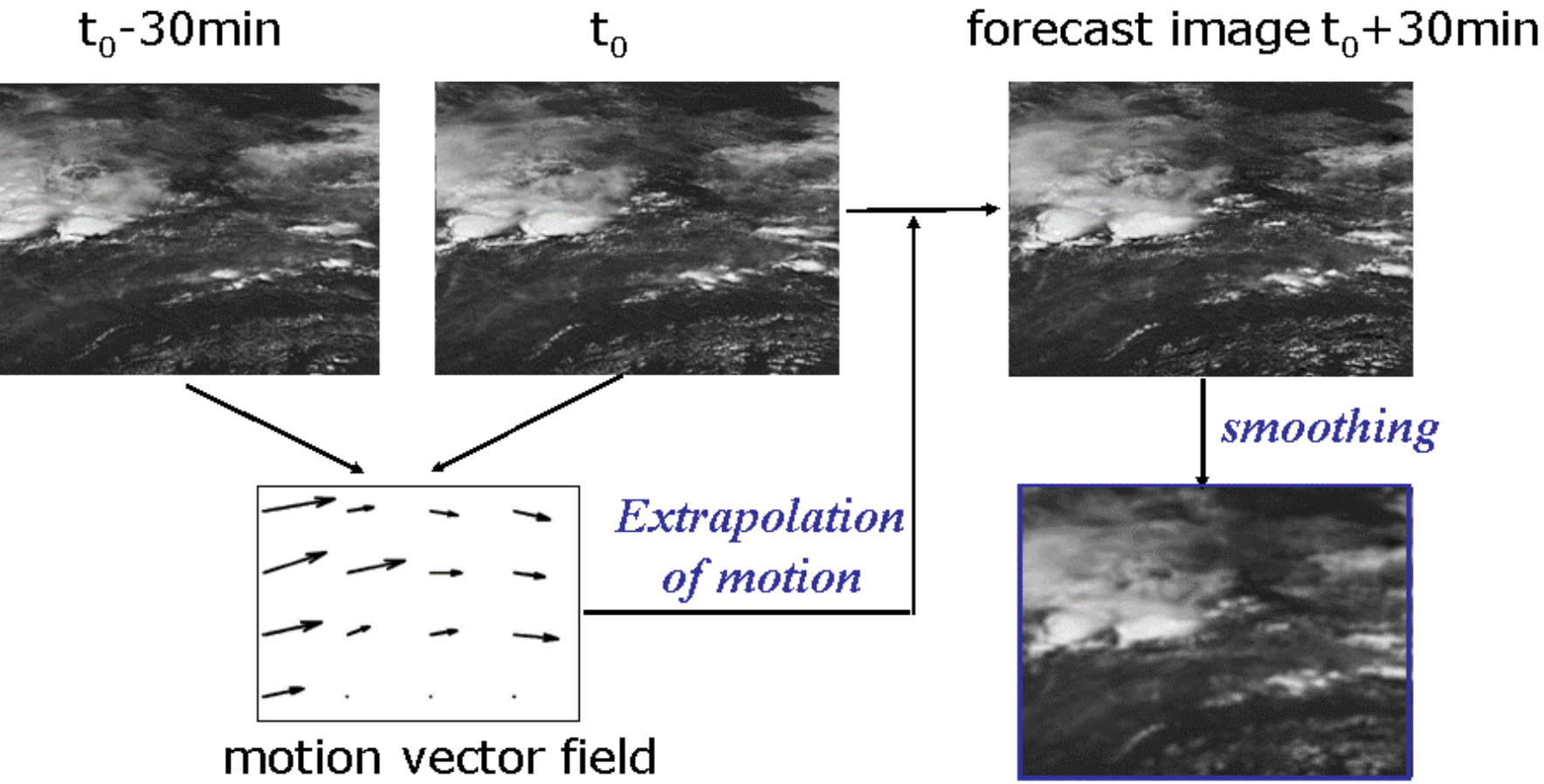
Settlement is up to about $300million per hour

Priorities for Australian solar forecasts are

Solar Flagship projects when they reach >30 MW output

Distributed rooftop PV systems

Forecasting solar radiation from satellite

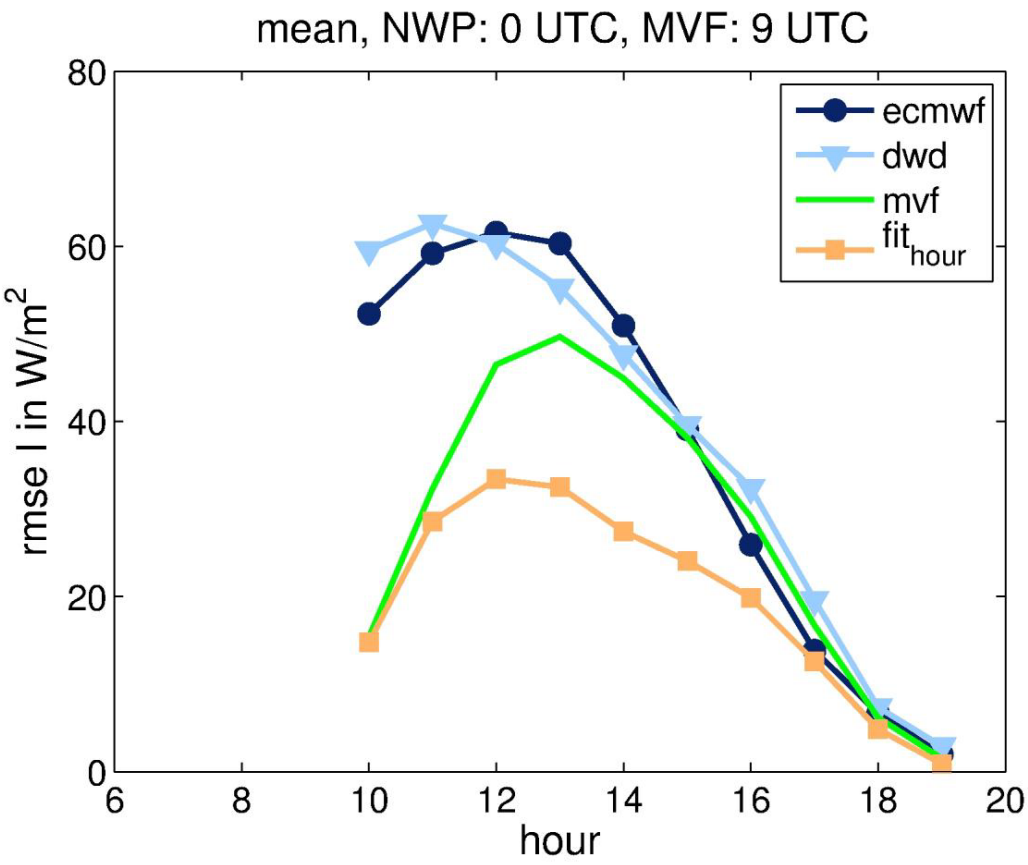


Source: Univ. Oldenburg

NWP-satellite hybrid solar forecast

Satellite based forecasts better than NWP forecasts up to 5 hours ahead

Larger improvement with combined forecast



Source: Univ. Oldenburg

Opportunities from advanced GEOs

Temporal resolution

- Reduce uncertainty, CMVs become feasible

Spectral resolution

- Better atmosphere and cloud properties

Physical approach with advanced geostationary imager

Retrieve

- *Cloud*
  - *Type*
  - *Height/temperature/pressure*
  - *Particle size, water path*
  - *Optical depth, albedo, transmission*
- *Column water vapour*
- *Aerosol*

Input to radiative transfer model → Direct, Diffuse, Global radiation fluxes

IEA/SHC Task 46

International Energy Agency / Solar Heating & Cooling Program

Task 46: *Solar Resource Assessment and Forecasting*

Best Practices Publications, workshops and presentations on key energy meteorology topics:

- Applications for high penetrations (variability, wind/solar systems)
- Data bankability (measurements, data filling and merging, uncertainty analysis, TMY and other data applications)
- Solar irradiance forecasting (All-sky cameras, CMVs, NWPs)
- Advanced resource modeling (retrieval methods, long-term analyses)

Australian Government
Bureau of Meteorology

Thank you…

Ian Grant
i.grant@bom.gov.au