Workshop on Potential Energy Management Applications for NASA Earth Science Resources

Workshop Analysis:

Recommendations for a Strategic Roadmap for a Potential Energy Management Focus Area of the NASA Applied Sciences Program

Submitted to:

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Executive Summary

The NASA Applied Sciences Program aims to demonstrate applications of NASA Earth Observation resources and build associated capacity in a variety of focus topics. Although Energy Management has been a program focus in the past, the Applied Sciences Program leadership is considering adding Energy Management to the list of application areas supported by the program which include Disasters, Ecological Forecasting, Health and Air Quality, Water Resources, and Wildfires. To help NASA define the framework for Energy Management as a potential addition to the NASA Applied Sciences Program, Battelle conducted a workshop on April 27, 2016. This report provides analysis and conclusions for NASA based on that workshop. Pre-workshop consultations and questionnaires also identified key themes, such as the fact that several NASA datasets are already supporting energy sector decisions. However, there are still needs for greater standardization of climate change data and scenarios, as well as increased collaboration across energy sector data users and providers. The workshop also identified themes based on suitability of opportunity, degree of user-driven interest, potential for valuable outcome, and timeframe for NASA to see results. “Low-hanging fruit” were identified, where potential application areas were ranked “high” in all areas. These potential application areas include: Electric Grid Load Management, Instantaneous to Seasonal with Output Forecasting of Renewable Energy sources; Water Resource Availability for Thermal Cooling and Hydropower Planning; Solar Resource Assessment; Wind Resource Assessment; Micro-grid System Design with Integrated Renewables; and Energy Efficiency of Buildings. NASA datasets in these areas are increasingly useful; however, in all areas, dataset maintenance, capacity building, and technical improvements to resolution (among other possible improvements) are needed. The workshop also found that the energy sector is diverse, with energy types, regions, experience with NASA data, time available, and planning horizons varying across user groups.

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1. Introduction

The NASA Applied Sciences Program aims to demonstrate applications of NASA Earth Observation resources and build associated capacity in a variety of focus topics. Although Energy Management has been a program focus in the past, the Applied Sciences Program leadership is considering adding Energy Management to the list of application areas supported by the program which include Disasters, Ecological Forecasting, Health and Air Quality, Water Resources, and Wildfires. To help NASA define the framework for Energy Management as a potential addition to the NASA Applied Sciences Program, Battelle conducted a workshop on April 27, 2016. This report provides analysis and conclusions for NASA based on that workshop.

1.1. Rationale for Workshop

The overall goal of the workshop and subsequent analysis is to help define a strategic potential Energy Management Application Area designed to fill users' critical needs and have a high impact in a sustained manner. The workshop was designed to gather input to address the following considerations:

- Overall definition of the scope and structure of a potential new application area, and alignment with NASA goals and commitments and other U.S. Government priorities.
- Identification of the most promising focus topics, including some possible short-term successes to demonstrate clear value from the application of NASA Earth Observation resources such as data products to invest in or capacity building to conduct.
- Identification of potential partners and stakeholders, and the relevant decision-support and information management systems, which could benefit from the addition of NASA Earth Observation Resources.
- Considerations for implementation of an Energy Management Application Area, such as optimizing the public-private interface, lessons learned from past and current applications of Earth observations for energy management (by NASA and other U.S. and international organizations).
- A timeline and targets for a potential Energy Management Application Area.

As detailed in Chapter 2, Battelle invited a cross-section of potential end users and other stakeholders to the workshop to gather input on the above-listed considerations.

1.2. Purpose of this Document

This Analysis Report summarizes the methods that our team used to structure the workshop and analyze workshop outputs, and then presents results and recommendations for the NASA Applied Sciences Program. The report is organized as follows:

- Chapter 2- Workshop Input Gathering and Analysis Methods
- Chapter 3- Analysis of Specific Applications Areas
- Chapter 4- Business Engagement Models
- Chapter 5- Program Metrics, Tracking, and Timeline
- Chapter 6- Conclusions/Summary and Near-Term Steps

This report builds upon two previous deliverables which Battelle submitted to NASA as part of this project:

- Pre-Workshop Planning Summary (Deliverable 1, Submitted March 4, 2016)
- Pre-Workshop Consultations and Proceedings Summary (Deliverable 2, Submitted July 7, 2016)

1.3. Project Team

This project is led by Ms. Erica Zell, a Senior Research Scientist with Battelle, who has more than 10 years of experience supporting satellite remote sensing applications and energy sector decision-support projects, with a focus on electric load forecasting and solar and wind resource assessment projects. Ms. Zell has 20 years of experience conducting applied research and policy and programmatic support in the fields of renewable and fossil energy projects, air quality, environmental impact assessment, and climate change adaptation. She serves as the Co-Chair of the Energy and Climate Work Group for the Earth Science Information Partnership (ESIP). The following Battelle staff also supported this project:

- Annie Lane, a Market Manager for Battelle in the Energy Management Group, with experience leading Smart Grid and other projects for utilities.
- Natasha Sadoff, a Research Scientist for Battelle in the Advanced Analytics Group, with experience supporting multiple NASA projects and workshops, and experience conducting literature reviews involving renewable energy and climate change.

Battelle is supported in this effort by NASA Langley Research Center (LaRC), specifically Dr. Paul Stackhouse, who leads ongoing energy management projects as part of his work at NASA. Battelle and Dr. Stackhouse (collectively, the team) are working under the direction of Dr. Richard Eckman, who served as the previous Energy Management Area Program Lead for the NASA Applied Sciences Program.

1.4. Energy Management Sector Context

For purposes of this report, our team defines the energy management sector to include the following topics:

- Assessment and harnessing of energy sources:
  - Fossil fuels (including transport and processing)
  - Nuclear energy (including transport and processing)
  - Renewable energy (solar, wind, hydropower, geothermal, ocean energy, biomass)
- Electricity generation, transmission, and distribution
- Energy efficiency and use (building, industrial, transportation, agriculture)
- Energy development and use-related emissions and impacts to the environment
- Climate resiliency of the energy sector
- Universal energy access (including electricity and modern cooking fuels/methods)

From the start of planning for this workshop, there have been significant policy developments that affect the rapidly evolving energy management sector, both domestically and globally. For

example, internationally, in December 2015, the Conference of Parties (COP-21) of the United Nations Framework Convention for Climate Change reached the Paris Agreement to combat climate change and accelerate actions and investments, many of which relate to the energy sector. More broadly, energy demand, energy policies, and energy sector technologies are rapidly evolving, such as the rapid price decrease in solar- and wind-based power technologies. Simultaneously, risks to the energy management sector from extreme weather, sea-level rise, and other changes such as water availability, are increasing. Also, the Sustainable Development Goals have re-emphasized the need to expand global access to modern energy services.

As further detailed in this report, these developments offer unique/new opportunities for the NASA Applied Sciences Program to leverage its Earth Science resources to benefit the energy management sector, and society as a whole. These opportunities align with NASA's Strategic Goals and with other initiatives supported by the U.S. government such as the Group on Earth Observations (GEO) and the Sustainable Development Goals. Refer to the Pre-Workshop Planning Summary for details on the current context of the energy management sector.

2. Workshop Input Gathering and Analysis Methods

This chapter briefly summarizes the team's methods to gather input via the workshop and to analyze the input received at the workshop. Refer to the previously referenced deliverables for additional details.

2.1. Pre-Workshop Activities

Battelle identified potential speakers and invitees based on an online literature review with a focus on interested and engaged parties in Earth observations, and through the professional networks of our Battelle team and NASA partners. For the literature review, the team identified and reviewed approximately 40 documents on Earth observation needs in the energy sector and current applications of satellite data. These documents were authored by organizations such as World Bank, Electric Power Research Institute, DOE, GEO, USGEO, European Space Agency, USAID, and Asian Development Bank, along with a host of industry associations, private research firms, and academia. Subsequently, over the course of several months before the workshop, the team conducted pre-workshop consultations with potential speakers and workshop invitees.

The Battelle team conducted pre-workshop consultations with 8 potential speakers, as listed in Table 1.

Table 1. Workshop Speaker Consultations

Organization	Speaker Name(s)
World Bank	Silvia Martinez Romero, Nathan Blair
Bentley Systems, Inc.	Drury Crawley
U.S. Department of Energy	Craig Zamuda
International Solar Energy Society	David Renne
World Energy and Meteorological Council	Alberto Troccoli
San Diego Gas and Electric	Brian D'Agostino
California Energy Commission	Guido Franco

The Battelle team conducted pre-workshop consultations via email questionnaire, as shown in Figure 1.

Figure 1. Questionnaire for Workshop Invitees

NASA Energy Management Stakeholder Workshop Ideation Workshop

Pre-Workshop Questionnaire

Thank you for your interest in the Energy Management Stakeholder Ideation Workshop! Please respond to the questions below so that we have a better understanding of your work and perspectives as we prepare for the workshop. This information will be used to inform the workshop presentations and goals.

Please submit the completed questionnaire to Natasha Sadoff (sadoffn@battelle.org) by March 31.

Name:

Organization and Role:

1. **Would you classify your organization's role as an energy sector end user of data, an intermediate value-added provider, or another role related to program management and research? Please explain.**

2. **Within that role, what Earth observation datasets or information (satellite data, weather forecasts, water levels, etc.) are most relevant to your work? What, if any, are your current sources of these Earth observations?**

3. **What are the key issues or challenges that are currently directing your need for Earth observations or information?**

    a. **What emerging or future concerns (out 5 years) are likely to take high priority?**

4. **If you consider yourself an end-user of information, what current decision-support systems (software, decision matrices, etc.) or methodologies do you use which could or do incorporate Earth observations?**

5. **Have you considered using NASA data in your decision-support systems? Why or why not?**

Battelle sent the questionnaire to all workshop invitees, of whom 11 responded, as listed in Table 2. Note that Battelle sent questionnaires both to confirmed attendees, and to several invitees who expressed interest in attending the workshop but had schedule conflicts. Battelle sent several reminders to encourage survey response, although the response level was only moderate.

Table 2. Workshop Participant Questionnaire Respondents

Organization	Name(s)
MIT	Claudio Vergara
National Institute of Building Sciences	Ryan Colker
Clean Power Research	Alemu Tadesse
NREL	Jill Engel-Cox
RETScreen International	Gregory Leng
Energy Intelligence Partners	Edward May
Con Edison	Greg Koumoullos
World Bank	Oliver Knight
World Bank/NREL	Nathan Blair
NOAA	Melinda Marquis
HOMER	Peter Lilienthal

The team's previous deliverable (Deliverable 2, Appendix A) contains copies of each of the completed questionnaires that Battelle received. In general, the following summarizes key results:

- Most data providers or end users were already somewhat engaged with the NASA Applied Sciences Program.
- Resolution improvements were needed so that information could be site-specific and actionable in risk-based decision making.
- Near-real time data availability is needed
- Uncertainty and confidence of scenarios, forecasts, and projections are important for decision making (including consistency in format, quality, and quantity).
- Collecting data that could be used to forecast climate impacts on industry and/or energy demand is increasingly important.
- Some respondents use vendors to access and manage NASA data in existing decision support systems, though working with NASA directly was also highlighted as attractive since it could cut down on costs (recognizing that NASA cannot compete with value-added business).
- No barriers were listed as to why participants did not use NASA data.

The pre-workshop consultations, together with the research conducted by our team as part of workshop design and planning, provided information to help us focus the workshop on the most promising areas of application

From the list of energy management sector topics given in Section 2.1 of Deliverable 1, the team identified a set of subtopics for further exploration in this report. Based on a literature review, the Team identified these subtopics as requiring a major expansion or shift within the subtopic itself, or based upon a recent (last ~5 years) advancement in relevant NASA Earth Observations or models, as being a potential strategic focus for a NASA Energy Management Application Area which would likely yield substantial benefits.

The following subtopic groupings attempt to capture the distinct focus areas of stakeholders, relevant studies, and associated tools and data needs:

- Focus Subtopic 1: Renewable Energy Resources (includes more of a policy modelling aspect, like Copernicus and JGCRI, than I had thought)
- Focus Subtopic 2: Building Energy Efficiency
- Focus Subtopic 3: Electric Grid Operation and Planning, Integration of Renewables, Smart Grids (Smart Grids didn't really come up at our workshop but maybe we didn't' have the right people there)- had more of a disasters focus than I had thought – the extreme weather events that take the grid down or cause huge demand or supply surges
- Focus Subtopic 4: Energy Sector Climate Vulnerability and Resilience
- Focus Subtopic 5: Energy Access in Developing Countries (more emphasis on socioeconomic data than I had thought and more system modelling)

2.2. Workshop

The workshop was structured to maximize input gathering, both from the presenters and from the workshop participants through facilitated discussion and a breakout session. Refer to Appendix A for the agenda. The team selected speakers for each focus topic from end users (California Energy Commission, San Diego Gas and Electric) of data, value-added providers (Clean Power Research, Bentley Systems) of data, and providers of data (IRENA, Copernicus Program) from an international perspective to address business engagement models. A total of 20 people attended the workshop as participants or speakers from external organizations (beyond NASA and Battelle organizers), as listed in Table 3. Each contributed ideas to discussions.

Table 3. Workshop Attendees

Name	Organization
Alberto Troccoli*	World Energy and Meteorology Council
Alemu Tadesse	Clean Power Research
Brian D'Agostino*	San Diego Gas & Electric Company
Carolina Barreto	Tetra Tech
Claudio Vergara	Tata Center, MIT
Craig Zamuda	Department of Energy
Dave Renné*	International Solar Energy Society
David Hunter	Electric Power Research Institute
Doug Vine	Center for Climate and Energy Solutions
Drury Crawley*	Bentley Systems
Edward May	Energy Intelligence Partners
Gregory Koumoullos	Con Edison
Guido Franco*	California Energy Commission

Name	Organization
Jill Engel-Cox	National Renewable Energy Laboratory
John Zack	AWS Truepower
Melinda Marquis	NOAA
Nathan Blair	World Bank/NREL
Nicolas Fichaux *	International Renewable Energy Agency
Silvia Martinez Romero*	World Bank
Stuart Gaffin	NASA Goddard Institute for Space Studies

* indicates workshop speaker

The team took notes on all presentations and discussion, including the report-back from the breakout session, and compiled notes from the flipchart presentations (summarized in Deliverable 2). The final discussion of the workshop focused on barriers to using Earth observations and several ways that the NASA Applied Science program could help address these barriers, including suggestions related to business engagement models.

2.3. Post-Workshop Analysis

The team developed a structured approach for integrating and analyzing both the information from pre-workshop activities and the input obtained at the workshop, in order to develop a set of recommendations for NASA (this report). Upon summarizing major comments and discussions from the workshop, the team shared the summary with workshop speakers and asked them to identify their key takeaway messages. The team then developed a matrix to populate with potential application areas and criteria deemed by the team to be of relevance for designing a potential Energy Management Focus Area, as follows:

- **Suitability of Opportunity** - Assessment of whether the potential application area is a good match with NASA's Earth science resources and commitments, rated overall as Moderate or High based on *(High indicates a strong match on resources and alignment; Moderate indicates adequate match on resources and alignment)*:
    - Key Relevant NASA Earth Resources
    - Alignment with NASA Applied Sciences Program and USG commitments including strategies and initiatives such as GEO, CEOS, Sustainable Development Goals, and Executive Orders such as Number 13653, Preparing the United States for the Impacts of Climate Change.

- **Degree of User-Driven Interest** – Extent to which energy management sector end users of data and value-added providers of data have expressed a need for testing out better information in their decision support systems *(Strong indicates an established user interest; Moderate indicates anecdotal or limited expression of user interest)*

- **Potential for Valuable Outcome** – The likelihood that NASA's investment in this application would generate substantial relative value for the energy management sector and/or energy users, considering factors such as the set of people or industries to which the application is applicable, any anticipated growth of that set of people or industries *(Likely indicates that results are anticipated to benefit much of an industry; Likely*

[Ongoing] indicates that results of NASA data applications are already providing broad benefits in the energy sector; Possible indicates that results are anticipated to benefit a subset of an industry or limited group of people)

- **Timeframe for NASA to See Results** – The soonest that NASA would see results or benefits reaching energy management sector users, starting from initiation of an application (or enhancement to a current application) (*Near-Term indicates results within 1-2 years; Mid-Term indicates results within 3-4 years)*

The team used the list of five energy topics from the pre-workshop analysis as the starting point for a list of potential application areas to be rated in the matrix. The team then identified one to three sub-topics for each of the five topics to align with the key issues framed by speakers and participants during the workshop. The sub-topics were also selected to each have a distinct set of stakeholders, a relatively coherent set of needs for Earth observations, and a focus on a distinct time frame (e.g., near-real time). Because the utility representatives at the workshop noted that their staff who focus on near-real time operation are distinct from staff who focus on longer-term planning, we broke out the sub-topics according to timeframe to align with this staffing structure.

This matrix only includes the topics prioritized for discussion at the workshop; thus, there are no topics that would be rated Low or Unlikely for Success; all topics have potential for success within the NASA Applied Sciences Program (i.e., according to the criteria, reasonably suitable, user-driven, valuable, and able to show results within at most 4 years).

The team assigned ratings for each potential application area (sub-topic) and criterion noted above based on the information gathered before and during the workshop, and the team's knowledge of Earth observation applications and the energy management sector. The team prepared a ratings summary and a supporting table for each potential application area with available evidence to support the rating. Chapter 4 provides the results of this analysis. The team also compiled information on potential program design from the workshop. Chapter 5 summarizes these themes.

3. Analysis of Specific Applications Areas

Table 4 provides a summary of the ratings assigned by the team, per the methodology described in Section 2.3. To support the ratings listed in Table 4, Tables 5 through 14 provide supporting evidence and details. For simplicity, these tables do not connect specific Earth observation needs to specific NASA satellites, sensors, and models – this information was previously summarized in Deliverable 1 (Table 6), which is included as Appendix A to this report for convenience. Also, note that all sub-topics listed are in alignment with the NASA Applied Science Program goals, and support CEOS and GEO initiatives; therefore this information is noted here rather than being repeated in each table.

Table 4. Specific Application Areas Analysis Ratings Summary*

Potential Application Area	Suitability of Opportunity	Degree of User-Driven Interest	Potential for Valuable Outcome	Timeframe for NASA to see Results
Electric Utility and Grid Operation				
1. Continuity of Service During and After Extreme Weather Events	Moderate	Strong	Likely	Near-Term
2. Electric Grid Load Management – Instantaneous to Seasonal Planning, and Output Forecasting of Variable Energy Sources	High	Strong	Likely	Near-Term
Mid-Term to Long-Term Planning for Resilience Across the Energy Sector				
3. Coastal Infrastructure Protection and Planning	High	Strong	Possible	Mid-Term
4. Climate Scenarios for Planning Shifts in Demand and Vulnerabilities of Infrastructure on a Timescale of Years to Decades	High	Moderate	Possible	Mid-Term
5. Water Resource Availability for Thermal Plant Cooling, Hydropower Viability	High	Strong	Likely	Near-Term
Renewable Energy Resource Assessment and Pre-Feasibility Studies				
6. Solar Resources	High	Strong	Likely (ongoing)	Near-Term
7. Wind Resources	High**/ Moderate	Strong	Likely (ongoing)	Near-Term
Expanding Electricity Access in Developing Countries				
8. Large-scale Electric Grid Extension, Utility Scale Power Production, Electrification Status	Moderate	Moderate	Possible	Near-term
9. Microgrid System Design with Integrated Renewables	High	Strong	Likely (ongoing)	Near-Term
Efficiency				
10. Energy Efficiency of Buildings	High	Strong	Likely (ongoing)	Near-Term

*Refer to Section 2.3 for description of each criterion and the possible ratings.

**High for NASA providing numerical weather modelling inputs; moderate for NASA providing high-resolution wind resource models.

Table 5. Continuity of Service During and After Extreme Weather Events

Continuity of Service During and After Extreme Weather Events
Description: This area focuses on the continuity of service of electric utilities and operation of the electric grid during and after extreme weather events, such as storms, strong precipitation events, extreme heat waves or cold snaps, and also related events such as wildfires. This topic requires electric utility staff to understand the weather forecast and potential system vulnerabilities, be able to reach assets to conduct repairs, and have adequate supplies of water and fuel, and adequate personnel available. This topic also involves power restoration plans that may rely on solar power as a post-storm back-up.
Suitability of Opportunity: Moderate
Key Relevant NASA Earth Resources: This area is strongly linked to disasters, a current application area of the Applied Sciences Program; much of NASA's efforts geared towards near-real time data for disasters would be relevant. For example, NASA's Land, Atmosphere Near real-time Capability for EOS (LANCE) supports application users interested in monitoring a wide variety of natural and man-made phenomena. Near Real-Time (NRT) data and imagery from the AIRS, AMSR2, MISR, MLS, MODIS, OMI and VIIRS instruments are available much quicker than routine processing allows. Although much of the near-real time weather information required by utilities is typically provided by NOAA, up-to-date information from NASA on snow cover, NDVI, flooded areas, fires and smoke, lightning strikes, and soil moisture is also relevant. Improvements to weather forecasts and estimates of their confidence developed by the NASA SPoRT Center in coordination with the National Weather Service could also be helpful. Also, historic climatology of surface meteorological conditions, such as from SSE or MERRA, could be used to calibrate impact of historical events, although this need is currently met through the National Climatic Data Center. **Alignment with programs and initiatives:** • With the current U.S. focus, this does not contribute to the SDGs • Aligns with Executive Order 13653 and DOE's Partnership for Energy Sector Climate Resilience
Degree of User-Driven Interest: Strong
The need for improved forecasting of extreme weather events is documented in literature (see Deliverable Report 1, Table 3). The topic of continuity of service during extreme events was raised frequently by attendees of the workshop, particularly by electric utility representatives. These representatives framed this topic as using data to develop situational awareness that translates into risk management for grid operations. Interest from regional transmission organizations needs to be explored, since they were not represented at the workshop. There are isolated examples of electric utilities using NASA information for this purpose, such as the development by San Diego Gas and Electric of a Fire Potential Index that uses daily NDVI and soil moisture data. Con Edison also uses NASA data to monitor tropical cyclones and sea surface temperatures. The current major data source is the National Weather Service, accessed in some cases through value-added providers (e.g., Schneider Electric, a weather vendor). Further exploration is needed to understand the specific operational systems that utilities use to manage events in real-time and assess whether spatial scales, repeat cycle, and latency of NASA data are adequate.
Potential for Valuable Outcome: Likely
Improving applicability of data for ensuring continuity of service would impact the entire electric transmission and distribution industry, and electric utilities as well, although specific issues of concern vary by region. Obtaining adequate spatial resolution for an electric grid could require significant NASA investment, although applicability of existing products with current or more rapid availability should be explored first. The development of data access systems and tools customized for users' needs, and associated capacity building and outreach activities, would require a moderate investment. As weather continues to get more extreme as predicted with climate change, this area will draw increasing attention.
Timeline to Results: Near-Term
For existing products with adequate characteristics, near-term results are possible.

Table 6. Electric Grid Load Management

Electric Grid Load Management – Instantaneous to Seasonal Planning and Output Forecasting of Variable Energy Sources
Description: This area focuses on the balancing of electricity supply and load demand on the electric grid. This balancing happens on many timescales, with adjustments being made in near-real time through dispatchable power and adjustable load, and also on a seasonal basis (out several months) with planning for supply matching anticipated demand. Forecasting of supply and demand (often weather sensitive) is also a major part of this topic area. In addition to solar and wind forecasting needed linked to the increasing grid penetration of utility scale variable renewable energy sources, the output of distributed solar PV panels in particular is now being forecasted and accounted for by utilities to better assess available electricity supply.
Suitability of Opportunity: High
Key Relevant NASA Earth Resources: At the sub-seasonal and seasonal scale, climate predictions developed by NASA, such as the Global Modeling and Assimilation Office or GMAO, provide relevant information. On the hourly to 2-week scale, the weather information needed is typically provided by NOAA and value-added weather service providers. Improvements to weather forecasts and estimates of their confidence developed by the NASA SPoRT Center in coordination with the National Weather Service could be helpful. For solar and wind forecasting, there are many relevant NASA resources including data on clouds, water vapor, aerosols, and other parameters that are used in solar radiation models and numerical weather models for wind resources; required latency needs to be addressed. **Alignment with programs and initiatives:** • With the current U.S. focus, this does not contribute to the SDGs • Aligns with Executive Order 13653 and DOE's Partnership for Energy Sector Climate Resilience
Degree of User-Driven Interest: Strong
This topic was raised in the literature and at the workshop primarily in the context of improving solar resource and wind resource forecasts and near-real time output estimates. The value-added solar resource information services sector raised this topic, as did wind resource providers. There are private sector software tools related to renewable energy forecasting and integration which can and do ingest NASA data. There are examples of utilities using seasonal forecasts and sea surface temperatures to plan for natural gas transmission and electric grid operations.
Potential for Valuable Outcome: Likely
Expanding the use of NASA data for electric grid load management would impact the entire electric utility sector and also the solar and wind resource sectors. Maintaining the current products utilized as listed above would not require significant investment beyond the existing NASA investment, besides increased investment for outreach. Improving the accuracy and documentation of these products could require a moderate investment. As penetration of renewables increases driven by policy and other factors, and climate becomes more variable, this area will draw increasing attention.
Timeline to Results: Near-Term
For maintaining existing products, near-term results can likely be obtained, and outreach can be done relatively quickly on product availability. Increasing product accuracy, such as improving accuracy and characterization of seasonal and sub-seasonal forecasts, would be a mid-term project.

Table 7. Coastal Infrastructure Protection and Planning

Coastal Infrastructure Protection and Planning
Description: This area focuses on the need to plan for and protect against storm surge, sea-level rise, and extreme weather or tides that affect coastal infrastructure and energy-related facilities in particular. Considerable energy infrastructure is located along coastal areas with easy access to fuel transport and cooling water, and proximity to populations. Offshore oil and gas production platforms in the Gulf of Mexico, and coastal refineries, also represent a significant infrastructure investment. As coastal areas are increasingly impacted by sea-level rise and extreme weather, energy sector staff must understand potential impacts and be able to plan accordingly.
Suitability of Opportunity: High
Key Relevant NASA Earth Resources: This application area has the potential to use NASA Earth resources that provide information on coastal environments, primarily sea-level change monitoring and projections and extreme weather forecasts. For example, enhanced weather forecasts and other model products from the NASA SPoRT Center are relevant. NASA's Sea Level Change portal (https://sealevel.nasa.gov/) and particularly the Data Analysis Tool (Alpha Version) could be highly relevant as well. Similarly, NASA data is already being used by external researchers to assess storm surge through hurricane flood atlases using space-based radar.[1] There are likely examples, such as through the NASA DEVELOP Program, of test NASA data applications on this topic. **Alignment with programs and initiatives:** • With the current U.S. focus, this does not contribute to the SDGs • Aligns with Executive Order 13653 and DOE's Partnership for Energy Sector Climate Resilience
Degree of User-Driven Interest: Strong
This topic was raised in the literature and at the workshop. There is particular interest due to strong hurricanes along the East Coast and Gulf Coast, and due to sea-level rise in California. The California Energy Commission already considers the vulnerability of energy infrastructure to weather-related events, including infrastructure that is coastal or along low-lying inland water bodies. PG&E has already convened an internal science team to evaluate climate risks, assess climate change modeling, and identify best practices for infrastructure adaptation and planning.
Potential for Valuable Outcome: Possible
Despite high suitability and strong user interest, specific storm surge products do not appear to be available currently from NASA, and thus NASA would need to make a considerable investment if the goal was to provide storm surge predictions. NASA predictions on storms and extreme weather are relevant, but NOAA is the primary agency providing such information, at least in the United States. Also, sea-level rise projections have considerable uncertainty and thus may not provide users the desired information. Regardless, there is considerable coastal energy infrastructure, and improving the protection of this infrastructure would impact a large portion of the U.S. population.
Timeline to Results: Mid-Term
Due to the need to decrease uncertainty in sea-level rise products and develop new storm surge products, this application area would likely not see results until the mid-term. Isolated examples of research projects using NASA data, such as hurricane flood atlases noted above, may show results in the near-term if proper engagement with users is completed.

[1] http://sbir.nasa.gov/success-stories/web-based-hurricane-storm-surge-and-flood-forecasting-using-optimized-ifsar-bald

Table 8. Climate Scenarios for Planning Shifts in Demand and Vulnerabilities of Infrastructure

Climate Scenarios for Planning Shifts in Demand and Vulnerabilities of Infrastructure on a Timescale of Years to Decades
Description: This area focuses on the risk management and resilience planning conducted by the energy sector, including (1) fossil fuel extraction and processing infrastructure, (2) fuel transportation and storage infrastructure, (3) electricity generation infrastructure (thermal and renewable), and (4) electricity transmission and distribution infrastructure. This area includes accounting for long-term shifts in energy demand and supply. Many energy infrastructure decisions affect timescales out to 30 years and beyond, requiring information on these timescales.
Suitability of Opportunity: High
Key Relevant NASA Earth Resources: NASA Goddard Institute for Space Studies (GISS) is heavily involved in running global circulation models projecting changes in climate out to 2100. NASA also is involved in comparing models, and in regional scale models and downscaling. In addition, NASA has already produced estimates of shifts in climate zones and heating and cooling degree days which could be very useful for estimating changes in electricity demand. Other historical NASA datasets combined with model projections could also support this focus area. Some specific needs cited in the literature for which NASA Earth Resources are likely relevant include: • Updated design criteria for warming permafrost and more intense storms • Thermal predictive models into reservoir level forecast • Improved forecasts of snowmelt • Extreme temperature scenarios for electric grid planning • Better assessment of flooding and wildfire prone areas • Agreed-upon set of down-scaled climate change and impact scenarios available for local or regional use **Alignment with programs and initiatives:** • With the current U.S. focus, this does not contribute to the SDGs • Aligns with Executive Order 13653 and DOE's Partnership for Energy Sector Climate Resilience
Degree of User-Driven Interest: Moderate
DOE's Climate Resilience Program has successfully engaged electric utilities and other energy stakeholders in their program, and appears to have strong interest and momentum on this issue. The issue is documented in GAO reports and in a recent DOE report, highlighting two key informational needs with regard to energy management and climate resilience: (1) Lack of relevant information: Available information is insufficient to identify vulnerabilities and support informed decision making about climate resilience solutions; and (2) Poor understanding of costs and benefits: Limited information is available on the costs to design, implement, and operate new resilience technologies and practices, and on how to evaluate the associated benefits. Workshop participants also highlighted this need. Note that electric utilities tend to express interest in "climate scenarios" (e.g., low/medium/high or wet/hot and dry/hot) and associated economic impacts and interpretations, rather than complex ensembles of climate models with well-characterized uncertainty (e.g., from NASA GISS) that are perceived as less actionable.
Potential for Valuable Outcome: Possible
Building climate resilience is relevant for the entire energy management sector. Many existing NASA datasets and model outputs as noted above could be relevant for this topic. Improvements to the models will be an ongoing, long-term project for NASA, which would likely be conducted regardless of this specific application. Interpretations of the model output to be most useful for the energy sector may be outside of NASA's area of expertise, thus requiring partnerships. This focus area is of increasing concern to the energy industry, and the U.S. energy supply chain has grown increasingly complex and interdependent. Also, many organizations besides NASA conduct climate modelling so NASA may not have unique resources to offer in this regard.
Timeline to Results: Mid-Term
Capacity building and outreach could be conducted in the near-term on existing data sets and model outputs. Improving model accuracy and getting users accustomed to how to work with output is likely a mid-term project.

Table 9. Water Resource Availability

Water Resource Availability for Thermal Plant Cooling, Hydropower Electricity Viability
Description: This area focuses on the need for water resources to be used for cooling of thermo-electric plants and to generate hydropower, part of the energy-water nexus. Water quality (particularly temperature) of surface water and quantity must be adequate for thermo-electric plants such as gas-fired and coal-fired power plants. Other renewable energy technologies also can require considerable water for operations, such as Concentrating Solar Power (CSP) and geothermal energy. As weather becomes more extreme, droughts become more intense, and population expands, particularly in arid areas of the United States, the need for sustainable and readily available water resources becomes critical. Forecasting of supply and demand is an important element of this area; water resource planners and electric utilities must be able to plan for water shortages and manage risk accordingly.
Suitability of Opportunity: High
Key Relevant NASA Earth Resources: NASA offers a plethora of water-related satellite products, such as precipitation, atmospheric temperature, groundwater storage, elevation, evaporation, and soil moisture, all of which contribute to run-off forecasting. In addition, NASA surface temperature measurements can be used to assess temperature (and footprint) of major rivers and surface water bodies. NASA snow and ice products are also available and relevant, including products such as snow cover and snow water equivalent. NASA-derived data on water levels in large reservoirs is also relevant for hydropower management. **Alignment with programs and initiatives:** • Water resource availability for broader applications – such as agriculture, food security, and others – is addressed by NASA ASP, SDGs, and other programs. This focus could be leveraged for energy applications that also require water availability information. • Aligns with Executive Order 13653 and DOE's Partnership for Energy Sector Climate Resilience • Highlighted as a key question in National Strategy for Civil Earth Observations
Degree of User-Driven Interest: Strong
This topic was raised in the literature and at the workshop. The U.S. the energy sector uses substantial water sources and will account for 85% of the growth of domestic water consumption between 2005 and 2030. Utilities and private companies already model climate-related water risks, in some cases using NASA data. Utilities would benefit from additional climate and water availability risk indices based on climate change projections. Data-driven energy infrastructure planning, with vulnerability assessments incorporating water resource changes, are important areas of user-driven interest.
Potential for Valuable Outcome: Likely (ongoing)
Private researchers and organizations have already begun work on tools for water resource planning. Additional resources are needed for understanding how water resources will change in the future. Minimal NASA investment may be needed to better connect water resource modelers using NASA data with the energy sector, to improve existing tools or create new ones. Results would translate into cost savings and infrastructure protection for the energy sector. However, refinement of predictive models (e.g., reservoir level or snowmelt) is needed, along with higher resolution data (at a scale fine enough to understand resources for specific energy installations).
Timeline to Results: Near-Term
Near-term results are possible since there are many currently applicable data products offered by NASA. Increasing resolution or improving predictive models may be a mid-term project.

Table 10. Solar Resources – Assessment and Pre-Feasibility Studies

Solar Resources - Assessment and Pre-Feasibility Studies
Description: This area focuses on the assessment of the characteristics and magnitude of solar resources for electricity generation. The specific parameters of interest depend somewhat upon the solar technology being employed. The required accuracy of the information and length of record to be considered depends upon the application – whether countrywide resource assessment, pre-feasibility studies, or facility design and financing. (The solar forecasting aspect of solar resources, identified as a high priority at the workshop, is captured in Table 5, Electric Grid Load Management.)
Suitability of Opportunity: High
Key Relevant NASA Earth Resources: Relevant NASA resources include data on clouds, water vapor, aerosols, ozone, and other parameters that are used in solar radiation models. Surface temperature and wind data is also relevant as is precipitation, land cover, elevation, and other datasets. Historical archives of 20+ years is required, such as that provided by SSE and POWER, although accuracy requirements increase as projects progress towards design, at which stage accuracies only achievable by ground-based data or highly tuned solar resource models are adequate. **Alignment with programs and initiatives:** • With an international focus, contributes to the SDGs • Aligns with Executive Order 13653 and DOE's Partnership for Energy Sector Climate Resilience, to the extent that adding solar power can boost the resilience of energy systems • Highlighted as a key question in National Strategy for Civil Earth Observations for forecasting at the 3-hour to inter-annual timescales
Degree of User-Driven Interest: Strong
The value-added solar resource services sector expressed strong interest in continuing to receive the required parameters from NASA, and in obtaining products with higher accuracy, such as cloud and aerosol products, as well, to support solar radiation modelling and solar resource forecasting. The emphasis was on working with the private sector for developing products rather than recreating what the private sector has already done or competing with the private sector. For facilitating siting and design, ground-based solar resource monitoring data is required, often in combination with longer-term historical satellite-based solar resource datasets to capture resource variability.
Potential for Valuable Outcome: Likely (ongoing)
Maintaining the current NASA products utilized for solar resource modelling, and the current solar resource estimates from SSE and POWER does not require any investment beyond the existing NASA investment. Increased investment would be required for expanded capacity building and outreach. Improving the accuracy and documentation of these products could require a moderate investment. As solar power production increases driven by policy and other factors, this area will draw increasing attention.
Timeline to Results: Near-Term
For maintaining existing products, near-term results can be achieved, and outreach can be done relatively quickly to advertise product availability. Increasing product accuracy and documentation likely would be a mid-term project.

Table 11. Wind Resources - Assessment and Pre-Feasibility Studies

Wind Resources – Assessment and Pre-Feasibility Studies

Description: This area focuses on the assessment of the characteristics and magnitude of wind resources for electricity generation. In addition to wind speed and direction and other meteorological variables at various hub heights about the surface, land cover information and other meteorological information is needed for numerical weather forecasting and wind resource modelling. The required accuracy of the information and length of record to be considered depends upon the application – whether countrywide resource assessment, pre-feasibility studies, or facility design and financing. For offshore wind resource projects, this potential application area includes characterization of the offshore working environment (ocean and atmosphere).

Suitability of Opportunity: High/Moderate

Key Relevant NASA Earth Resources: NASA resources offer considerable meteorological and land resource information that are highly suitable for use by wind resource developers and value-added data providers to conduct high resolution wind resource modelling for general assessments. NASA products such as MERRA and aerosol information is currently being used for wind resource assessments. NASA does not conduct its own high resolution wind resource modelling; therefore, in terms of products that directly provide wind resource information for assessments, the match with NASA resources is moderate at best. For facility siting and design, wind resource developers require hub-height wind resource and meteorological information from ground-based measurements not available from NASA. For offshore wind information, NASA scatterometry data can be useful for providing coarse-resolution global wind information, although accuracy degrades closer to coasts, where wind facilities are most likely to be sited. Other characterization of waves, currents, water temperatures, and weather are also relevant. ESA is using synthetic aperture radars for high-resolution regional winds.

Alignment with programs and initiatives:

- With an international focus, contributes to the SDGs
- Aligns with Executive Order 13653 and DOE program on Climate Resilience to the extent adding wind power boosts resilience of systems
- Highlighted as a key question in National Strategy for Civil Earth Observations for onshore and offshore

Degree of User-Driven Interest: Strong

This topic was raised in the literature and at the workshop. A wind resource developer at the workshop expressed strong interest in continuing to improve numerical weather modelling capabilities and wind resource modelling in collaboration with NASA. The emphasis was on working with the private sector for developing products rather than recreating what the private sector has already done (such as conducting high-resolution wind resource modelling) or competing with the private sector. Workshop participants also discussed wind resources in terms of forecasting output for grid stability (covered in a separate topic above), and also the need to engage on offshore wind projects.

Potential for Valuable Outcome: Likely (ongoing)

Success is likely, and in fact ongoing, for the use of NASA data as inputs to wind resource modelling. Maintaining the current NASA products utilized for modelling and the current wind data from SSE and POWER does not require any investment beyond the existing NASA investment. However, NOAA is also heavily invested in wind resources, so would somewhat “compete” with NASA in the U.S. Increased investment would be required for expanded capacity building outreach. A valuable outcome is possible for high-resolution wind resource modelling, although it would require substantial investment, and would need to be structured to complement the value-added service sector. As wind power production increases driven by policy and other factors, this area will draw increasing attention.

Timeline to Results: Near-Term

For maintaining existing products, near-term results are achievable, and outreach can be done quickly to advertise product availability. Developing high resolution wind resource modelling products would be a mid-term project.

Table 12. Large-scale Electric Grid Extension, Power Production, Electrification

Large-scale Electric Grid Extension, Utility Scale Power Production, Electrification Status
Description: This area focuses on large-scale electric grid extension and assessment of electrification needs, particularly in developing countries where geographic information on land cover, elevation, roads, natural resources, and populations is limited. Such data is required to assess costs for grid extension and to actually plan grid extension routes. This focus area also includes utility-scale power production, because it is not just the electric grid limiting access to electricity in places such as Sub-Saharan Africa and developing Asia, but the lack of power plants as well. Information on renewable resources that could be connected to the grid can also be relevant for transmission line routing and design, although renewable resource integration is covered in the subsequent table. The assessment of electrification status involves having good data on which communities have access to electricity, and assessment of populations (especially rural communities and informal urban communities/slums) which do not yet have electrification.
Suitability of Opportunity: Moderate
Key Relevant NASA Earth Resources: Relevant NASA Earth observations include satellite-derived geophysical, socioeconomic, and infrastructure information such as land cover, elevation, roads, biome types, and population density, much of which is accessible through NASA's SEDAC and the Land Processes DAAC. Data from Suomi NPP VIIRS is also relevant for assessing nighttime lights as an indicator of electrification, although not necessarily tied to household-level electrification. Climatological data such as from SSE and MERRA can help planners assess heating and cooling electricity loads to be met. High resolution imagery from Landsat may also be used to identify informal settlements and rural communities, and help plan transmission line routes and power plant sites, although even higher resolution imagery from other non-NASA sources may be more appropriate. **Alignment with programs and initiatives:** • Aligns with the SDG number 7 in particular on ensuring access to affordable, reliable, sustainable and modern energy for all
Degree of User-Driven Interest: Moderate
Although global access to clean energy (and electricity in particular) is largely a policy and financing issue, the literature does contain references to datasets required to help assess grid extension costs and plan projects. Stakeholders from World Bank and also academia that perform energy system extension modelling expressed interested in leveraging NASA data to support this purpose.
Potential for Valuable Outcome: Possible
If NASA data can become a key enabler for expanding modern energy access, the potential for impact is very large given the large fraction of people in Sub-Saharan Africa and developing Asia without such modern energy access. However, financing and policy issues are current barriers. The investment required by NASA to make existing data more easily available for such applications would be minimal if it is determined that spatial scales of NASA data are adequate for these purposes.
Timeline to Results: Near-Term
If the application of current NASA data products is found to be useful, this could be a near-term success through partnering with existing stakeholders that model and finance grid extension.

Table 13. Microgrid System Design and Integrated Renewables

Microgrid System Design and Integrated Renewables
Description: This area focuses on using microgrid systems, often powered by or incorporating renewable energy resources, to expand electricity access particularly in developing countries. In remote areas and on small islands, large-scale electric grid extension is not feasible, and so distributed renewable energy systems and microgrids are utilized as an alternative. This topic requires information on available renewable energy resources, land resource and housing information, and other relevant meteorological parameters for design.
Suitability of Opportunity: High
Key Relevant NASA Earth Resources: NASA currently provides solar and wind resource data for the resource assessment aspect of this topic, particularly the Surface Meteorological and Solar Energy (SSE) dataset which is used by HOMER and RETScreen. Other NASA land resource data (elevation, land cover, biome) and socioeconomic information or high-resolution imagery to assess housing infrastructure is also relevant. **Alignment with programs and initiatives:** • Aligns with the SDG number 7 in particular on ensuring access to affordable, reliable, sustainable and modern energy for all
Degree of User-Driven Interest: Strong
The literature review and workshop uncovered strong user interest in microgrid system design integrated with renewables. IRENA has also identified a strong need for renewable energy resource information for this purpose, which they support through their online global atlas. Organizations such as MIT and World Bank which develop models for and help finance micro-grid systems expressed particularly strong interest in collaborating with NASA on this topic.
Potential for Valuable Outcome: Likely (ongoing)
Since tools such as HOMER and RETScreen are currently available and utilizing NASA data, the potential for a valuable outcome is likely and in fact ongoing. Minimal investment is needed to maintain these applications. Additional investment is required for capacity building and outreach for new additional applications of existing datasets. The benefits of applications such as HOMER and RETScreen have been proven by their worldwide utilization. NASA could also explore providing datasets related to bio-energy (e.g., NDVI), waves or off-shore resources, and true color imagery to identify buildings and assess suitability for rooftop solar. This exploration may require more significant investment.
Timeline to Results: Near-Term
Near-term results are being achieved currently. Exploration of the application of other datasets could be a near-term or mid-term project depending on the applicability of the current NASA datasets for such applications.

Table 14. Energy Efficiency of Buildings

Energy Efficiency of Buildings
Description: This area focuses on using meteorological and solar resource information for building standards, design, efficient operation, and performance monitoring. This area has typically used long-term (30+ years) historical datasets, and is increasingly including climate projections or more recent weather data due to increasing climate variability and change.
Suitability of Opportunity: High
Key Relevant NASA Earth Resources: Long-term NASA historical datasets and assimilations of surface meteorological parameters such as wind, temperature, precipitation, and other factors are highly relevant, such as that provided by SSE and MERRA. Near-real time data may be needed for operational decisions, but historical data which is available days or months after collection should be adequate for most other applications. **Alignment with programs and initiatives:** • With an international focus, contributes to the SDGs • Aligns with Executive Order 13653 and DOE's Partnership for Energy Sector Climate Resilience
Degree of User-Driven Interest: Strong
The National Institute of Building Science, ASHRAE, and value-added providers have expressed interest in working with NASA to continue using NASA products and explore future collaboration.
Potential for Valuable Outcome: Likely (ongoing)
Minimal investment would likely be needed from NASA to continue this ongoing application (e.g., of SSE data by ASHRAE) and potentially expand it. This focus area covers a very large buildings sector and is gaining increased attention due to climate change mitigation and adaptation concerns.
Timeline to Results: Near-Term
For maintaining existing products, including historical datasets and projections of shifts in climate zones (within the U.S.), near-term results are achievable, and outreach can be done relatively quickly to advertise product availability. Increasing projections of shifts in climate zones could also be a (potentially) near-term endeavor.

In addition to the potential application areas described in Tables 5-14, there are several other potential application areas that the team feels should be considered for inclusion in a potential new Energy Management Focus Area. These potential application areas were mentioned in passing at the workshop, but were not fully explored because specific users or experts on these topics were not represented at the workshop due to limitations in workshop space and funding. These are as follows:

- **Energy System Policy, Market, and Integrated Assessment Models** - This area focuses on modelling energy systems from a technical, policy, and/or economic perspective to test scenarios and manage risk for policy support, resource management, and other purposes. Examples of such models are developed and operated by governmental and industry associations such as ASHRAE, DOE, NREL, Energy Information Agency (EIA), EPRI. NASA's historical climatological datasets and potentially other datasets are likely relevant, and have been used to some degree in the past, such as collaborations between NASA and ASHRAE and NREL. There is potentially strong user interest, but further exploration is needed through discussion with representatives from each organization.

- **Other Renewable Energy Resources** – In addition to solar power, wind power, and hydropower which were the primary focus of workshop discussion, other types of renewable energy were mentioned in the afternoon breakout groups. Specifically, geothermal energy and ocean energy (wave, current, and tidal) were mentioned as growing areas of interest within the energy sector. Ocean energy is identified as a topic for explanation in the National Civil Earth Observation Strategy. NASA satellite data has been applied for studying geothermal energy, for example using thermal infrared data. There is potentially strong user interest, but further exploration is needed through discussion with end users and researchers focused on these topics.

4. Program Design

The addition of an Energy Management application area to the Applied Sciences Program would require consideration of several program design characteristics, such as the methods for identifying and engaging with stakeholders; and the shaping of the program scope, activities, and timeline. This chapter identifies common themes echoed by participants and speakers that are relevant to these design characteristics. Other relevant design characteristics include program metrics and timelines, although the workshop participants did not provide any input on these topics.

The primary input on program design characteristics came from a sub-set of workshop participants and speakers – those that are already familiar with the NASA Applied Sciences Program or parallel programs in Europe and beyond. The most parallel benchmark program discussed at the workshop was the European Union (EU) Copernicus Climate Change Services (C3S) Program. Other U.S. Federal agency programs (NOAA and DOE) related to the energy sector also informed the discussion. Input on the role of the private sector was received from several value-added providers and developers. Discussion on the IRENA Global Solar and Wind Atlas and operating model also provided relevant information on program design.

The EU Copernicus Program is described on the program website as “Europe’s Eyes on Earth – harnessing world leading science and technology to equip society to understand and adapt to our changing environment” (Trocolli presentation). The funding is 4.3 billion Euros for 2014-2020, and it has six information services: land, marine, atmosphere, climate, security, and emergency. Data from these programs is free and open to all.CS3 program is the most parallel to a potential Energy Management application area for the NASA Applied Sciences Program, given Copernicus’s focus on applying space-based atmospheric, land, and ocean observations to benefit the energy sector.

4.1. Stakeholder Engagement

For the NASA Applied Sciences Program leadership to determine methods for identifying and engaging with stakeholders for a new Energy Management application area, a critical first step is determining what types of stakeholders should be engaged and for what purposes. The team prepared a conceptual map of the various energy sector users and organizations with respect to flow of data and information, in order to identify the types of stakeholders that could be engaged (for a workshop or a new program). Figure 2 depicts the flow of data for energy sector decisions, and the types of stakeholders involved at each stage. As seen in the graphic, data users are involved throughout the process as data becomes information usable for decision-support. For example, though datasets may be produced by the private sector, different data users such as the World Bank take up that data and make it into information by visualizing or analyzing it and presenting it in usable ways. In that way, it becomes usable for decision-support by a different set of users for various actions.

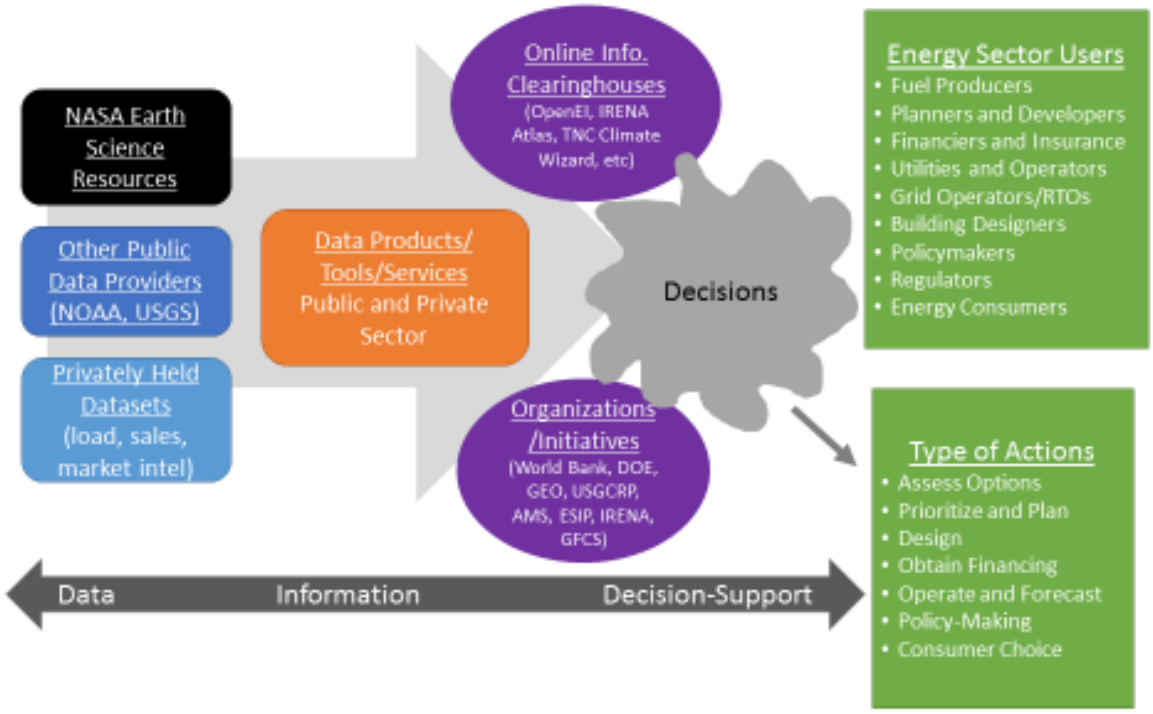


Figure 2. Data Flow Model for Energy Management

In line with the Applied Sciences Program model, the previous projects funded under the Energy Management Application Area included cross-cutting teams of data providers, data product or service providers, and energy sector users such as utilities. Researchers were also engaged in project teams. Anecdotal evidence suggests that previous projects could have had a larger impact if they had included influential industry leaders or industry associations, or high-level executives, instead of focusing on partnerships with mid-level staff at small service providers.

Workshop participants for this project included representatives from all different types of organizations identified in Figure 2. The “Energy Sector Users” were the most difficult to engage, although they were the team’s primary target. The team believes this is because energy sector users have day-to-day jobs with little room to engage in what is likely seen as “extra-curricular” activities with little benefit, at least in the short term.

For a future potential the Energy Management Application Area, engagement with organizations/initiatives and online information clearinghouses (both shown in purple in Figure 2) would be important in order to leverage existing established programs and relationships with energy sector users. For example, organizations and agencies such as DOE, World Bank, and IRENA already have programs with energy sector end users that could benefit from additional engagement of NASA on ways that Earth science resources could help meet program objectives. (Each of these organizations expressed interest in further engaging with NASA). Similarly, the primary ultimate source of weather information for many energy sector users is NOAA, an organization which also expressed interest in further collaboration with NASA.

A future Energy Management Application Area would also need to engage with the private sector focused on providing tailored data products, tools, and services to energy sector users. Our experience is that many utilities rely on such private sector companies for tailored,

understandable information to support decision-making. Such private sector companies (e.g., Clean Power Research at the workshop) have developed considerable expertise in using and tailoring NASA Earth observations, and have developed relationships with many energy sector end users. NASA should avoid re-creating any information that these companies have already developed, and instead engage with them to see how NASA can provide improved data inputs or fill niches not addressed by companies. To avoid preferential treatment of a small group of companies, the Applied Sciences Program management could explore innovative approaches such as:

- Working with industry associations
- Providing open competition for partnership with NASA, and ensuring that project results get disseminated publicly for all to benefit.

In addition, workshop participant noted that many scientific societies and non-governmental organizations such as the American Meteorological Society (AMS), Earth Science Information Partnership (ESIP), the Group on Earth Observations (GEO), and the World Energy and Meteorology Council (WEMC) include a focused group on energy applications of Earth Science resources. The Applied Sciences Program should leverage the expertise and programs of these organizations to develop and vet ideas and implement and evaluate pilot applications.

Finally, the team notes that the energy sector is very diverse in terms of energy types, operational responsibilities, regions, challenges, and experience working with NASA data. There is also a great diversity within utilities in terms of job responsibilities, with some focused on immediate operations, and some (at larger utilities, such as Duke) focused on innovative data applications and long-term planning. NASA engagement with the latter group of people may be more fruitful since exploring innovation (including partnership with NASA) would likely be seen as part of their job responsibilities. Similarly, energy sector users and value-added providers that are highly familiar with NASA resources may be interested in specific product improvements (latency, accuracy, documentation), whereas other users may need introductory capacity building highlighting possibilities of NASA data applications including case studies documenting clear benefits to companies. For example, workshop participants new to NASA data at the workshop asked questions such as: Does NASA do seasonal forecasts? How deep can you measure water temperature? What can NASA contribute to wind resource assessment? On the other hand, experienced NASA data users at the workshop made targeted suggestions on the NASA data products to be improved to support, for example, solar resource forecasting.

4.2. Program Scope, Activities, and Timeline

The Applied Sciences Program management would also need to address program scope, activities, and timeline for a new Energy Management Application Area, as follows:

- **Scope** determination would include identifying how broad or narrow to make the program in terms of topic areas. Drawing from the analysis in Chapter 3, there was no single clear topic area of guaranteed maximum benefit, but rather a spectrum of topic areas with diverse potential benefits. Program budget and opportunities to collaborate as discussed in the previous section would help determine the program scope. NASA should consider dividing an energy management focus area into activities to maintain

and improve existing applications, and activities to explore novel applications or expansions.

- The **activities** for an Energy Management Application Area likely would include pilot projects awarded through open competition, but should also include a strong capacity building and outreach component. Given that this would be a new (though previously addressed) area for NASA with many unknowns, it may be appropriate to award 12- to 18-month pilot projects followed by extensions for those projects showing significant promise or success. The degree of specificity in the pilot project request for proposal could be relatively high, drawing on the results of this workshop and other expert input, to keep the projects focused on the greatest areas of need. In addition, workshop participants expressed strongly that existing applications of NASA data in the energy sector (e.g., the work of Paul Stackhouse at LaRC) are valuable and should be continued. Workshop attendees and speakers provided several examples of NASA data already being applied in the energy sector. NASA should consider more fully documenting existing applications of its Earth science resources in the energy sector and providing some measure of value. The capacity building aspect could range from developing fact sheets and websites providing summaries for the energy sector of available resources, to developing targeted ARSET courses for the energy sector, to reaching out at conference and in gray literature to energy sector end users.

- While the **timeline** for an Energy Management Application Area would be constrained by available funding windows, the team recommends leveraging the momentum of the workshop, and subsequent follow-up calls conducted through the ESIP Energy and Climate Work Group, to continue engaging energy sector end users and value-added providers. Several of the workshop attendees sent follow-up emails to our team expressing interest in continuing engagement, and also called into subsequent ESIP Energy and Climate Work Group calls. These participants include Con Edison, California Energy Commission, EPRI, World Bank, DOE, and others. One participant is even asking for assistance in identifying relevant solar resource data. NASA should consider methods to meet some needs expressed in the workshop over the next several months and year, in addition to potential longer term program rollout. These methods could include developing training resources, conducting additional regionally or topically focused workshops to assess needs, and sponsoring end users and value-added providers to attend ESIP meetings or other relevant forums in which NASA is engaged, such as AMS, WEMC, GFCS, and GEO.

More broadly, the following needs were highlighted by workshop participants, which could be addressed as part of program design:

- A need to package the data better for improved accessibility
- A need for better explanation of (and possibly new) data formats
- Better explanation of Level 1, 2, and 3 data
- Better data documentation
- A need for input from financers and utilities on acceptable percentage of uncertainty in renewable resource or other related data
- A need for technical advancement:
    - Various applications were identified and could be selected for immediate implementation by NASA, such as temporal and spatial resolution improvements.
    - Uncertainty in data must be addressed so that data is policy-relevant and appropriate for decision making.

- A need for improved accessibility and outreach:
  - Improved communication should be a top priority for NASA.
  - Creative models of engagement should be considered to widen the pool of data users.
- A need for more partnerships:
  - There is a need to recognize regional energy priorities; for example, fire and drought are issues in the West coast while flooding and heat waves are issues on the East coast.
  - Collaboration with the private sector is important.

Workshop participants discussed several ways that the NASA Applied Science program could help address these barriers:

- Provide support to incorporate more Earth observation data into tools (e.g., one being developed at MIT) that support energy system analysis and extension
- Provide a tailored service (in partner with universities, communicators such as Google) that provides Earth observation data for the energy sector, with access to help on specific data products, and a way to provide feedback to NASA.
  - Provide ways to get feedback to NASA
- Have an app to advertise new products, similar to what Power Africa does, specifically for the energy sector and NASA Earth Science.

5. Conclusions and Recommendations

The team's conclusion from this workshop is that there is strong interest in an Applied Sciences Program Energy Management Application Area, and a strong potential for valuable results. Appendix B contains the slides that were presented to NASA Applied Sciences Program Management on August 11, 2016, summarizing the team's findings from the workshop.

Over the past 5-10 years, there has been an increased interest by energy sector end users in renewable energy, better planning for climate variability and change, and more efficient use of resources. This, in turn, has driven the interest of utilities and project developers in better Earth observations and other data and methodologies for planning, short-term operations, and long-term risk management. Accordingly, the value-added private sector providing services to energy sector end users has grown, and programs such as WEMC have developed, providing a plethora of new partners for an Applied Sciences Program Energy Management Application Area to engage. NASA datasets are seen as increasingly useful for energy sector applications, but dataset maintenance, capacity building, and improvement is needed. Concurrently, the initiative to increase access to modern energy services worldwide has been renewed, and financing particularly related to renewable energy, in light of the Paris Agreement, is emerging.

While the most obvious Earth observations of relevance to the energy sector are weather affecting supply, demand, and infrastructure operations, other NASA Earth observation information is also relevant to the energy sector including land use, vegetation, water resource, snow, socioeconomic, wildfire, and air quality information. Historical climate records and seasonal to long-term projections of climate such as those produced by NASA are also highly relevant to the energy sector.

In terms of specific topics for an Applied Sciences Program Energy Management Application Area, there are six topics which our team ranked as the highest, meaning they are most likely to show broad benefits over the next 1-2 years after initiation:

- Electric Grid Load Management, Instantaneous to Seasonal with Output Forecasting of Renewable Energy sources
- Water Resource Availability for Thermal Cooling and Hydropower Planning
- Solar Resource Assessment
- Wind Resource Assessment
- Micro-grid System Design with Integrated Renewables
- Energy Efficiency of Buildings

Details of the specific applications, relevant stakeholders, and Earth observations are provided in Chapter 3. Each of these topics is already being addressed to some degree by NASA, whether through the funding provided to Dr. Paul Stackhouse at LaRC, or through the activities of other NASA Centers (e.g., JPL's NASA Snow Mapper in California). Maintaining these investments is important; additional investment in these topic areas is expected to yield increased benefits.

The team also ranked the two following topic areas as promising, but slightly less so than those topics listed above:

- Continuity of Service for Extreme Events
- Large-scale Electric Grid Extension, Utility Power Production, Electrification Status

Finally, the following two areas are likely to show results in the mid-term (3-4 years), but require improvements to NASA data and model outputs and/or maturation of energy sector decision support systems first:

- Coastal Infrastructure Protection and Planning
- Climate Scenarios for Planning Shifts in Demand and Vulnerabilities of Infrastructure on a Timescale of Years to Decades

The activities conducted through the NASA Applied Sciences Program on Disasters and Water Resources have considerable overlap with the highest priority topic areas for energy. Along with activities at the NASA centers related to the energy sector, considerable leveraging and extension of benefits may be possible with these activities and a new Energy Management Application Area. Similarly, the capacity building needs for certain subsets of the energy sector could initially be met by leveraging existing programs such as ARSET.

The team received only limited input on design of an Energy Management Application Area at the workshop. Workshop participants emphasized the importance of engagement with private sector value-added providers and collaboration with DOE, NOAA, and other organizations.

The team offers the following recommendations to the NASA Applied Sciences Program regarding energy management over the next 1-2 years, while a decision about a full new application area is being made:

1. Document and tell the story of ways that NASA data is already benefitting the energy sector, to share both internally to justify funding, and externally to increase knowledge and use.
2. Conduct capacity building and outreach for existing products that could be applied within the “Low-Hanging Fruit” Category (the six topics areas ranked the highest).
3. Maintain momentum of the workshop through ESIP, by conduct additional workshops and/or ESIP meetings that bring together energy sector users and data providers to improve collaboration.
4. Explore partnerships with World Bank ESMAP, DOE ‘Partnership for Climate Resilience’, EPRI, and also partner with other NASA centers and Water Resource Disaster areas within the current Applied Sciences Program.
5. Leverage NASA programs such as ARSET, SERVIR, and Worldview; customize each of these to include a special test case or application with a sub-sector of energy users.

Appendix A: NASA Satellite Missions/Instruments Measuring Parameters of Interest

Table A-1 (reproduced from Deliverable 1, Table 6) provides examples of NASA Earth observation missions that provide data products which could meet energy management sector user needs, either directly or through input to additional models such as cloud information for solar resource forecasting.

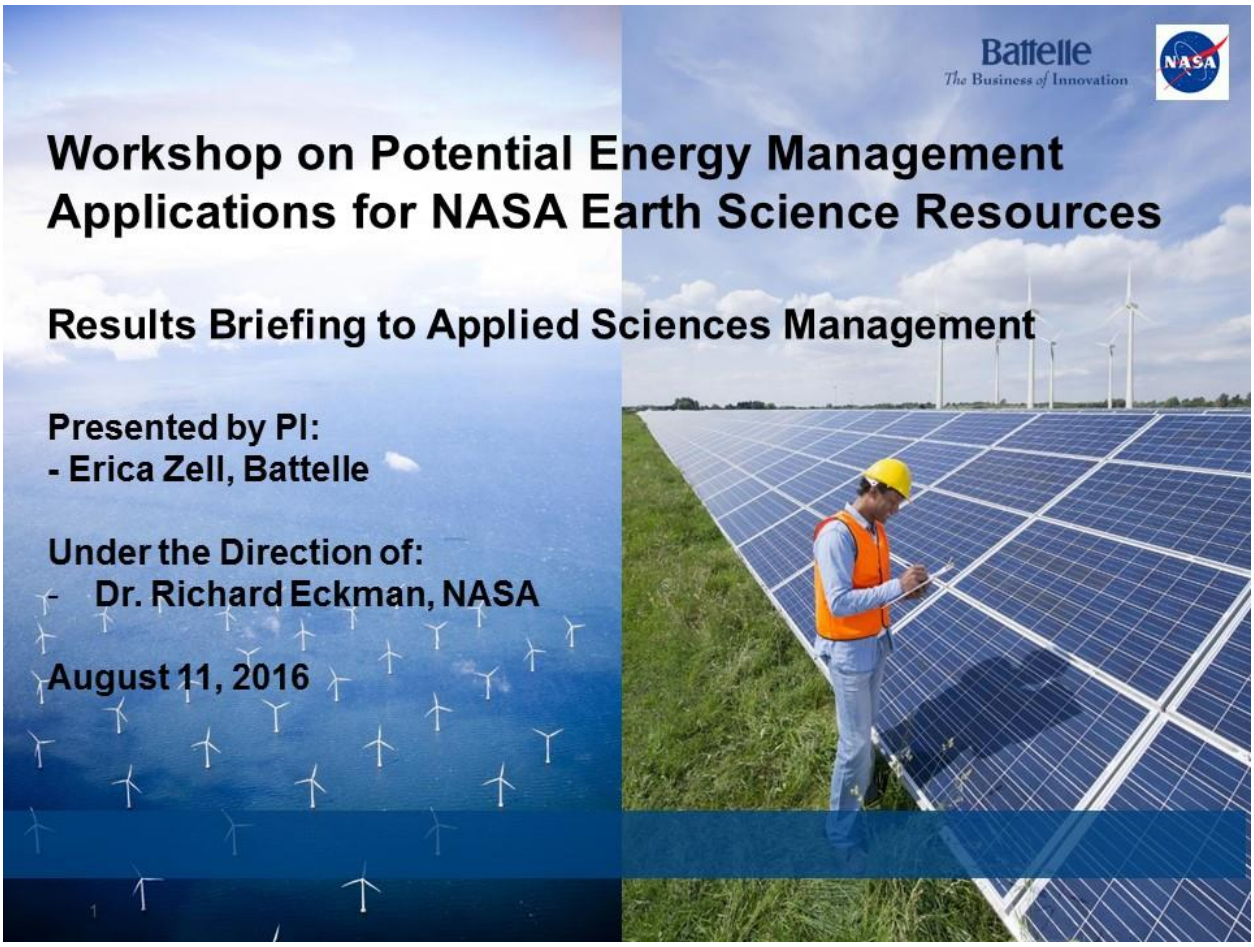
Table A-1. Examples of Current NASA Missions Providing Data Related to Energy Sector Needs.

Parameter Type	Satellite Missions/Instruments (Parameter)
Solar Resources	Solar Radiation and Climate Experiment (SORCE) STPSat-3 Total Solar Irradiance Calibration Transfer Experiment (TCTE) (non-NASA) (extraterrestrial solar irradiance)
	Aqua/Terra/NPP Cloud and Earth Radiant Energy System (CERES) (surface solar fluxes including direct and diffuse)
	DISCOVR NISTAR (surface solar flux) (products not available yet)
Meteorological Parameters	CALIPSO, CloudSat, GPM/GMI and DPR, Terra/Aqua/MODIS, Terra MISR, Aqua AIRS, Aura OMI, Suomi NPP VIIRS, DISCOVR/NISTAR and EPIC (cloud water and other cloud information)
	GPM/GMI and DPR, CloudSat (precipitation)
	Aqua AIRS/AMSU/HSB, Aura HIRDLS (atmospheric temperature)
Atmospheric Composition	Terra/Aqua/MODIS, Aqua AIRS, Aura MLS, Suomi NPP CRIS, GPM GMI, Joasn-2 (water vapor)
	CALIPSO, Terra/Aqua/MODIS, Terra MISR, Suomi NPP VIIRS, Aura OMI, DSCOVR/EPIC (aerosols)
	Aura OMI, Aura MLS, Aura TES, Aura HIRDLS, Aqua AIRS, OCO-2, DSCOVR/EPIC (ozone, gases)
Land Parameters	Shuttle Radar Topography Mission (SRTM, flown in 2000) (elevation/topography)
	Terra/Aqua/MODIS, Terra MISR, Terra ASTER, Suomi NPP VIIRS, Aura OMI DISCOVR/EPIC, Landsat (surface reflectance, albedo)
	Terra ASTER, Terra/Aqua/MODIS, Aqua AIRS, Suomi NPP VIIRS (land surface temperature)
	Terra/Aqua/MODIS, Suomi NPP VIIRS, Landsate (thermal anomalies, active fires, burned area)
	Terra/Aqua/MODIS, Landsat, Terra MISR, Suomi NPP VIIRS (land cover, surface type)
	Terra/Aqua/MODIS, Suomi NPP VIIRS, Landsat (snow cover)
	Suomi NPP VIIRS, Terra/Aqua/MODIS (nighttime lights)
Offshore Environment	ISS-RapidScat (ocean surface winds)
	Jason-2, 3 (ocean altimetry)

Parameter Type	Satellite Missions/Instruments (Parameter)
Vegetation and Soil	Terra/Aqua/MODIS, Sumoi NPP VIIRS (enhanced vegetation index [EVI], normalized difference vegetation index [NDVI])
	SMAP, Landsat TM (soil moisture)
Water	Jason-2 (lake/reservoir/ocean height)
	Terra/Aqua/MODIS (near-surface water and sea-surface temperature)
	GRACE (data that can be used to study groundwater storage)

(GPM = Global Precipitation Measurement; Suomi NPP = National Polar-Orbiting Partnership; SMAP= Soil Moisture Active Passive; GRACE = Gravity Recovery and Climate Experiment; NISTAR= National Institute of Standards and Technology Advanced Radiometer; EPIC = The Earth Polychromatic Imaging Camera)

Appendix B: Briefing Slides Summarizing Findings for NASA Applied Sciences Program Management (not including back-up slides)



Briefing Agenda

- Purpose
- Pre-Workshop Activities
- Workshop Details
- Analysis Methods
- Results Summary
- Program Design Considerations
- Recommendations and Conclusions

Purpose

- Conduct a workshop with energy management sector stakeholders for feedback on:
  - Whether and how the NASA Applied Sciences Program (ASP) should develop an Energy Applications Area
  - Focus topics and program design options
- Synthesize pre-workshop information and workshop input, and analyze to develop recommendations for NASA ASP on potential new Energy Application Area

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Pre-Workshop Activities

As summarized in Deliverables 1 and 2:

- Literature review
- Identification of focus topics
  - Considered documented needs, match with NASA resources, criticality/growth of topic
- Speaker consultations
- Identification of participants and questionnaire distribution
- Guidance for speaker presentations; break-out group activity design to achieve desired workshop outputs

Example Documents

Literature Review Highlights

- Identified and reviewed approximately 40 documents on EO needs in the energy sector and current applications of satellite data
- Author organizations included World Bank, Electric Power Research Institute, Industry Associations, DOE, GEO, USGEO, Private Firms, European Space Agency, USAID, Asian Development Bank, Academia

Key Results:

- Many of the needs are step improvements or expansions on current applications
- Climate vulnerability and resilience has a newer set of needs and less developed decision support systems to ingest EO data
- Modern energy access:
  - Needs (and datasets) highly developed in terms of renewable resource assessment, micro-grids, and hydropower
  - Needs less identified for large-scale grid design, expansion

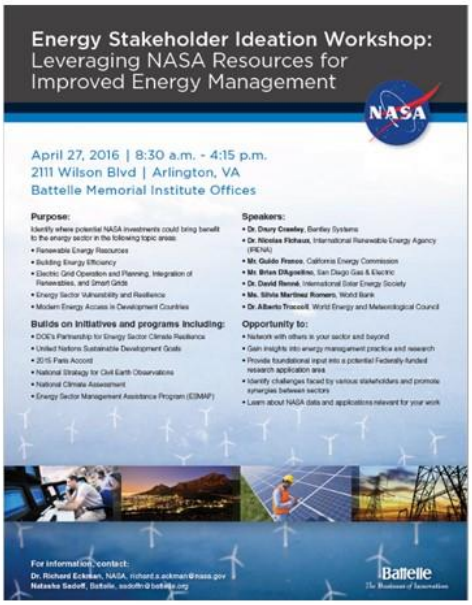
Workshop Speakers Consultations

- Selected from team contacts and literature review to provide users' perspectives on focus topics

Organization	Speaker Name(s)
World Bank	Silvia Martinez Romero, Nathan Blair
Bentley Systems, Inc.	Drury Crawley
U.S. Department of Energy	Craig Zamuda*
International Solar Energy Society	David Renne
World Energy and Meteorological Council	Alberto Troccoli
San Diego Gas and Electric	Brian D'Agostino
California Energy Commission	Guido Franco

*ended up as break-out group facilitator but not speaker

Workshop Materials



NASA Energy Management Stakeholder Ideation Workshop

April 27, 2016 | 8:30 a.m. - 4:15 p.m.
Battelle | 2111 Wilson Blvd | Suite 1000, Arlington, VA

8:30 – Bagels, Coffee. and Registration

9:00 – Welcome (Rich Eckman, NASA)
- Workshop Purpose and Outcomes
- Workshop Participant Introductions

9:20 – Diverse Challenges for the Energy Sector (Erica Zell, Battelle)
- Highlighting current challenges from user perspectives

9:45 – Earth Observations for Energy Management (Paul Stackhouse, NASA)
- Brief intro on NASA Earth Observations and Applied Sciences Program and current and past NASA energy application projects
- Available data, models, assimilations, projections

10:10 – Engagement Models for the Earth Science Community (Alberto Troccoli, World Energy and Meteorology Council)
- Examples of models of engagement in the energy sector

10:30 – Break

10:45 – Topic Framing by Stakeholders and Panel Discussion
- Climate Resilient Planning (Guido Franco, California Energy Commission)
- Electric Grid Operation/Smart Grid (Brian D'Agostino, San Diego Gas and Electric)
- Energy Efficiency (Drury Crawley, Bentley Systems)
- Renewable Energy and Grid Integration (David Renné, International Solar Energy Society)
- Universal Energy Access (Silvia Martinez Romero, World Bank)

12:15 – Lunch (Catered)
- Networking, NASA mini-booth
- Speaker, Nicolas Fichaux, International Renewable Energy Agency (IRENA)

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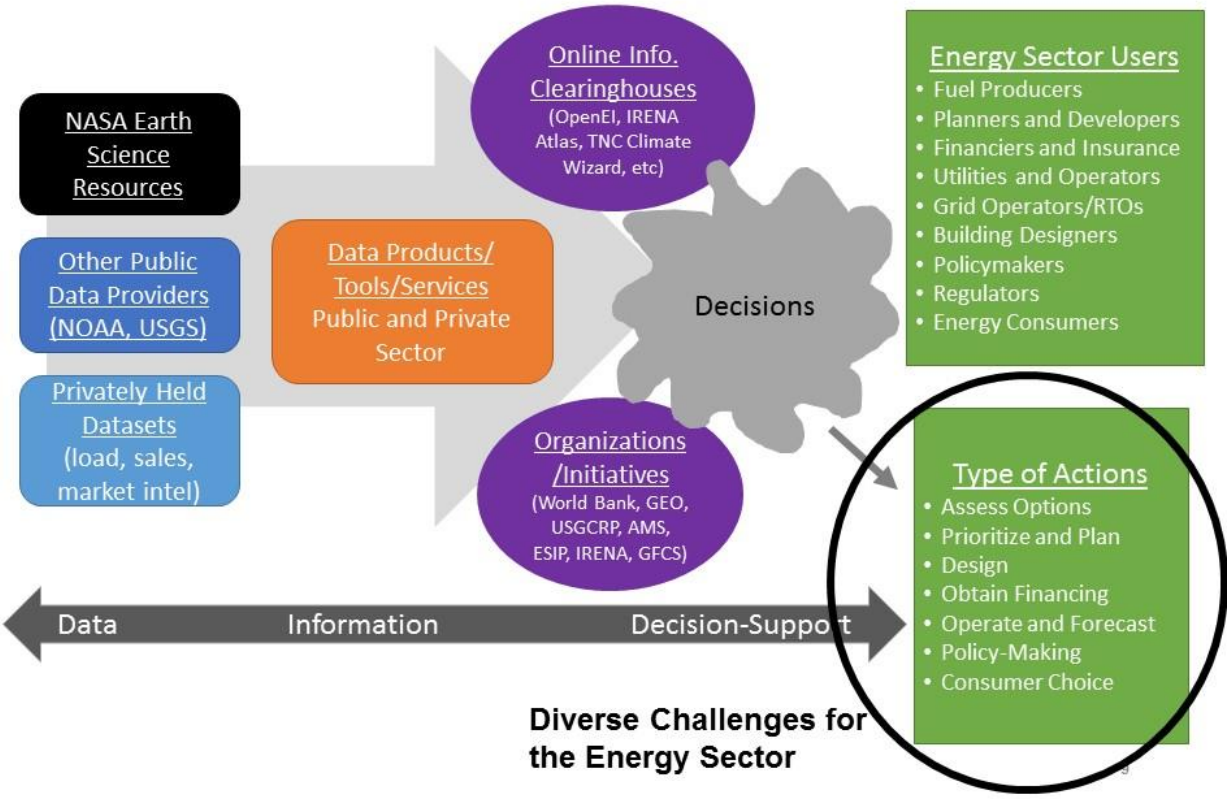
Energy Sector Decision Support Data Flow



Workshop Attendees (20)

Name	Organization
Alberto Troccoli	World Energy and Meteorological Council
Alemu Tadesse	Clean Power Research
Brian D'Agostino	San Diego Gas & Electric Company
Carolina Barreto	Tetra Tech
Claudio Vergara	Tata Center, MIT
Craig Zamuda	Department of Energy
Dave Renné*	International Solar Energy Society
David Hunter	Electric Power Research Institute
Doug Vine	Center for Climate and Energy Solutions
Drury Crawley	Bentley Systems
Edward May	Energy Intelligence Partners
Gregory Koumoullos	Con Edison
Guido Franco	California Energy Commission
Jill Engel-Cox	National Renewable Energy Laboratory
John Zack	AWS Truepower
Melinda Marquis	NOAA
Nathan Blair	World Bank/NREL
Nicolas Fichaux	International Renewable Energy Agency
Silvia Martinez Romero	World Bank
Stuart Gaffin	NASA Goddard Institute for Space Studies

Participant Questionnaires

- Sent to all invitees who confirmed interest/attendance – cross-section of energy sector with attention given to regional representation, organization type, focus topic
- Requested information on job responsibilities, use of Earth observations, current data sources, etc

Questionnaire Respondents

Organization	Name(s)
MIT	Claudio Vergara
National Institute of Building Sciences	Ryan Colker
Clean Power Research	Alemu Tadesse
NREL	Jill Engel-Cox
RETScreen International	Gregory Leng
Energy Intelligence Partners	Edward May
Con Edison	Greg Koumoullos
World Bank	Oliver Knight
World Bank/NREL	Nathan Blair
NOAA	Melinda Marquis
HOMER	Peter Lilienthal

Participant Questionnaire Response Summary

- Most data providers or end users were already somewhat engaged with the NASA Applied Sciences Program.
- Resolution improvements were needed so that information could be site-specific and actionable in risk-based decision making.
- Near-real time data availability is needed
- Uncertainty and confidence of scenarios, forecasts, and projections are important for decision making
- Collecting data that could be used to forecast climate impacts on industry and/or energy demand is increasingly important.
- Some respondents use vendors to access and manage NASA data in existing decision support systems, though working with NASA directly was also highlighted as attractive since it could cut down on costs (recognizing that NASA cannot compete with value-added business).
- No barriers were listed as to why participants did not use NASA data.

Workshop Charge

- Identify where potential NASA investments could bring benefit to the energy sector focused on:
  - Renewable Energy Resources
  - Building Energy Efficiency
  - Electric Grid Operation and Planning, Integration of Renewables, and Smart Grids
  - Energy Sector Vulnerability and Resilience
  - Modern Energy Access in Developing Countries
- Desired outputs:
  - Potential "focus areas" (both energy type and decision-support need, such as design, operations, long-term planning, forecasting)
    - Low-hanging fruit
    - Mid-term opportunities
  - Alternative business engagement models for NASA Applied Sciences Program potential Energy Management focus

Example of Framing Each Sub-Topic

Sub-topic 2: Building Energy Efficiency

Relevant EOs:

Especially surface weather, climate, and solar resource data

Historical data (climatology), potentially near-real time data for applications with Smart Grids

- Approximately 41% of total U.S. energy consumption in 2014 was used for building heating, cooling, and lighting. (Source: EIA)
- Emphasis on reduction of GHGs has increased attention on building energy efficiency.

Example priority needs:

Climate Zones, and heating and cooling degree days (including any shifts from climate change)

Example of Framing Each Sub-Topic

Sub-topic 2: Building Energy Efficiency (cont.)

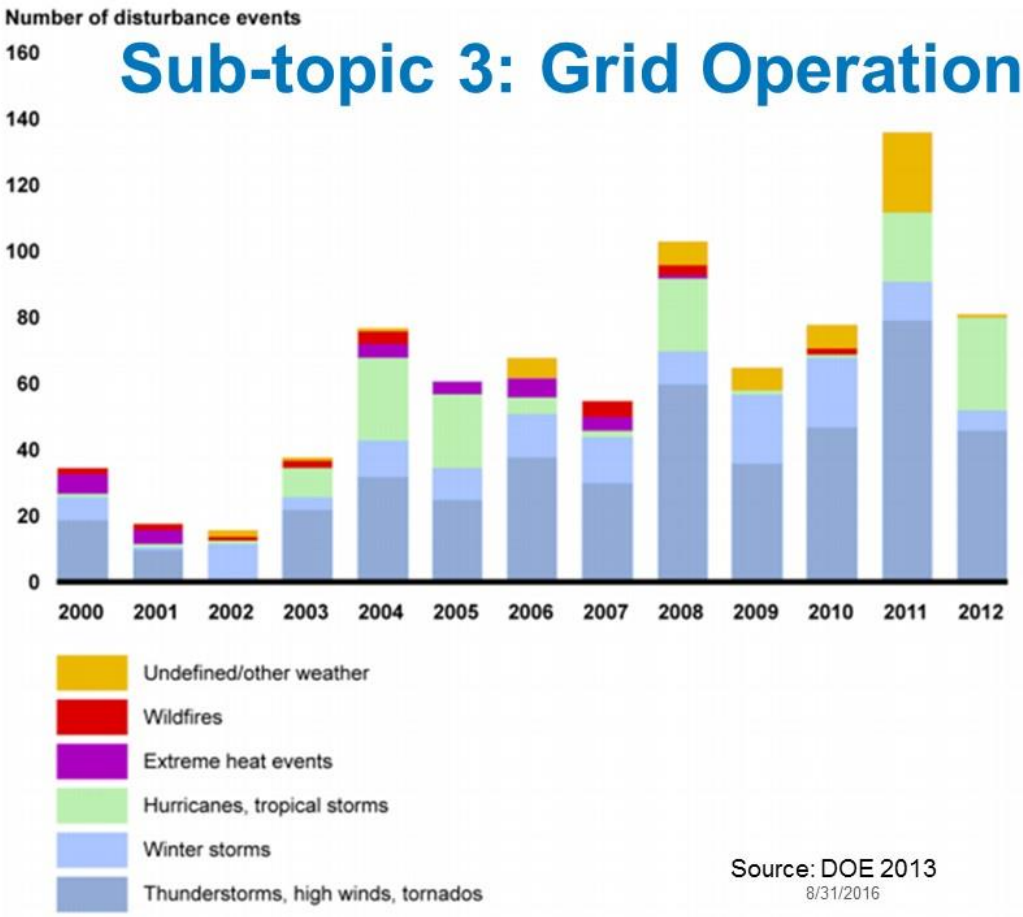
Example Stakeholders and Decision Support Systems:

- City governments- focused on improving building energy efficiency to reduce GHGs
- Building design software and other software (e.g., RETScreen Clean Energy Management)
- National Renewable Energy Laboratory's EnergyPlus Simulation Program which incorporates weather data and ASHRAE Design Conditions Design Day Data file
- DOE's Building Performance Index on energy-related characteristics of commercial and residential buildings
- State and Local Energy Efficiency Action Network

Key Themes We Heard

- Several NASA (and NOAA/weather) datasets are **already** supporting energy sector decisions such as load management, solar resource assessment, fire risk, operational planning, energy efficient design, etc
  - Participants asked that these applications be maintained, with NASA focusing on improving data access, timeliness, quality, and education on appropriate use, without competing with the private sector
- There is a need for standardized **climate change scenarios** and methods for climate change impact assessment on the energy sector (key message from DOE)
- There are opportunities for **innovative** applications of NASA physical and socioeconomic data in extending grid access, assessing geothermal resources, compiling wave statistics, assessing climate impacts on hydropower and coastal infrastructure risks, improving land cover data, etc
- NASA **collaboration** with NOAA, DOE, NGOs, utilities, renewable energy business, international finance organizations is encouraged

Sub-topic 3: Grid Operation



Source: DOE 2013

8/31/2016

Post-Workshop Analysis

Our team developed four criteria to rate potential application areas:

1. **Suitability of Opportunity** - Assessment of whether the potential application area is a good match with NASA's Earth science resources and commitments, rated overall as Moderate or High based on:
   - Key Relevant NASA Earth Resources
   - Alignment with NASA Applied Sciences Program and USG commitments including GEO, CEOS, Sustainable Development Goals, and Executive Orders
     - ***High*** *indicates a strong match on resources and alignment*
     - ***Moderate*** *indicates adequate match on resources and alignment*
2. **Degree of User-Driven Interest** – Extent to which energy management sector end users of data and value-added providers of data have expressed a need for testing out better information in their decision support systems
   - ***Strong*** *indicates an established user interest*
   - ***Moderate*** *indicates anecdotal or limited expression of user interest*

Post-Workshop Analysis (cont)

3. **Potential for Valuable Outcome** – The likelihood that NASA's investment in this application would generate substantial relative value for the energy management sector and/or energy users, considering factors such as the set of people or industries to which the application is applicable, any anticipated growth of that set of people or industries
   - ***Likely*** *indicates that results are anticipated to benefit much of an industry*
   - ***Likely [Ongoing]*** *indicates that results of NASA ASP actions are already providing benefits*
   - ***Possible*** *indicates that results are anticipated to benefit a subset of an industry or limited group of people*
4. **Timeframe for NASA to See Results** – The soonest that NASA would see results or benefits reaching energy management sector users, starting from initiation of an application (or enhancement to a current application)
   - ***Near-Term*** *indicates results within 1-2 years*
   - ***Mid-Term*** *indicates results within 3-4 years*

Potential Application Area Results Summary

Six areas ranked the highest in all categories (with Near-Term Results):

- 2- **Electric Grid Load Mgmt**, Instantaneous to Seasonal with Output Forecasting of RE sources
- 5- **Water Resource Availability** for Thermal Cooling and Hydropower Planning
- 6- **Solar Resource** Assessment
- 7- **Wind Resource** Assessment
- 9 – **Micro-grid System Design** with Integrated Renewable
- 10- **Energy Efficiency** of Bldgs

Possible "Low-Hanging Fruit"

- ✓ Highly Suitable for NASA
- ✓ Strong User Interest
- ✓ Likely (and ongoing) Valuable Outcomes
- ✓ Near-Term (1-2 year) Results

Potential Application Area	Suitability of Opportunity	Degree of User-Driven Interest	Potential for Valuable Outcome	Timeframe for NASA to see Results
Electric Utility and Grid Operation				
1. Continuity of Service During and After Extreme Weather Events	Moderate	Strong	Likely	Near-Term
2. Electric Grid Load Management – Instantaneous to Seasonal Planning, and Output Forecasting of Variable Energy Sources	High	Strong	Likely	Near-Term
Mid-Term to Long-Term Planning for Resilience Across the Energy Sector				
3. Coastal Infrastructure Protection and Planning	High	Strong	Possible	Mid-Term
4. Climate Scenarios for Planning Shifts in Demand and Vulnerabilities of Infrastructure on a Timescale of Years to Decades	High	Moderate	Possible	Mid-Term
5. Water Resource Availability for Thermal Plant Cooling, Hydropower Viability	High	Strong	Likely	Near-Term
Renewable Energy Resource Assessment and Pre-Feasibility Studies				
6. Solar Resources	High	Strong	Likely (ongoing)	Near-Term
7. Wind Resources	High**/ Moderate	Strong	Likely (ongoing)	Near-Term
Expanding Electricity Access in Developing Countries				
8. Large-scale Electric Grid Extension, Utility Scale Power Production, Electrification Status	Moderate	Moderate	Possible	Near-term
9. Microgrid System Design with Integrated Renewables	High	Strong	Likely (ongoing)	Near-Term
Efficiency				
10. Energy Efficiency of Buildings	High	Strong	Likely (ongoing)	Near-Term

*Refer to Section 2.3 for description of each criterion and the possible ratings.
**High for NASA providing numerical weather modelling inputs; moderate for NASA providing high-resolution wind resource models.

Results Summary (cont.)

Two other areas in the **Near-Term Results** category, but not ranked highest on other criteria:

- 1- **Continuity of Service** for Extreme Events
- 8-**Large-scale Electric Grid Extension**, Utility Power Production, Electrification Status

Two areas in the **Mid-Term Results** category, with High Suitability:

- 3- Coastal Infrastructure Protection and Planning
- 4- Climate Scenarios for Planning Shifts in Demand and Vulnerabilities of Infrastructure on a Timescale of Years to Decades

Potential Application Area	Suitability of Opportunity	Degree of User-Driven Interest	Potential for Valuable Outcome	Timeframe for NASA to see Results
Electric Utility and Grid Operation				
1. Continuity of Service During and After Extreme Weather Events	Moderate	Strong	Likely	Near-Term
2. Electric Grid Load Management – Instantaneous to Seasonal Planning, and Output Forecasting of Variable Energy Sources	High	Strong	Likely	Near-Term
Mid-Term to Long-Term Planning for Resilience Across the Energy Sector				
3. Coastal Infrastructure Protection and Planning	High	Strong	Possible	Mid-Term
4. Climate Scenarios for Planning Shifts in Demand and Vulnerabilities of Infrastructure on a Timescale of Years to Decades	High	Moderate	Possible	Mid-Term
5. Water Resource Availability for Thermal Plant Cooling, Hydropower Viability	High	Strong	Likely	Near-Term
Renewable Energy Resource Assessment and Pre-Feasibility Studies				
6. Solar Resources	High	Strong	Likely (ongoing)	Near-Term
7. Wind Resources	High**/ Moderate	Strong	Likely (ongoing)	Near-Term
Expanding Electricity Access in Developing Countries				
8. Large-scale Electric Grid Extension, Utility Scale Power Production, Electrification Status	Moderate	Moderate	Possible	Near-term
9. Microgrid System Design with Integrated Renewables	High	Strong	Likely (ongoing)	Near-Term
Efficiency				
10. Energy Efficiency of Buildings	High	Strong	Likely (ongoing)	Near-Term

*Refer to Section 2.3 for description of each criterion and the possible ratings.
**High for NASA providing numerical weather modelling inputs; moderate for NASA providing high-resolution wind resource models.

Program Design Considerations

- Stakeholders- identification, engagement methods
  - "Don't Reinvent the Wheel" (Dave Renne, on working with private sector)
  - Partner with ESIP, AMS, NOAA, DOE, GFCS, ISES, etc.
  - Creative methods such as hackathons, challenges, contests
- Program Scope, Activities, Timeline
  - Given previous program experience, consider 18-month pilot model, with continuances for significant success
  - Perhaps identify specific thought-leaders, champions, organizations with broad influence as targeted partners on targeted topics

Conclusions

- There is strong interest, potential, and opportunity in NASA APS starting an Energy Application Area
- Interest in renewable energy, better planning for climate variability and change, and more efficient use of resources has increased interest, and driven development of a value-added climate/renewable energy/grid sector
- NASA datasets are seen as increasingly useful, but dataset maintenance, capacity building, and improvement is needed
- The energy sector is DIVERSE - energy types, regions, experience with NASA data, time available, planning horizon
  - Considerable work has been done to engage the energy sector and define needs, but limited work with regard to what NASA has to offer

Recommendations (For Next Year)

1. Document and tell the story of ways that NASA data is already benefitting the energy sector
2. Conduct capacity building and outreach for existing products that could be applied within the “Low-Hanging Fruit” Category
3. Maintain momentum of workshop through ESIP, conduct additional workshops on focused regions and topics
4. Conduct additional work on Program Design Considerations
5. Explore partnerships with World Bank ESMAP, DOE ‘Partnership for Climate Resilience’, EPRI, etc.
6. Leverage NASA programs such as ARSET, SERVIR, Worldview; customize with a specific focus on sub-sectors of energy users