APS GREENHOUSE GAS INVENTORY

2015 ASSESSMENT

A Report by the APS Greenhouse Gas Inventory Advisory Committee

September 2018

APS physics™

ABOUT APS

Founded in 1899 to advance and diffuse the knowledge of physics, the American Physical Society (APS) is now the nation's leading organization of physicists with approximately 54,000 members in academia, national laboratories and industry. APS has long played an active role in the federal government; its members serve in Congress and have held positions such as Science Advisor to the President of the United States, Director of the CIA, Director of the National Science Foundation and Secretary of Energy.

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The American Physical Society has sole responsibility for the contents of this report, and the questions, findings, and recommendations within.

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For additional information, including the participant bios and the workshop charge and agenda, please visit: www.aps.org/policy/reports/

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SUMMARY

As a follow-up activity to the APS 2015 Statement on Earth's Changing Climate, the Society conducted this internal analysis of its greenhouse gas inventory. As the first professional scientific society to broadly evaluate its emissions for public posting, APS provides leadership on climate change and establishes a precedent for other societies to follow.

INTRODUCTION

OVERVIEW

Thousands of companies annually report their greenhouse gas (GHG) emissions with goals of improving transparency, increasing efficiencies, reducing costs, and helping manage risks that arise from climate change.

As the initial follow-up activity to the American Physical Society's (APS's) 2015 Statement on Earth's Changing Climate, the Society conducted an internal analysis of its daily operations and select associated activities to determine its 2015 GHG inventory, which is also often referred to as a carbon footprint. This assessment was the first by APS and is intended to be an ongoing activity.

As the first professional scientific society to broadly evaluate its GHG inventory, APS has the opportunity to provide leadership on climate change and establish a precedent for other societies to follow.

PROCESS

The GHG Inventory Advisory Committee, which includes C. William McCurdy (chair), William Barletta, Robert Jaffe, Dan Dahlberg, James Taylor (APS COO), Mark Doyle (APS CIO), Francis Slakey (APS Chief Government Affairs Officer) and Mark Elsesser (Manager of Science Policy at the APS Office of Government Affairs), managed APS's 2015 GHG Inventory project. The Committee is overseen by the Panel on Public Affairs (POPA) – an APS Council-elected body – and reports directly to the APS CEO, Kate Kirby. During the project, the Committee was supported by Anthesis, a global specialist consultancy skilled in GHG inventory development. Anthesis assisted APS in determining its 2015 GHG inventory and helped develop the tools and institutional knowledge necessary for APS to conduct its own GHG inventory going forward.

APS's 2015 GHG inventory was developed according to The Climate Registry's (TCR's) well-established and industry-recognized standards. The Climate Registry is a community of nearly 300 public and private organizations and 60 states and provinces from across North America bound by a common goal – to measure and manage GHG inventories in a high quality, consistent way in order to lessen the impacts of climate change.

BACKGROUND

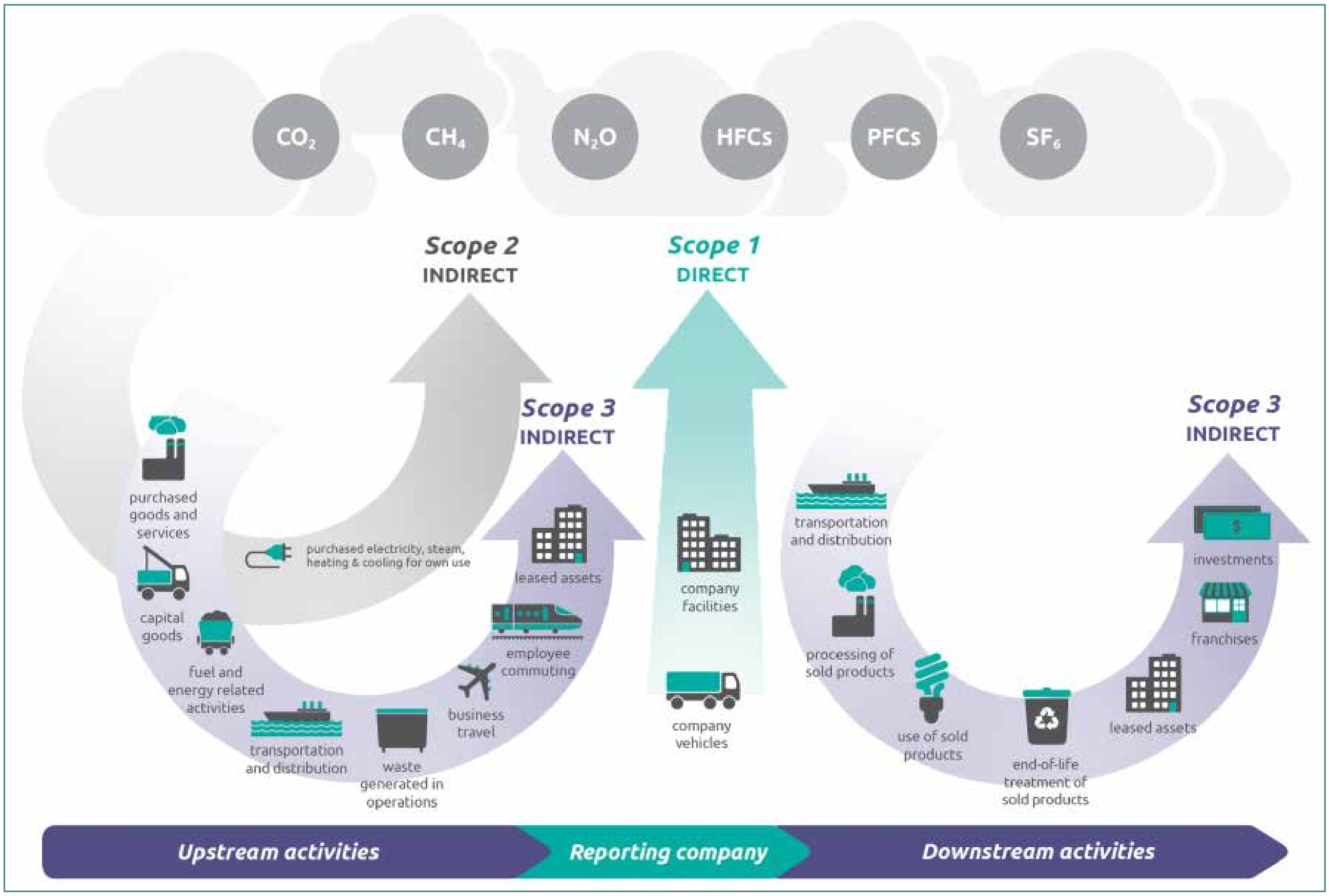
In recent years, corporations and organizations have begun determining the environmental impact of their businesses by measuring their GHG inventory – the total sets of greenhouse gas emissions caused by an organization, event, product or person.

TCR has drawn from existing GHG programs and protocols, including the World Resources Institute and the World Business Council for Sustainable Development's *GHG Protocol Corporate Accounting and Reporting Standard*, to develop its General Reporting Protocol (GRP), which embodies GHG accounting best practices. GRP divides GHG emissions into three categories, referred to as Scopes, when determining an organization's GHG inventory. The Scopes are based on levels of organizational responsibility and control and are defined as:

- **Scope 1:** Emissions from direct energy combustion that occurs on-site or from owned vehicle operation; also includes direct industrial/HVAC gas emissions
- **Scope 2:** Indirect emissions resulting from the purchased energy generation, often in the form of electricity, steam (district heating), or chilled water (district cooling)
- **Scope 3:** Other indirect emissions that are a result of organizational activities; includes emissions from business travel, employee commuting, waste management and supplier or outsourced activities

In addition to APS's Scope 1 and 2 GHG inventory, which was verified by an independent third-party (Cameron-Cole), APS estimated the GHG emissions associated with the following subset of Scope 3 categories recommended by POPA:

- APS Co-located Servers
- APS Member Travel to/from APS National Meetings
- APS's Investment Portfolio



Source: WRI/WBCSD Corporate Value Chain (Scope 3) Accounting and Reporting Standard, page 5.

SCOPE 1 & SCOPE 2
OVERALL RESULTS

Note: All results are given in metric tons of CO_2e.

APS Overall GHG Footprint

Scope	Emission Source	2015 [CO_2e]	% of S1+ S2 (MKT-based)
S1	Natural Gas	1.31	0.16
S1	Propane	147.99	18.10
S1	Distillate Fuel	0.16	0.02
S1	Vehicles	0.84	0.10
S2	Natural Gas (LOC)	12.15	
S2	Natural Gas (MKT)	12.15	1.49
S2	Electricity (LOC)	655.13	
S2	Electricity (MKT)	655.13	80.13
Totals			
S1 + S2 (LOC-based)	--	817.58	--
S1 + S2 (MKT-based)	--	817.58	--

APS GHG Emissions by Location

APS Site	APS Control (%)	Total Emissions (LOC) [CO_2e]	Total Emissions (MKT) [CO_2e]	Per Employee (LOC)	Per Employee (MKT)
College Park	25.3	244.46	244.46	3.13	3.13
Ridge	100	501.48	501.48	3.46	3.46
Washington	0	71.63	71.63	10.23	10.23

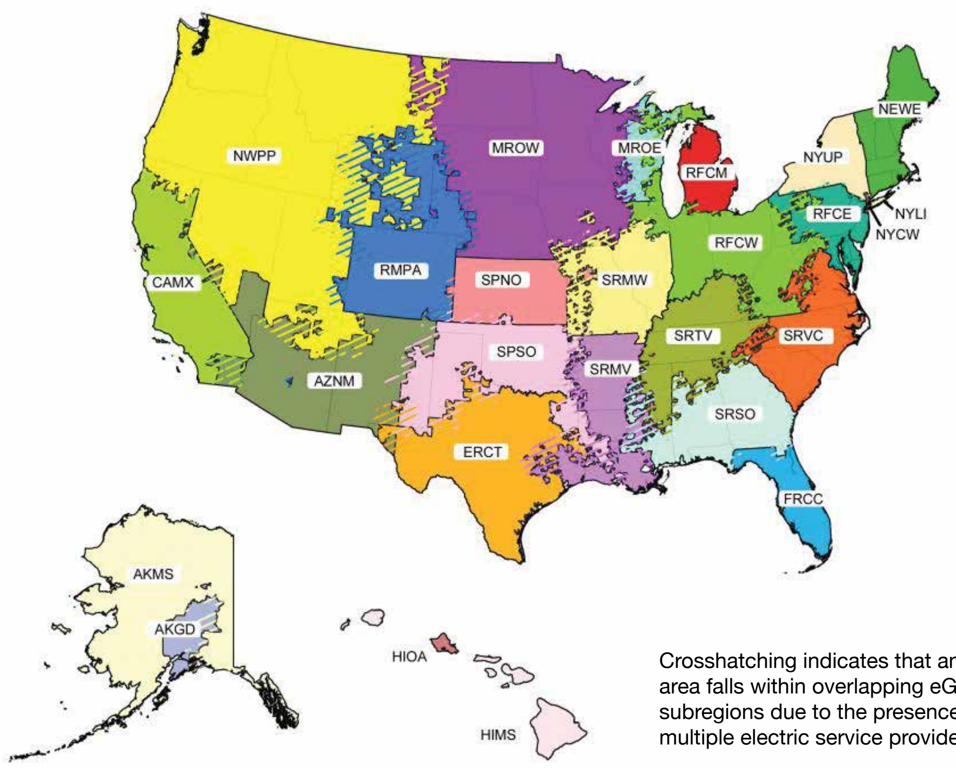
Note: APS has 100% control of decisions impacting emissions at its Ridge facility, partial control over decisions impacting emissions at its College Park facility, and zero control over decisions impacting emissions at its Washington, DC facility.

LOCATION-BASED VS. MARKET-BASED

The location-based method quantifies the average emissions from electricity generated and consumed in an organization's geographic region(s) of operations, primarily using grid-averaged emission factors. This method reflects the GHG emissions from locally-generated electricity delivered through the grid and transparently demonstrates local conditions and the impacts of energy conservation. Please note that it does not reflect any electricity purchasing choices made by the organization.

APS used the U.S. EPA Power Profiler tool to determine its facilities' Emissions & Generation Resource Integrated Database (eGRID) subregions (shown below). Please note that the APS Ridge facility is located in the NYLI subregion. This region does not include the hydroelectric power generated in other parts of New York state, which is reflected in its emission factor.

Map of eGRID Subregions



Crosshatching indicates that an area falls within overlapping eGRID subregions due to the presence of multiple electric service providers.

Source: USEPA, eGRID2014, January 2017

The market-based method quantifies emissions from the electricity generated and consumed that organizations have purposefully purchased, using emission factors conveyed through contractual instruments between the organization and the electricity provider. This method reflects the GHG emissions associated with choices an organization makes about its electricity supply, and it allows organizations to claim the specific emission rate associated with these purchases. Organizations that do not have contractual instruments for energy (e.g., renewable energy certificates) or supplier specific rates (e.g., green power program) should use residual mix subnational emission factors, which quantify energy production and do not include voluntary renewable energy purchases. However, if TCR-approved residual mix emission factors are not available, TCR protocol requires organizations to use the eGRID emission factors previously used for the location-based calculations.

Because no TCR-approved residual emission factors were available, APS used eGRID emission factors for its market-based calculations. Therefore, APS's location-based and market-based emissions were equal for 2015.

SCOPE 1 DIRECT EMISSION
SAMPLE CALCULATIONS

Emission Source: Stationary Combustion (Propane)
Category: Scope 1 Direct Emissions
APS Site: Ridge, NY
APS Ownership: 100%
Data Source: Monthly gas bills/Statements
Party Responsible: Mark Doyle, Mark Beacon
Reporting Protocol: Emissions are reported in metric tons of CO_2e

Stationary combustion occurs in large (power plants, refineries, etc.) and small (furnaces, boilers, etc.) sources, releasing CO_2 and trace amounts of CH_4 and N_2O. To calculate GHG emissions from stationary combustion sources, APS used monthly utility statements that included total fuel amounts used.

Below is a sample calculation for the APS Ridge facility, which uses propane for heating and cooling. The propane usage – given in gallons (gal) – is for Q1 2015. The calculations were completed using the most current EPA emission factors (November 2015) and global warming potentials (GWPs) (IPCC AR5, 2014).

$$10{,}925\ gal \times \left(\frac{5.66 \times 10^{-3}\ mt\ CO_2}{gal}\right) \times \left(\frac{1\ CO_2e}{1\ CO_2}\right) = 61.84\ mt\ CO_2e$$

$$10{,}925\ gal \times \left(\frac{9 \times 10^{-7}\ mt\ CH_4}{gal}\right) \times \left(\frac{28\ CO_2e}{1\ CH_4}\right) = 0.275\ mt\ CO_2e$$

$$10{,}925\ gal \times \left(\frac{5.40 \times 10^{-8}\ mt\ N_2O}{gal}\right) \times \left(\frac{265\ CO_2e}{1\ N_2O}\right) = 0.156\ mt\ CO_2e$$

The sum of the CO_2, CH_4 and N_2O emissions – given in mt CO_2e – represents the total GHG emissions for propane use at the APS Ridge facility for Q1 2015.

$$61.84\ mt\ CO_2e + 0.275\ mt\ CO_2e + 0.156\ mt\ CO_2e = 62.27\ mt\ CO_2e$$

Emission Source:	Stationary Combustion (Natural Gas)
Category:	Scope 1 Direct Emissions
APS Sites:	College Park, MD (American Center for Physics)
APS Ownership:	25.299%
Data Source:	Monthly gas bills/Statements
Party Responsible:	James Taylor, Maria Inch
Reporting Protocol:	Emissions are reported in metric tons of CO_2e

Below is a sample calculation for the APS College Park Facility, which uses natural gas for its water heater. The natural gas usage – given in therms – is for Q1 2015. The calculations were completed using the most current EPA emission factors (November 2015) and GWPs (IPCC AR5, 2014). The volume of natural gas used in this calculation (78.42 therms) has taken into account an operational control pre-factor (0.19), which is determined by APS's operational footprint within the American Center for Physics.

$$78.42\ therms \times \left(\frac{5.31 \times 10^{-3}\, mt\ CO_2}{therm}\right) \times \left(\frac{1\, CO_2e}{1\, CO_2}\right) = 4.16 \times 10^{-1}\ mt\ CO_2e$$

$$78.42\ therms \times \left(\frac{4.80 \times 10^{-7}\, mt\ CH_4}{therm}\right) \times \left(\frac{28\, CO_2e}{1\, CH_4}\right) = 1.05 \times 10^{-3}\ mt\ CO_2e$$

$$78.42\ therms \times \left(\frac{1.00 \times 10^{-8}\, mt\ N_2O}{therm}\right) \times \left(\frac{265\, CO_2e}{1\, N_2O}\right) = 2.08 \times 10^{-4}\ mt\ CO_2e$$

The sum of the CO_2, CH_4 and N_2O emissions – given in mt CO_2e – represents the total GHG emissions for natural gas use at the APS College Park facility for Q1 2015.

$$4.16\times10^{-1}\ mt\ CO_2e + 1.05\times10^{-3}\ mt\ CO_2e + 2.08\times10^{-4}\ mt\ CO_2e = 0.42\ mt\ CO_2e$$

Emission Source:	Mobile Combustion (Gasoline Light-Duty Truck)
Category:	Scope 1 Direct Emissions
APS Sites:	Ridge, NY
APS Ownership:	100%
Data Source:	Gas Receipts and APS staff travel estimates
Party Responsible:	Mark Doyle, Mark Beacon
Reporting Protocol:	Emissions are reported in metric tons of CO_2e

Mobile combustion refers to any emissions source capable of emitting GHGs while moving from one place to another (automobiles, trains, planes, etc.). The combustion of fossil fuels in these mobile sources produce GHG emissions CO_2, CH_4 and N_2O. CO_2 emissions are calculated using gallons of fuel consumed; CH4 and N2O are calculated using miles traveled. Emissions from CH4 and N_2O strongly depend on emission control technologies (ECT), which vary by the year, make and model of the vehicle. The calculations were completed using the most current EPA emission factors (November 2015) and GWPs (IPCC AR5, 2014).

APS owns a 1999 Toyota Tacoma (Light-Duty Truck) based at its Ridge facility. APS Staff estimates the vehicle's mileage usage was 75% highway and 25% city. Using this distribution and the total gallons purchased (20.64 gallons via receipts), APS estimated total miles driven in Q1 2015 to be 479.9. Shown below are calculations for CO_2, CH_4, and N_2O.

$$20.64\ gal \times (\frac{.0088\ mt\ CO_2}{gal}) \times (\frac{1\ CO_2e}{1\ CO_2}) = 0.181\ mt\ CO_2e$$

$$479.9\ miles \times (\frac{3.21 \times 10^{-8}\ mt\ CH_4}{mile}) \times (\frac{28\ CO_2e}{1\ CH_4}) = 4.31 \times 10^{-4}\ mt\ CO_2e$$

$$479.9\ miles \times (\frac{5.64 \times 10^{-8}\ mt\ N_2O}{mile}) \times (\frac{265\ CO_2e}{1\ N_2O}) = 7.17 \times 10^{-4}\ mt\ CO_2e$$

The sum of the CO_2, CH_4 and N_2O emissions – given in mt CO_2e – represents the total GHG emissions from the light-duty truck at the APS Ridge facility for Q1 2015.

$$0.181\ mt\ CO_2e + 4.31 \times 10^{-4}\ mt\ CO_2e + 7.17 \times 10^{-4}\ mt\ CO_2e = 0.189\ mt\ CO_2e$$

Emission Source:	Purchased Natural Gas
Category:	Scope 2 Indirect Emissions
APS Sites:	Washington, DC
APS Ownership:	0%; APS leases office space
Data Source:	Monthly Utility Bills/ Statements
Party Responsible:	Joanne Murphy, Mark Elsesser, Jeanette Russo
Reporting Protocol:	Emissions are reported in metric tons of CO_2e

Below is a sample calculation for the APS Washington, DC facility (National Press Building Office Suite), which uses natural gas for heating. The natural gas usage – given in therms – is for Q1 2015. The calculations include an efficiency prefactor (1/0.75), which is standard for purchased heating calculations.

Sample calculations for the APS DC facility for CO_2, CH_4 and N_2O are shown below. The calculations were completed using the most current EPA emission factors (November 2015) and GWPs (IPCC AR5, 2014).

$$\frac{1}{0.75} \times 983.36\, therms \times \left(\frac{5.31 \times 10^{-3}\, mt\; CO_2}{therm}\right) \times \left(\frac{1\, CO_2e}{1\, CO_2}\right) = 6.96\; mt\; CO_2e$$

$$\frac{1}{0.75} \times 983.36\, therms \times \left(\frac{4.80 \times 10^{-7}\, mt\; CH_4}{therm}\right) \times \left(\frac{28\, CO_2e}{1\, CH_4}\right) = 1.77 \times 10^{-2}\; mt\; CO_2e$$

$$\frac{1}{0.75} \times 983.36\, therms \times \left(\frac{1.00 \times 10^{-8}\, mt\; N_2O}{therm}\right) \times \left(\frac{265\, CO_2e}{1\, N_2O}\right) = 3.47 \times 10^{-3}\; mt\; CO_2e$$

The sum of the CO_2, CH_4 and N_2O emissions – given in mt CO_2e – represents the total GHG emissions for natural gas use at the APS DC facility for Q1 2015.

$$6.96\; mt\; CO_2e + 1.77 \times 10^{-2}\; \mathrm{mt\; CO_2e} + 3.47 \times 10^{-3}\; mt\; CO_2e = 6.98\; mt\; CO_2e$$

Emission Source:	Electricity
Category:	Scope 2 Indirect Emissions
APS Sites:	Ridge, NY
APS Ownership:	100%
Data Source:	Monthly Utility Bills/ Statements
Party Responsible:	Mark Doyle, Mark Beacon
Reporting Protocol:	For the location-based method, emissions are reported in metric tons (mt) of CO_2e. For the market-based method, emissions are reported in mt of CO_2e.

The generation of electricity through the combustion of fossil fuels typically yields CO_2, and to a small extent, N_2O and CH_4. Reporting protocol requires GHG emissions from electricity to be reported using two methods – location-based (LOC) and market-based (MKT). The location-based method quantifies the average emissions from electricity generated and consumed in an organization's geographic region(s) of operations. This method reflects the GHG emissions from locally generated electricity delivered through the grid and transparently demonstrates local conditions and the impacts of energy conservation. It does not reflect any purchasing choice(s) made by an organization.

Using emission factors provided by the Emissions & Generation Resource Integrated Database (eGrid 2012) for each GHG gas, the LOC indirect emissions from electricity consumption at each APS facility were determined using monthly utility statements.

Sample calculations for the APS Ridge facility using the location-based method for CO_2, CH_4 and N_2O are shown below. The electricity usage – given in megawatt-hours (MWh) – is for Q1 2015. The LOC emission factors used (eGRID 2012) represent average emissions from all the electricity produced in a defined grid distribution region. The GWPs (IPCC AR5, 2014) were used to convert GHG emissions into units of CO_2e.

$$120.928\ MWh \times \left(\frac{5.45\times10^{-1}\ mt\ CO_2}{MWh}\right) \times \left(\frac{1\ CO_2e}{1\ CO_2}\right) = 65.89\ mt\ CO_2e$$

$$120.928\ MWh \times \left(\frac{3.55\times10^{-5}\ mt\ CH_4}{MWh}\right) \times \left(\frac{28\ CO_2e}{1\ CH_4}\right) = 0.120\ mt\ CO_2e$$

$$120.928\ MWh \times \left(\frac{4.48\times10^{-6}\ mt\ N_2O}{MWh}\right) \times \left(\frac{265\ CO_2e}{1\ N_2O}\right) = 0.143\ mt\ CO_2e$$

The sum of the CO_2, CH_4 and N_2O emissions – given in mt CO_2e – represents the total GHG emissions for electricity use at the APS Ridge facility for Q1 2015.

$$65.89\ mt\ CO_2e + 0.120\ mt\ CO_2e + 0.143\ mt\ CO_2e = 66.15\ mt\ CO_2e$$

Emission Source:	Electricity
Category:	Scope 2 Indirect Emissions
APS Sites:	College Park, MD (American Center for Physics)
APS Ownership:	25.299%
Data Source:	Monthly Utility Bills/ Statements
Party Responsible:	James Taylor, Maria Inch
Reporting Protocol:	For the location-based method, emissions are reported in metric tons (mt) of CO_2e. For the market-based method, emissions are reported in mt of CO_2.

The calculation methodologies for Scope 2 indirect emissions from electricity use at the APS College Park facility (American Center for Physics) were similar to those used for the APS Ridge facility, with an additional pre-factor to reflect the facility's co-operators. Because of its co-operation of the American Center for Physics, APS is responsible for 19% of the electricity use for the facility, and this operational percentage is entered as an "operational control pre-factor" for the College Park facility's electricity emission calculations.

Sample calculations for the APS College Park facility using the location-based method for CO_2, CH_4 and N_2O are shown below. The electricity usage – given in megawatt-hours (MWh) – is for Q1 2015. The pre-factor used reflects APS's co-ownership of the facility. The LOC emission factors used (eGRID 2012) represent average emissions from all the electricity produced in a defined grid distribution region. The GWPs (IPCC AR5, 2014) were used to convert GHG emissions into units of CO_2e.

$$0.19 \times 1{,}122\ MWh \times \left(\frac{3.89 \times 10^{-1}\ mt\ CH_4}{MWh}\right) \times \left(\frac{1\ CO_2e}{1\ CO_2}\right) = 83.15\ mt\ CO_2e$$

$$0.19 \times 1{,}122\ MWh \times \left(\frac{1.20 \times 10^{-5}\ mt\ CH_4}{MWh}\right) \times \left(\frac{28\ CO_2e}{1\ CH_4}\right) = 0.072\ mt\ CO_2e$$

$$0.19 \times 1{,}122\ MWh \times \left(\frac{5.21 \times 10^{-6}\ mt\ N_2O}{MWh}\right) \times \left(\frac{265\ CO_2e}{1\ N_2O}\right) = 0.29\ mt\ CO_2e$$

The sum of the CO_2, CH_4 and N_2O emissions – given in mt CO_2e – represents the total GHG emissions for electricity use at the APS College Park facility for Q1 2015.

$$83.15\ mt\ CO_2e + 0.072\ mt\ CO_2e + 0.29\ mt\ CO_2e = 83.51\ mt\ CO_2e$$

Emission Source:	Electricity
Category:	Scope 2 Indirect Emissions
APS Sites:	Washington, DC
APS Ownership:	0%; APS leases office space
Data Source:	Monthly Utility Bills/ Statements
Party Responsible:	Joanne Murphy, Mark Elsesser, Jeanette Russo
Reporting Protocol:	For the location-based method, emissions are reported in metric tons (mt) of CO_2e. For the market-based method, emissions are reported in mt of CO_2.

The calculation methodologies for Scope 2 indirect emissions from electricity use at the APS Washington, DC facility (National Press Building Office Suite) were similar to those used for the APS Ridge facility, with an additional pre-factor to reflect that office space is leased from another owner. Because it leases space, APS is responsible for its share of the building's electricity used based on the fraction of the building its offices occupy and the building's occupancy rate. The calculation of this pre-factor is shown below.

$$4{,}582\ ft^2\ (APS\ Office) \div 354{,}617\ ft^2\ (Building) \div .7889\ (Occupancy) = 1.64 \times 10^{-2}$$

Sample calculations for the APS DC facility using the location-based method for CO_2, CH_4 and N_2O are shown below. The electricity usage – given in kilowatt-hours (MWh) – is for Q1 2015. The LOC emission factors used (eGRID 2012) represent average emissions from all the electricity produced in a defined grid distribution region. The GWPs (IPCC AR5, 2014) are used to convert GHG emissions into units of CO_2e.

$$1.64 \times 10^{-2} \times 1{,}805\ MWh \times \left(\frac{3.89 \times 10^{-1}\ mt\ CO_2}{MWh}\right) \times \left(\frac{1\ CO_2e}{1\ CO_2}\right) = 11.51\ mt\ CO_2e$$

$$1.64 \times 10^{-2} \times 1{,}805\ MWh \times \left(\frac{1.20 \times 10^{-5}\ mt\ CH_4}{MWh}\right) \times \left(\frac{28\ CO_2e}{1\ CH_4}\right) = 9.92 \times 10^{-3}\ mt\ CO_2e$$

$$1.64 \times 10^{-2} \times 1{,}805\ MWh \times \left(\frac{5.21 \times 10^{-6}\ mt\ N_2O}{MWh}\right) \times \left(\frac{265\ CO_2e}{1\ N_2O}\right) = 4.08 \times 10^{-2}\ mt\ CO_2e$$

The sum of the CO_2, CH_4 and N_2O emissions – given in mt CO_2e – represents the total GHG emissions for electricity use at the APS Washington, DC facility for Q1 2015.

$$11.51\ mt\ CO_2e + 0.00992\ mt\ CO_2e + 0.0408\ mt\ CO_2e = 11.6\ mt\ CO_2e$$

CO-LOCATED SERVERS - SAMPLE CALCULATIONS & RESULTS

Emission Source:	Co-located Servers
Category:	Scope 3 Indirect Emissions
APS Sites:	Sunnyvale, CA
APS Ownership:	0%
Data Source:	Monthly Usage Data
Party Responsible:	Mark Doyle
Reporting Protocol:	Emissions are reported in metric tons of CO_2e.

APS calculated the emissions associated with its co-located servers (electricity use) at an Equinix Silicon Valley Data Center, which are categorized as “purchased goods and services.”

Equinix provided monthly usage data in kilovolt-amps (kVA), which was converted to kWh using an estimated power factor, 0.98, provided by Equinix. The electricity usage was divided into two parts – usage from the IT equipment and usage from overhead equipment. The usage distribution was determined using the power usage effectiveness (PUE) of Equinix’s SV6 location, which was 1.71. PUE is the ratio of total amount of energy used by a data center facility to the energy delivered to computing equipment.

Calculations for the IT equipment at the Sunnyvale facility (SV6) using the location-based method for CO_2, CH_4 and N2O are shown below. The electricity usage – given in kilowatt-hours (MWh) – is for 2015. The location-based emission factors used (eGRID 2012) represent average emissions from all the electricity produced in a defined grid distribution region. The GWPs (IPCC AR5, 2014) are used to convert GHG emissions into units of CO_2e.

$$131.18\ MWh \times \left(\frac{2.95 \times 10^{-1}\ mt\ CO_2}{MWh}\right) \times \left(\frac{1\ CO_2e}{1\ CO_2}\right) = 38.7\ mt\ CO_2e$$

$$131.18\ MWh \times \left(\frac{1.41 \times 10^{-5}\ mt\ CH_4}{MWh}\right) \times \left(\frac{28\ CO_2e}{1\ CH_4}\right) = 5.18 \times 10^{-2}\ mt\ CO_2e$$

$$131.18\ MWh \times \left(\frac{2.57 \times 10^{-6}\ mt\ N_2O}{MWh}\right) \times \left(\frac{265\ CO_2e}{1\ N_2O}\right) = 8.93 \times 10^{-2}\ mt\ CO_2e$$

Calculations for the overhead equipment are shown below. The electricity usage – given in kilo-watt-hours (MWh) – is for 2015 and adjusted to account for SV6's PUE (1.71). The location-based emission factors used (eGRID 2012) represent average emissions from all the electricity produced in a defined grid distribution region. There is a pre-factor based on the site's PUE provided by Equinix. The GWPs (IPCC AR5, 2014) are used to convert GHG emissions into units of CO_2e.

$$93.14\ MWh \times (\frac{2.95 \times 10^{-1}\ mt\ CO_2}{MWh}) \times (\frac{1\ CO_2e}{1\ CO_2}) = 27.48\ mt\ CO_2e$$

$$93.14\ MWh \times (\frac{1.41 \times 10^{-5}\ mt\ CH_4}{MWh}) \times (\frac{28\ CO_2e}{1\ CH_4}) = 3.68 \times 10^{-2}\ mt\ CO_2e$$

$$93.14\ MWh \times (\frac{2.57 \times 10^{-6}\ mt\ N_2O}{MWh}) \times (\frac{265\ CO_2e}{1\ N_2O}) = 6.34 \times 10^{-2}\ mt\ CO_2e$$

The sum of the CO_2, CH_4 and N_2O emissions – given in mt CO_2e – for the IT equipment (38.84 mt CO_2e) and overhead equipment (27.57 mt CO_2e) represent the total GHG emissions for electricity use at the Equinix SV6 facility for 2015.

The total GHG emissions for APS's co-located servers in 2015 were approximately 66.41 mt CO_2e.

TRAVEL TO/FROM APS MEETINGS - METHODOLOGY & RESULTS

Emission Source:	APS Member Travel to/from APS Meetings
Category:	Scope 3 Indirect Emissions
APS Sites:	NA
APS Ownership:	0%
Data Source:	Meetings Registration
Party Responsible:	NA
Reporting Protocol:	Emissions are reported in metric tons of CO_2e.

For APS's 2015 inventory, six national meetings were analyzed: March Meeting (San Antonio, TX); April Meeting (Baltimore, MD); Division of Atomic, Molecular and Optical Physics (DAMOP; Columbus, OH); Division of Plasma Physics (DPP; Savannah, GA); Division of Nuclear Physics (DNP; Santa Fe, NM); and Division of Fluid Dynamics (DFD; Boston, MA).

METHODOLOGY

APS employed the distance-based method, which was adapted from the Greenhouse Gas Protocol's *Technical Guidance for Calculating Scope 3 Emissions* and approved by Anthesis (GHG consultancy), to estimate its Scope 3 emissions associated with conference travel. The distance-based method relies on knowing the distance traveled between two locations via a given mode of transportation.

The general formula for emissions of CO_2 equivalents (CO_2e) using the distance-based method is:

$$CO_2e\ emissions\ = \sum\left[\begin{pmatrix} distance\ traveled \\ by\ vehicle\ type \end{pmatrix} \times \begin{pmatrix} vehicle\ specific \\ emission\ factor \end{pmatrix} \times (GWP)\right]$$

APS used vehicle specific emission factors and GWPs provided by the U.S. EPA and IPCC, respectively.

Currently, APS collects each attendee's affiliation/home institution during meeting registration. A "registration data set" that included a list of attendees and their affiliated institutions was provided for each of the six APS meetings.

Arthur Smith (APS Lead Data Analyst; Ridge, NY) developed a computer program to implement the distance-based calculation methodology. The program utilizes the following procedures:

1. The Global Research Identifier Database (GRID) was used to look up institution latitude/longitude coordinates.

2. The airport nearest to the conference convention center was determined from Google Maps, ignoring small, regional airports.

3. Distance traveled was determined to be the great-circle distance (the shortest path separating two points on the surface of a sphere) between the origin location and the destination airport or conference venue.

4. Distances were divided into four categories:

    a. Driving (< 150 miles)
    b. Short-haul flight (< 300 miles)
    c. Medium-haul flight (300 – 2300 miles)
    d. Long-haul flight (> 2300 miles)

5. The driving distance from the airport to the conference convention center was included for attendees who traveled via airplane.

6. Emissions were calculated by applying the appropriate emission factors and GWPs.

7. For attendees with no institution listed in the registration data set, the average per person emissions for the given meeting was applied. For any given meeting, this amounted to less than 1.5% of attendees.

RESULTS

The emissions associated with attendee travel to and from six APS 2015 national meetings were calculated as outlined above, and the results are displayed in Table 1. All results displayed are for round-trip travel, and emissions are reported in kilograms of CO_2 equivalents (kg CO_2e) or metric tons of CO_2 equivalents (mt CO_2e).

Table 1: GHG emissions from travel to/from APS 2015 national meetings

Meeting	Location	Number of Attendees	Percent International	Per Person Avg (kg CO_2e)	Total Emissions (mt CO_2e)
March	San Antonio, TX	8,931	27.5%	792	7,073
April	Baltimore, MD	1,538	4.8%	303	465
DAMOP	Columbus, OH	1,101	21.0%	560	616
DPP	Savannah, GA	1,766	14.6%	605	1,068
DFD	Boston, MA	3,473	34.2%	756	2,625
DNP	Santa Fe, NM	646	6.1%	406	262
Total					**12,110**

The total GHG emissions from APS member travel to/from six of its 2015 national meetings were approximately 12,110 mt CO_2e.

Travel associated with the March Meeting produced an estimated 7,073 mt CO_2e – more than all other meetings combined. While the March Meeting has the largest overall attendance, its average per person emissions was also the largest. In particular, the March Meeting's average per person emissions were more than double the April Meeting. Both the March Meeting and DFD had the highest average per person emissions (> 700 kg CO_2e per person), which can be partially attributed to the percentage of attendees traveling from international institutions.

The distribution of transportation modes used and the average total distance traveled for each meeting are displayed in Table 2. Due to the assumptions made in the calculation methodology – e.g., ignoring layovers – emissions scaled with average distance traveled.

Table 2: Distribution of transportation modes for travel to APS meetings

	March	April	DAMOP	DPP	DFD	DNP
Car only	3.5%	24.6%	5.3%	0.0%	13.7%	12.0%
Short-haul	4.4%	17.6%	14.7%	2.8%	8.5%	0.9%
Medium-haul	66.9%	42.4%	60.2%	70.2%	34.0%	84.3%
Long-haul	25.2%	15.5%	19.8%	27.0%	43.9%	2.8%
Avg. distance (mi)	2,457	906	1,709	1,893	2,271	1,297

A COMPARISON: RESULTS FROM MARCH AND DAMOP 2010-2016

To investigate the effect of the meeting location on emissions, we calculated estimated emissions for two of the six meetings, March Meeting and DAMOP, from 2010-2016. The March Meeting was chosen because it has the largest attendance, and DAMOP was chosen because it occurred in a wide range of locations during the past 7 years. The estimated emissions are displayed in Table 3 (March Meeting) and Table 4 (DAMOP).

Table 3: APS March Meeting Emissions: 2010-2016

Year	Location	Total Attendees	Percent International	Per Person Avg (kg CO_2e)	Total Emissions (mt CO_2e)
2010	Portland, OR	7,296	25.0%	788	5,748
2011	Dallas, TX	7,856	23.9%	653	5,130
2012	Boston, MA	9,577	26.7%	625	5,990
2013	Baltimore, MD	8,909	25.2%	605	5,392
2014	Denver, CO	8,906	26.3%	727	6,475
2015	San Antonio, TX	8,931	27.5%	792	7,073
2016	Baltimore, MD	9,773	25.4%	633	6,183

Table 4: APS DAMOP Meeting Emissions: 2010–2016

Year	Location	Total Attendees	Percent International	Per Person Avg (kg CO_2e)	Total Emissions (mt CO_2e)
2010	Houston, TX	1,056	16.5%	543	573
2011	Atlanta, GA	1,053	18.8%	509	536
2012	Orange County, CA	990	20.2%	748	741
2013	Quebec City, Can.	855	30.9%	632	541
2014	Madison, WI	1,041	18.8%	515	536
2015	Columbus, OH	1,101	21.0%	560	616
2016	Providence, RI	1,291	22.5%	587	758

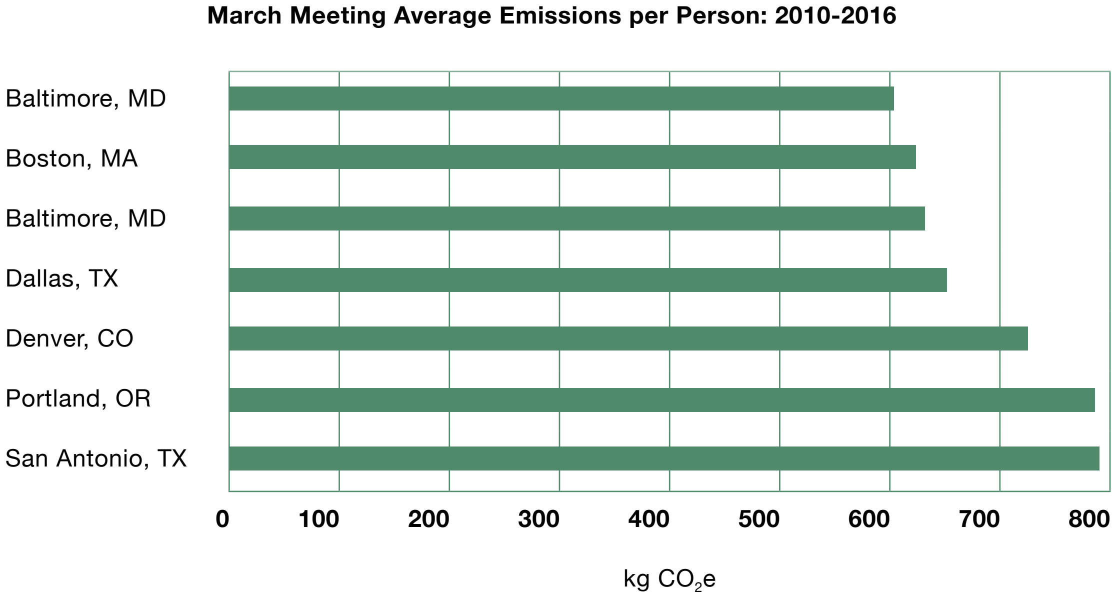
As was the case for 2015, emissions associated with attendee travel to the March Meeting are nearly an order of magnitude greater than the emissions associated with DAMOP. However, within each meeting, international attendance remains relatively constant, with the exception of DAMOP 2013, which was held in Quebec City, Canada.

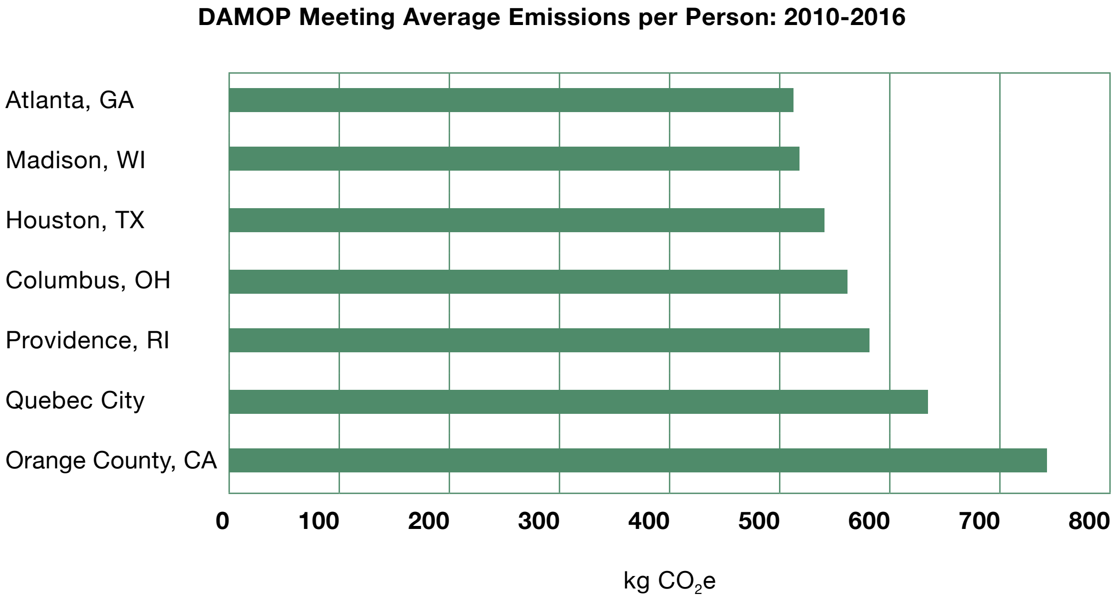
The average emissions per person provide a metric to compare emissions between locations for each meeting location. Plots of average emissions per person for each location are displayed in Figure 1.

Note that the March Meeting was held in Baltimore in 2013 and 2016 and the graph below shows the average value for per person emissions for each year. March Meeting emissions were consistently lower when the meeting was held in Baltimore, MD. The per person average emissions for DAMOP were highest in 2012 when the meeting was hosted in Orange County, CA, and were minimized when the meeting was hosted in Atlanta, GA (2011) and Madison, WI (2014).

Due to the assumptions made in the calculation methodology, the effect of location on emissions can only be approximated. The results indicate locations that minimize or maximize the average distance traveled by attendees, which, in general, correlates with emissions. However, for meetings that occurred at locations with smaller airports, such as Providence, RI, including layovers in emission calculations could significantly impact the results.

Figure 1: Average emissions per person by location for March Meeting and DAMOP





INVESTMENT PORTFOLIO - METHODOLOGY & RESULTS

Emission Source:	APS Investment Portfolio
Category:	Scope 3 Indirect Emissions
APS Sites:	NA
APS Ownership:	100%
Data Source:	APS Finance
Party Responsible:	Jane Gould
Reporting Protocol:	Emissions are reported in metric tons of CO_2e.

As part of APS's 2015 GHG Inventory, emissions associated with the Society's investment portfolio were examined. There is limited guidance available for GHG emissions calculations related to investment portfolios, particularly for the case of broad-based mutual funds. Because of this, APS worked with Anthesis to develop a robust methodology for estimating the GHG emissions associated with its investments.

METHODOLOGY

APS developed its methodology to calculate its investment portfolio emissions based on the Greenhouse Gas Protocol's (GHGP's) average-data method, which involves estimating the Scope 1 and Scope 2 emissions from investee companies and then allocating emissions based on the investor's equity stake.

As shown in the equation below, the average-data method calculates the Scope 1 and 2 GHG emissions from an equity investment by multiplying the investee company's revenue by the emission factor associated with its operating sector. An investor's emissions are based off its share of equity.

$$\begin{aligned} &Emissions\ from\ equity\ investments \\ &\quad = \sum \big((investee\ company\ total\ revenue\ (\$) \\ &\quad \times emission\ factor\ for\ investee's\ sector\ (kg\ CO_2e/\$\ revenue)) \\ &\quad \times share\ of\ equity \big) \end{aligned}$$

RESULTS

APS staff examined the Society's investment portfolio to determine its distribution of funds. Approximately 75% of APS's investment portfolio resides in broad-based mutual funds, and there are no indications that any investments are disproportionately emissions-heavy, e.g., APS does not own energy sector-specific mutual funds. Most of the balance of the portfolio exists in fixed income investments, with a small percentage invested in a proprietary hedge fund for which there is little information available. However, it does not appear that anything in the proprietary fund is sector-specific, which could tilt the overall estimates.

To determine if calculating its investment-related GHG emissions was feasible using the average-data method, APS did an initial test using the Vanguard Total Stock Market Index Fund Institutional Shares (VITSX), the largest holding by percentage in its portfolio.

APS began by calculating the GHG emissions related to the largest holding within VITSX – Apple. There are approximately 5.247 billion total shares outstanding of Apple. VITSX holds approximately 107.36 million shares, which is approximately 2.05% equity.

APS owns approximately 449,860 shares of VITSX. With a net asset value (NAV) of 57.68 and net assets of $79.4 billion, there are approximately 1.376 billion shares outstanding of VITSX. Therefore, APS owns 0.033% of the total VITSX shares, which is approximately 0.000675% of Apple's total equity.

APS used emission factors from the Comprehensive Environmental Data Archive (CEDA), a GHGP-approved third party database, for its investment calculations. Because the CEDA database was created using 2002 as its reference year, APS deflated CEDA's category emissions factors by 1.32 - the inflation between 2002 and 2015 - resulting in the 2015 emissions factors shown in Table 6. APS classified Apple in the "electronic computer manufacturing" category and used an inflation-adjusted CEDA emissions factor - 0.183 CO_2e/$ revenue - corresponding to that sector. Apple's annual revenue for 2015 was approximately $$233.72B. Using the average-data method formula (shown below), APS calculated that its equity stake in Apple from the VITSX fund accounted for approximately 289 mt CO_2e in 2015.*

$$
\begin{aligned}
&Emissions\ from\ Apple\ investment \\
&\qquad = ((233.72\ billion\ (\$) \times 0.183\ (kg\ CO_2e/\$\ revenue)) \times 6.85\ x\ 10^{-6})
\end{aligned}
$$

Next, APS employed this methodology to calculate the GHG emissions for the remainder VITSX's top ten holdings. The results are shown in the following tables:

* *Note: All equity calculations were performed using the Society's investment information from its 2015 Annual Report and market information (share price, outstanding shares, etc.) from January 2017.*

Table 5

Company Name	Total Outstanding Shares (in billions)	Shares Held in VITSX (in millions)	VITSX Equity Stake (%)	APS Equity Share (%)
Apple	5.247	107.36	2.05	6.75E-04
Microsoft	7.728	156.55	2.03	6.68E-04
Exxon Mobil	4.147	87.9	2.12	6.99E-04
Johnson & Johnson	2.721	57.66	2.12	6.99E-04
JPMorgan	3.578	75.82	2.12	6.99E-04
Berkshire Hathaway	2.466	39.40	1.60	5.27E-04
Amazon	0.475	8.56	1.80	5.95E-04
General Electric	8.846	187.37	2.12	6.99E-04
Facebook	2.89	49.60	1.72	5.66E-04
AT&T	6.141	130.16	2.12	6.99E-04

Table 6

Company Name	APS Equity Share (%)	Annual Revenue (in billions of US$)	CEDA Category	Emissions Factor (inflation-adjusted)	Metric Tons of CO_2e
Apple	6.75E-04	233.72	Computer manufacturing	0.183	289
Microsoft	6.68E-04	93.58	Software publishers	0.066	41
Exxon Mobil	6.99E-04	259.49	Oil and gas extraction	0.380	690
Johnson & Johnson	6.99E-04	70.07	Pharmaceutical manufacturing	0.215	105
JPMorgan	6.99E-04	93.54	Investments and related activities	0.057	37
Berkshire Hathaway	5.27E-04	210.82	Insurance agencies, brokerages	0.068	76
Amazon	5.95E-04	107.01	Wholesale trade	0.133	85
General Electric	6.99E-04	117.39	Industrial machinery manufacturing	0.421	345
Facebook	5.66E-04	17.93	Internet publishing and broadcasting	0.160	16
AT&T	6.99E-04	146.80	Telecommunications	0.132	136

APS's total 2015 GHG emissions for the top ten equity holdings in VITSX were estimated to be 1820 metric tons of CO_2e. VITSX includes 3,592 total holdings and the top ten holdings account for 15.6% of its net assets. The GHG emissions related to just VITSX's top ten holdings are greater than the APS's annual GHG emissions from its day-to-day operations.

APS's entire investment portfolio includes more than a single mutual fund and was valued at approximately $135 million. At that time, the total fair market value associated with APS's VITSX holding was equal to approximately $25.2 million – approximately 18.7% of APS's investment portfolio value.

To estimate the GHG footprint due to the Society's investment portfolio, APS made the following two assumptions:

1. The 84.4% of VITSX holdings not included in its top 10 holdings resemble the top 10 equities
2. The remainder of APS's investment portfolio is similar to the VITSX fund

These assumptions were reviewed by Anthesis and deemed to be sufficient for their intended use. Using these two assumptions, APS calculated that its entire VITSX equity stake was responsible for approximately 11,667 metric tons of CO_2e and its entire investment portfolio was responsible for approximately 62,393 metric tons of CO_2e.

The total GHG emissions for APS's investment portfolio in 2015 were approximately 62,393 mt CO_2e.

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To: Kate Kirby, APS Chief Executive Officer

From: C. William McCurdy, GHG Inventory Advisory Committee Chair C. Will McCurdy

Date: September 7, 2017

Re: GHG Inventory – Next Steps & Proposed Actions

Background
As a follow-up activity to the APS 2015 Statement on Earth's Changing Climate, APS elected to conduct an internal analysis of its greenhouse gas (GHG) inventory for fiscal year 2015.

The GHG Inventory project has been managed by the GHG Inventory Advisory Committee, which is overseen by the APS Panel on Public Affairs and reports directly to the APS CEO. Additionally, APS selected the Anthesis Consulting Group – a global specialist consultancy skilled in GHG inventory development – to support the Committee and assist APS in determining its inventory. Anthesis was also charged with helping APS develop the tools and institutional knowledge necessary for the Society to conduct its own GHG inventory going forward.

Status
APS has completed the vast majority of its 2015 GHG inventory, including all of the Society's Scope 1 and 2 emissions and two Scope 3 emission categories: APS member travel to/from six of its national meetings and APS's investment portfolio, which are by far the two most dominant contributors to APS's GHG footprint.

APS's Scope 1 & 2 emissions were verified by an independent third party (Cameron-Cole) and publicly posted online with the Climate Registry. APS is the first professional scientific society to broadly evaluate its GHG emissions and publicly post the results.

Recommendations
The GHG Inventory Advisory Committee reviewed the results-to-date and held a meeting to determine what – if any – actions APS should consider taking going forward. The Committee unanimously agreed to recommend the following set of actions for consideration by the APS Board:

Scopes 1 & 2: APS Daily Operations

- **Consider Purchasing Renewable Energy Certificates (RECs):** APS should investigate the possibility of purchasing RECs for the electricity used by APS at each of its three locations – Ridge, NY; College Park, MD; and Washington, DC. OPA staff should work with the appropriate APS staff at College Park and Ridge to determine the practical and economic feasibility of purchasing RECs at each location.

- **Improve Buildings' Energy Efficiencies:** OPA staff should work with building management at the National Press Building and the co-owners of the American Center for Physics (ACP) to improve the energy efficiencies of the buildings, where possible.

Scope 3: APS Meetings Travel and Investments

- **Include GHG Impact in Choosing Meeting Locations:** APS should encourage the Meetings Department and Unit leaders to include the GHG impact of proposed meeting locations as one of APS's selection criteria when choosing national meeting locations. For instance, this may involve giving preference to locations that have energy efficient convention centers, are airline hubs, or have demonstrated emissions reductions programs. OPA staff can work with Meetings staff and Unit leaders to evaluate GHG emissions for potential meeting locations.

- **Consider Offering Carbon Offsets for Meeting Travel:** APS should consider developing a program/mechanism to enable APS meeting attendees the opportunity to purchase carbon offsets for the emissions associated with their travel to/from the meeting as a part of the registration process. OPA staff should research and evaluate various carbon offset programs to determine their impact and accountability. OPA staff should develop a short list of appropriate programs for consideration by the APS Board. Additionally, an appropriate badge marker/sticker indicating participation in the carbon offset program should be awarded to participating attendees at registration, which will help to spread awareness and encourage participation.

- **Explore Ways to Improve Travel Data and Model:** The OPA should determine if refinements to its current model for calculating emissions from attendee travel could significantly improve its accuracy. If so, then APS should determine the feasibility of collecting additional information at registration (mode of transportation to/from airport, connecting flights/layovers, etc.) to provide better estimates of the GHG impact associated with attendee travel. APS should assure attendees that any collected data would be anonymized prior to data analysis by APS or a third party in a way that would ensure it cannot be attributed to individuals.

- **Engage Investment Managers:** APS should develop contacts with the asset managers responsible for managing mutual funds within the APS portfolio. OPA staff should work with the APS CFO to engage fund managers and advocate that they support – via voting shares – shareholder resolutions aimed at addressing climate change and its potential impacts.

Community Outreach

- **Promote GHG Activities:** APS should inform its membership through a "Back Page" article in APS News. To encourage scientific societies and other like-minded organizations to take similar action, APS should also publicize its GHG inventory activities more broadly, potentially through an article in the National Academies "Issues in Science and Technology."