PowerHouse

(1) Award Information

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Principal Investigator: Alan Lishness (September 2012-June 2014), Leigh Peake (July 2014-February 2015)

TEAM MEMBERS:

Gulf of Maine Research Institute (GMRI)
Alan Lishness, Chief Innovation Officer (retired)
Leigh Peake, Chief Education Officer
Thomas Farmer, New Products Manager
Gayle Bodge, *PowerHouse* Program Manager

Iberdrola USA
Laney Brown, Director of Smart Grid Planning and Programs

Central Maine Power (CMP)
Barbara Simmons-Haltof, IT Technical Support for MDM
Paul Sisson, Business Technical Support for MDM
Leona Michelsen, Energy Manager Integration
Donna McNally, IT Technical Management Support
Jayme Holland, Energy Manager Implementation
Khanh Vo, Energy Manager Support
Tom Barks, Lead Analyst - Research

Tilson
Joshua Broder, Chief Executive Officer
Chad Flynn, VP IT Consulting, Technical Architect
Richard Evans, AMI Team Lead
Rich Spies, Project Manager
Kim Shelly, Senior Developer
Ben Birney, Senior Developer
Matt Merrill, Senior Developer

Image Works
Dana Hutchins, President, Creative Director
Misty Mallar, Information Architect, Project Manager
Liem Khuu, Solutions Architect, Programmer

Maine Mathematics and Science Alliance (MMSA)
Jan Mokros, Senior Project Director
Lynn Farrin, STEM Education Specialist

Gulf of Maine Research Institute
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(2) LIMITATIONS AND LIABILITY

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The Gulf of Maine Research Institute does not claim intellectual property restrictions for its role in *PowerHouse* as performed under DE-FOA-0000609.

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(3) Executive Summary

Under Phase I of the Smart Grid Data Access Pilot Program, the Gulf of Maine Research Institute (GMRI) partnered with Central Maine Power (CMP), and the Maine Mathematics and Science Alliance (MMSA) and engaged key vendors Tilson Government Services, LLC (Tilson), and Image Works to demonstrate the efficacy of *PowerHouse*, an interactive online learning environment linking middle school students with their home electricity consumption data provided through CMP's Advanced Metering Infrastructure (AMI).

The goal of the program is to harness the power of youth to alter home energy consumption behaviors using AMI data. Successful programs aimed at smoking cessation, recycling, and seat belt use have demonstrated the power of young people to influence household behaviors. In an era of increasing concern about energy costs, availability, and human impacts on global climate, GMRI sought to demonstrate the effectiveness of a student-focused approach to understanding and managing household energy use. We also sought to contribute to a solid foundation of science-literate students who can analyze evidence to find solutions to increasingly complex energy challenges.

While technical hurdles prevented us from achieving the scale of student engagement projected in the original proposal, results from Phase I nevertheless demonstrate the effectiveness of *PowerHouse* to bring science and math home to the kitchen table and to help students and families understand and manage electricity consumption:

- 144 teachers learned about *PowerHouse* through workshops or other events and 33 teachers engaged students in the *PowerHouse* curriculum in their classrooms over the duration of this project. Fifty teachers have shared plans to use *PowerHouse* during this calendar year (2015).
- Over the duration of this project, 1630 students created accounts on *PowerHouse* and 295 of these students connected their CMP Energy Manager electricity data to *PowerHouse*.
- During our most recent complete school year (2013-2014):
    - 9 teachers engaged their students in a 4 (or more) week experience using *PowerHouse* curriculum
    - Those 9 teachers represented 357 students
    - 114 of the 357 students were connected to their CMP Energy Manager data through *PowerHouse*; the remaining students used the *PowerHouse* program and curriculum without connecting to Energy Manager

The number of student accounts connected to their CMP AMI electricity data through *PowerHouse* is far below the goal of 1000 accounts. This is primarily attributable to successive technical challenges described in more detail below. However, program staff continue to address all aspects of this challenge: ongoing recruitment of teachers into *PowerHouse*, classroom processes to smooth out communications with families, and streamlining the technology. We anticipate reaching the goal of 1000 total CMP-connected accounts by the close of the 2015-2016 school year.

Initial measures with regard to reducing home energy consumption are inconclusive. Qualitative measures of student engagement with energy consumption behavior, and its link to the environment, were extremely high during the time of program implementation. Two sets of data of actual energy savings resulting from students' experiments show conflicting results. Savings ranged from a decrease of 14.9% to an increase of 17.4%. The treatment group overall behaved worse than the control group (3.5% savings versus 2.8% savings respectively), but the treatment groups included in these very preliminary analyses were too small to allow us to draw conclusions from this data. Overall we hypothesize that detecting the impact of students' energy reduction experiments (for example, swapping out home lighting to CFL bulbs) was confounded by energy use patterns elsewhere in the home.

(4) Actual Accomplishments Versus Goals of Project

Five project objectives were identified at the time of the proposal as described below. The fifth (business planning for scaling and expansion in the domestic retail electricity market) was pended at the time of our no-cost extension (10/31/13).

Project Objective 1: To provide electricity use data to Maine's 7th and 8th-graders involved in STEM education via the Gulf of Maine Research Institute's PowerHouse program and CMP's AMI network and online Energy Manager.

Led by Gayle Bodge, GMRI's PowerHouse Program Manager, and in collaboration with MMSA, we recruited 26 teachers to pilot the *PowerHouse* program. They attended a 2-day teacher training in January of 2013. Over the course of the spring of 2013, 23 of those teachers worked with students and their families to create 1054 student accounts. Of these, 181 connected their *PowerHouse* accounts with CMP's AMI data. This represents a 17% connection rate.

Feedback from these teachers and students formed the basis of significant revisions to the web interface as well as GMRI staff efforts to support teachers, students, and families in the process of connecting their *PowerHouse* and CMP accounts.

In the 2013-2014 school year, after additional training events for both existing and new participant teachers, 9 teachers engaged their students in 4 (or more) weeks of *PowerHouse* curriculum in their classrooms, resulting in 357 student accounts of which 114 were actively connected to Energy Manager. This represents a connection rate of 31.9%, almost double compared to the prior year. We hypothesize that a deeper and longer engagement with students in *PowerHouse* curriculum motivated more students and families to connect their CMP AMI data to *PowerHouse*.

Our focus at the start of the 2014-2015 school year was to implement another round of improvements to the program and interface that were suggested by participating teachers during the prior 18 months. Therefore, at the time of this report, we have just re-opened the website and teachers are just launching *PowerHouse* in the classroom, and student accounts are just being created. We thus cannot yet report rates of connected accounts for the current school year.

Based on the results above, GMRI, CMP, and Tilson have clearly demonstrated that it is possible to connect 7th and 8th grade students to their home electricity consumption data via CMP's AMI network and online Energy Manager. Creating this connection is currently a multi-step process:

- Teachers create *PowerHouse* accounts and link those accounts to CMP's Energy Manager.
- Teachers secure parental permission for students to access their home electricity consumption data through CMP's Energy Manager. Over the course of the project, GMRI and participating teachers achieved an astonishing 85% sign-off from parents for student use of their electricity data, a significant vote of confidence in GMRI as a trusted education partner.
- Parents not yet participating in Energy Manager sign on and create an account. Confirmation and completion of account setup follows approximately 24 hours after the initial request.
- Teachers design and implement a system for establishing student accounts on *PowerHouse*, some of which will be connected to Energy Manager and some of which will not.

All project partners agree that simplifying the account creation process will significantly increase the number of student accounts accessing home electricity data through CMP's Energy Manager. Given that student account connection rates vary from 17-31%, GMRI staff devoted time to building methods by which students without connected accounts could still participate in the educational aspects of the program. Most notably, staff created a "mystery home" where students view Energy Manager consumption data for an anonymous Maine household. They can also manually enter their own home's electricity use as on *PowerHouse's* dynamic home inventory.

Project Objective 2: To demonstrate, document and evaluate the effectiveness of student engagement with CMP's home electricity use data and student interest and ability to impact household behaviors around energy use patterns.

Two goals related to this objective were described at the time of the proposal:

1. Changes in household electricity management will be measured by documented reductions in monthly electricity use. CMP's Energy Manager and GMRI's online learning portal have provisions for documenting changes in home electricity use on a month-by-month basis. GMRI has set a goal of a 5% reduction in electricity used based on the household behavioral impacts of student engagement. Additionally, CMP will utilize the analytical tools and lessons learned from the Information Research Study conducted under the Smart Grid Investment Grant to assess effectiveness of this new initiative.
2. GMRI and MMSA staff will administer pre- and post-training surveys to teachers and students to determine the extent to which students understand the principles of energy production and consumption and show an increased understanding of energy use in their own homes, and have an increased interest in STEM-related courses.

An additional benchmark was that CMP would successfully port customer usage data from 1000 selected households to GMRI's *PowerHouse* student online learning environment. CMP's Energy Manager would also track modifications in energy usage across those 1000 households in the Phase I Demonstration.

GMRI, MMSA, and CMP collaborated to create a combination of quantitative and qualitative measures of the impact of *PowerHouse* on household energy use and on student interest in managing energy use in their households. GMRI and CMP were successful in constructing a system by which to track modifications in energy usage for any *PowerHouse* student connected to their CMP Energy Manager account. However, over the period of the project, 349 household accounts were connected to electricity usage data from CMP's Energy Manager in comparison to the target of 1,000 households. These represent a combination of student, teacher, and school administrator accounts. It is important to note that connected accounts represent only a fraction of the total number of households engaged with and interested in evaluating household energy use patterns through the *PowerHouse* program. Increasing the percentage of connected accounts is a clear priority for *PowerHouse* going forward so that we can assess program impacts on changes in behavior and reduction in electricity usage.

Measures of Student Engagement with Household Energy Use

Project staff collected substantial evidence of student engagement around monitoring and reducing household energy use. As a start, teachers and students were surveyed separately to gain an initial understanding of student/family behavioral change around electricity use. 62% of student respondents suggested that *PowerHouse* caused them to think about or change the way they used electricity at home. 50% of students reported having conversations with their families, such as, "I showed them how we can see what amount of electricity we're using and why. I showed them how to save electricity too."

GMRI staff observed and documented how Jenny Galasso and Rick McGuire, 7/8th grade science and math teachers at Bath Middle School, implemented an innovative expeditionary unit they developed about energy. Their goal was for students to examine their electricity use through *PowerHouse* and make evidence-based decisions about reducing their household electricity use with their families.

> The first week of my investigation, my family went through life as usual, unnecessary lights were on, and we had no idea how much electricity we were using. But, throughout the second week, we monitored our electricity use with *PowerHouse*, and turned off all unnecessary lights. The smallest things can make a big difference. During that week my family saved 26 kWh, that's about 8% by just turning off lights… My carbon footprint was reduced by about 8% in just one week; imagine what a month or even a year could do! That's 1352 kWhs my family could save, about one metric ton of carbon. It is important to continue monitoring electricity use, and turning off lights because our environment needs it… The hardest change for anyone to make, is to be aware. A simple change, and being aware of your electricity use, will go a long way. - *Eighth grade student investigation report*

Bath Middle school students also employed behavioral science techniques, such as social norming and modeling, as well as using their personal experiences reducing electricity usage to develop public service announcements. This was a collaborative project, with students working in teams facilitated by their math, science, and computer teachers. Students felt empowered to share their experiences and knowledge with their peers, families, town officials, and staff from GMRI, MMSA, and CMP by hosting a presentation of their public service announcements and conservation plans. They knew the work they did, in their classrooms and at home, made a difference.

Measures of Household Energy Savings

Initial results regarding impact on actual household energy use are inconclusive. (A more detailed description of electricity usage data over the life of the project is included as Appendix A.) Project staff had hypothesized electricity usage reductions of 5% in households where students were actively engaged with *PowerHouse* accounts connected to CMP usage data. Over the course of the project, changes in energy consumption in connected households during the time when students were engaged with *PowerHouse* ranged from a decrease of 14.9% to an increase of 17.4% in usage.

Given the program's behavioral approach, a high percentage of connected accounts per classroom are needed to produce statistically significant results correlating the impact of *PowerHouse* to a reduction in electricity use. Central Maine Power's lead analyst, Tom Barks, produced a preliminary report that illustrated this point. Of the 12 towns researched, only 2 contained 50 or more data points (students whose *PowerHouse* accounts connected with their home electricity use). While this report was not produced as an evaluative tool, initial estimates suggest a trend toward savings of 5% or more. Again, more data points are needed to confirm these initial results. Overall we hypothesize that detecting the impact of students' energy reduction experiments (for example, swapping out home lighting to CFL bulbs) was confounded by energy use patterns elsewhere in the home. In addition, the *PowerHouse* curriculum was designed to support students to engage in a one-time investigation to reduce electricity use. We're currently developing new curriculum to focus families on identifying and making prolonged energy reduction behavior changes over an extended period of time.

To mitigate the approximately 70% of students per class not connected to their home electricity data, project staff recently worked with Image Works to develop and implement a home electricity inventory that helps students identify appliances with the highest energy demand. Work with teachers and students in the current school year will allow us to test this tool in supporting students to develop the most impactful household experiments possible.

Project Objective 3: To leverage the Maine Learning Technology Initiative (MLTI), which provides every Maine 7th- and 8th-grader and their teacher with a personal laptop computer connected to high speed Internet access in the classroom.

Since 2002, Maine committed to providing every 7th- and 8th-grader in the state with their own personal computer that connects to high-bandwidth Web access in every classroom. Maine has exceeded that goal and is well on its way to 100% coverage in 7-12th grades statewide. This infrastructure presented a unique opportunity to test and refine the *PowerHouse* program. Every student was able to access *PowerHouse* in the classroom, and take the technology home to share with their families.

Project Objective 4: To provide a relevant and compelling STEM education opportunity as a means to cultivate and support a scientifically-literate workforce.

For the 2013/14 school year, we decided to simultaneously support teachers in implementing *PowerHouse* and select a few classrooms for focused observations. This met two goals of 1) documenting case studies of teacher-developed STEM curriculum, and 2) testing user experience to inform the next iterations of the web platform. From mid-October through December 2013, GMRI staff observed *PowerHouse* being implemented at Bath Middle School. This resulted in the development of a comprehensive curriculum starting with math and science exercises around electricity and culminating in a deeper understanding of the link between residential electricity use and climate change. Students conducted scientific experiments that resulted in home energy conservation plans and culminated with Public Service Announcements. These were presented on December 18, 2013 to classmates, members of the Bath town council, GMRI staff, and local newspapers. GMRI staff also observed *PowerHouse* at Portland's Breakwater School and Windham Middle School, which resulted in additional teacher-developed STEM resources on the program website.

GMRI, MMSA, and Bath Middle School teachers, Jennifer Galasso and Richard McGuire, collaborated to document their classroom *PowerHouse* experience by writing a white paper (see Appendix B, An Energy Expedition). This paper shares the STEM activities they developed to engage their students with *PowerHouse* data and climate change concepts.

> Abstract:
> Integrated science and math classes engaged eighth-grade students in an energy expedition to investigate their home electricity use, develop scientific understandings of how that use impacts the Earth, and use data as evidence to change their families' energy habits. Throughout this experience teachers incorporated the Next Generation Science Standards scientific practices, cross-cutting concepts, and disciplinary core ideas with emphasis on MS-ESS 3.C "…humans have become one of the most significant agents of change in the near-surface Earth system. And because all of the Earth's subsystems are interconnected, changes in one system can produce unforeseen changes in others (NRC 2012)."
>
> Electricity is an integral part of modern life and one that is often overlooked. To make electricity use visible to students, teachers incorporated *PowerHouse*, a newly developed, inquiry-based, virtual learning environment. *PowerHouse* provides families access to their household electricity use data by connecting to smart electrical meters. Engaging students with personally relevant information, like home electricity consumption data, puts them at the center of their learning. Realizing the impact of their household energy usage empowers students to make informed decisions about how they use electricity at home and engage productively in the quest for climate change solutions. – An Energy Expedition.

GMRI is currently seeking publication opportunities.

Project Objective 5: To increase the marketplace for third party solutions, in Phase II, GMRI and Tilson will undertake a business planning process to prepare for scaling and replicating the PowerHouse model in the domestic retail electricity market.

At the time of the no-cost extension *PowerHouse* was removed from Phase II of Smart Grid Data Access, removing this objective from the program.

(5) Summary of Project Activities

An overview of project activities is presented in the table below. Following the table are narrative descriptions of accomplishments related to significant areas of project activity: project management, teacher engagement, connecting student accounts, curriculum development, learning assessment, and web site development.

Project Timeline	**Milestones**	**Participation**		
		Workshop Attendance	**New Teachers Using *PowerHouse***	**New Student Accounts**
Q3 2012	Received Department of Energy Grant			
Q4 2012	Recruited 26 teachers for prototyping and developed specifications for website			
Q1 2013	Workshop for prototyping teachers and website BETA launch	26		
Q2 2013	Teachers tested the family communication strategy, connecting to CMP data, classroom observations		23	1200
Q3 2013	Minor web edits and content development			
Q4 2013	½ day workshop and observations at Bath Middle School	12	2	80
Q1 2014	Hired new staff	5	3	90
Q2 2014	Added carbon output layer, developed content and hosted 2 introductory workshops, recognized by White House	36	4	190

Q3 2014	Developed specifications for inventory, community, and registration web edits and hosted 1 introductory workshop	20		
Q4 2014	Major web edits, content development, launch of live website and hosted 1 introductory workshop, presented at Behavior Energy and Climate Change conference	45	1	70

Project Management

The project team met in person and/or by phone conference every Friday morning starting August 2012 led by GMRI New Products Manager Tom Farmer and Rich Spies, the contract project manager provided by Tilson. This time was critical to addressing final data privacy and security issues as we vetted and initiated connection methodology with CMP and CMP's data visualization vendor. Initial meetings established project budgeting and reporting structures. Additional meetings were established as needed to address issues related to customer login to CMP's Energy Manager and GMRI's *PowerHouse* environment, management of customer privacy/security, co-branding between *PowerHouse* and CMP, coordination and development of a publicity plan, and *PowerHouse* program development.

The project team gained significant insight through annual engagement with GMRI's education advisory board in October 2012, 2013, and 2014. In particular, this group considered methodologies for building out long-term experiences for families, personalizing the *PowerHouse* experience through mapping of both energy use and behaviors around energy use, and integration of behavioral incentives to influence actions.

Another significant area of program management activity included legal consultation to guarantee appropriate levels of permissions for students to connect to household accounts at Central Maine Power. This work began in October 2012 assisted by the law firm Drummond Woodsum. GMRI staff and Drummond Woodsum counsel drafted a program descriptor and permission form to introduce *PowerHouse* to parents as well as a concise privacy policy and user agreement for utility account owners (parents, teachers) in the *PowerHouse* program. These documents were vetted with CMP counsel and finalized to match current technology and program goals as of December, 2012.

We re-engaged counsel when student observations confirmed that *PowerHouse* would benefit from a combination of web edits including (1) decoupling individual accounts from teachers/schools (leading to more persistent savings) and (2) giving students access to social sharing and therefore norming to maximize impact on engagement and presumably energy behavior of other household members. We worked again with Drummond Woodsum during the spring of 2014 to ensure a safe online environment for under 13 year olds, in alignment with the Children's Internet Protection Act (CIPA) and the Children's Online Privacy Protection Act (COPPA) regulations. We also revised our permission letter, privacy policy, and user agreement.

Teacher Engagement

September 2012-June 2013

GMRI collaborated with MMSA to recruit teachers, beginning in September 2012. Teachers were vetted for past experience working with science process (including data visualization and/or evidence-based reasoning) in either GMRI's or MMSA's education programs, responsiveness, and comfort with the "messiness" of prototyping a new program.

In January of 2013, *PowerHouse* and MMSA staff met with 26 teachers for a 2-day professional development session in which all aspects of the program including example curriculum were explored. Sixteen schools were represented and typically included math-science teacher teams. Teachers left the January workshop with the goal of immediately connecting as many families as possible with CMP's Energy Manager portal—the first technical step in connecting family data to *PowerHouse*. Even though *PowerHouse* connection issues had not been resolved in late January, we felt this process was important as this started the flow of data in Energy Manager and, eventually, *PowerHouse* accounts. To this end, teachers sent home a packet of information including (1) an opt-in form, (2) a permission slip, and (3) instructions for connecting to CMP's Energy Manager.

Once accounts were set up, GMRI and MMSA staff visited all schools at least once to check in, provide assistance, and document accomplishments where appropriate. Starting in February 2013, GMRI and MMSA held virtual monthly meetings with teachers to provide support. Over time, teachers began to share curriculum ideas and success stories. Each month included two webinars to meet the scheduling needs of teachers as closely as possible. Webinars were recorded for teachers who were not able to participate.

A culminating "Dine and Discuss" event was held on May 21, 2013. Teachers reviewed program elements from account creation to curriculum. In sharing their *PowerHouse* experiences, teachers also looked ahead to how they would incorporate *PowerHouse* into their curriculum during the 2013-2014 school year. The night concluded with teachers suggesting *PowerHouse* program upgrades and use scenarios.

"What I liked about PowerHouse from the very beginning is that the program presents a non-polarizing way to look at electricity consumption, with data, without any finger-pointing. PowerHouse is real and helps students make connections among energy, economics, and carbon footprint, in a way that is non-political. I think this is going to be increasingly … the way we'll create a more sustainable future." Kirk Niese, Teacher, Mt. Ararat Middle School, Topsham, Maine

July 2013-June 2014

Starting in July 2013, GMRI staff began recruiting teachers for a second year of implementation, including teachers involved in the first cohort. GMRI and MMSA staff ran two webinars in August 2013 to introduce new teachers to *PowerHouse* and bring first-cohort teachers up to speed on web enhancements based on their feedback. Webinars were followed by an in-person "Dine and Discuss" event in September 2013 to share new curriculum developed by *PowerHouse* and MMSA staff in collaboration with first-cohort teachers. This event also served to develop a support network between and among *PowerHouse* staff and both new and experienced teachers.

The result was a dramatic increase in total interested teacher participants from 26 to 75, including 25 of the first cohort of participants. Account statistics at the start of the 2013/14 school year indicated 61 teachers created accounts. Several engaged their students, which resulted in 310 student accounts, 85 of whom successfully connected their home data to *PowerHouse*. These numbers increased over the course of the year to 93 teacher accounts. The webinars and in-person event led to 114 students and 44 teachers successfully connected their home electricity data to *PowerHouse*.

Teachers' implementation of *PowerHouse* was supported throughout the year through personal communication and a second "Dine and Discuss" event in March 2014 introducing the new carbon tool (described under Web Site Development below). We also ran teacher development workshops on May 9th and May 15th, serving 26 teachers from 17 schools, 10 of which were new to *PowerHouse*.

July 2014-February 2015

Web site developments (described below) prevented availability of the *PowerHouse* program for teachers throughout the first half of the 2014/15 school year. GMRI staff nevertheless engaged with teachers through several professional development events and local education conferences in anticipation of the site's launch in January 2015. August 2014 featured two teacher summer institutes that included 19 teachers from 13 schools, 7 of which are new to the *PowerHouse* program. The remainder of Q3 2014 was focused on improving the user experience based on teacher recommendations.

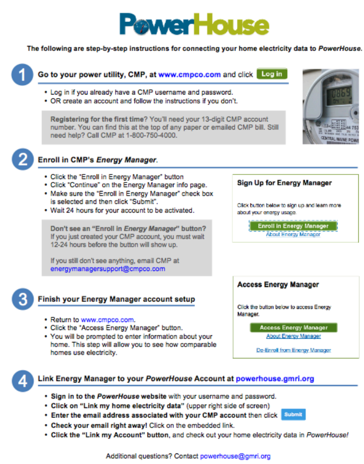
A new cohort of teachers was recruited to implement *PowerHouse* during the later half of the 2014/15 school year. On December 12, 2014 (and prior to release of the updated *PowerHouse* website) another 41 teachers from 23 schools attended a *PowerHouse* introductory workshop. Participants experienced and tested the new *PowerHouse* community function as well as the new

Home Inventory tool (described under Web Site Development below). The completely revised *PowerHouse* site launched in February 2015 and staff have been actively engaged supporting teachers to enroll students and plan implementation of the curriculum. Based on these recent events and conversations, staff anticipate approximately 20 teachers will attempt *PowerHouse* in spring 2015 and another 30 in the 2015-2016 school year.

Connecting Student Accounts

In Spring 2013, at the end of our first cohort of teachers implementing the program, 1054 *PowerHouse* accounts had been created. Of those, 181 (17%) were connected with CMP's Energy Manager, far short of our aspiration of 1000 connected accounts. During this time and due to web development, teachers engaged parents/guardians with signing up for Energy Manager first, before engaging their students with creating *PowerHouse* accounts. We hypothesized that the reverse approach, engaging students first may motivate increased connection.

For the 2013/14 school year, we reversed the sign-up and connection process, engaging students first in creating *PowerHouse* accounts. They then took home a simplified 4-step form to complete with their parent/guardian.


PowerHouse

The following are step-by-step instructions for connecting your home electricity data to *PowerHouse*.

1 **Go to your power utility, CMP, at www.cmpco.com and click** Log in

- Log in if you already have a CMP username and password.
- OR create an account and follow the instructions if you don't.

Registering for the first time? You'll need your 13-digit CMP account number. You can find this at the top of any paper or emailed CMP bill. Still need help? Call CMP at 1-800-750-4000.

2 **Enroll in CMP's *Energy Manager*.**

- Click the "Enroll in Energy Manager" button
- Click "Continue" on the Energy Manager info page.
- Make sure the "Enroll in Energy Manager" check box is selected and then click "Submit".
- Wait 24 hours for your account to be activated.

Don't see an "Enroll in *Energy Manager*" button? If you just created your CMP account, you must wait 12-24 hours before the button will show up.

If you still don't see anything, email CMP at energymanagersupport@cmpco.com

Sign Up for Energy Manager
Click button below to sign up and learn more about your energy usage.
Enroll in Energy Manager
About Energy Manager

3 **Finish your Energy Manager account setup**

- Return to www.cmpco.com.
- Click the "Access Energy Manager" button.
- You will be prompted to enter information about your home. This step will allow you to see how comparable homes use electricity.

Access Energy Manager
Click the button below to access Energy Manager.
Access Energy Manager
About Energy Manager
De-Enroll from Energy Manager

4 **Link Energy Manager to your *PowerHouse* Account at powerhouse.gmri.org**

- **Sign in to the *PowerHouse* website** with your username and password.
- **Click on "Link my home electricity data"** (upper right side of screen)
- **Enter the email address associated with your CMP account** then click Submit
- **Check your email right away!** Click on the embedded link.
- **Click the "Link my Account" button,** and check out your home electricity data in *PowerHouse!*

Additional questions? Contact powerhouse@gmri.org

We also decided to conduct focused work in several selected classrooms (in Bath, Portland, and Windham) to both research implementation and push hard to get a significant proportion of students signed into both *PowerHouse* and connected to CMP. Given the program's behavioral approach, many students associated with the same teacher are needed to produce statistically significant results around electricity savings. CMP's senior analyst, Tom Barks, produced a preliminary report that illustrated this point. Of the 12 towns researched, only 2 contained 50 or more data points—students whose *PowerHouse* accounts connected with their home electricity use. What we found was that engaging students first, and implementing a 4+ week curriculum using *PowerHouse,* increased connection rates from 17 to 31%.

To comply with the Children's Online Privacy Protection Act (COPPA), student accounts were linked with their teacher's account—a responsible adult. At the end of the first two school years (2012/13 and 2013/14), *PowerHouse* accounts had to be deleted because accounts were only linked to schools and specific teachers.
In 2014 we began drafting specifications for a new registration process that would allow students to maintain their accounts indefinitely. This would allow us to engage participants in long-term behavior change around electricity reduction and build the online *PowerHouse*

community. We worked with Drummond Woodsum to ensure alignment with COPPA laws surrounding online accounts for children under 13. In the summer we began working with GMRI's Ocean Data Products team who specializes in Drupal programming (the platform that *PowerHouse* is built within) to update the online registration for *PowerHouse* and add new user profiles with permissions that adhere to COPPA laws.

Currently we're testing a behavioral approach to motivate students to connect their accounts to *PowerHouse*. By making visible how many students have completed each step, we're hypothesizing that they will feel a larger role and responsibility in the process as well as motived by seeing their peers complete steps.

Curriculum Development

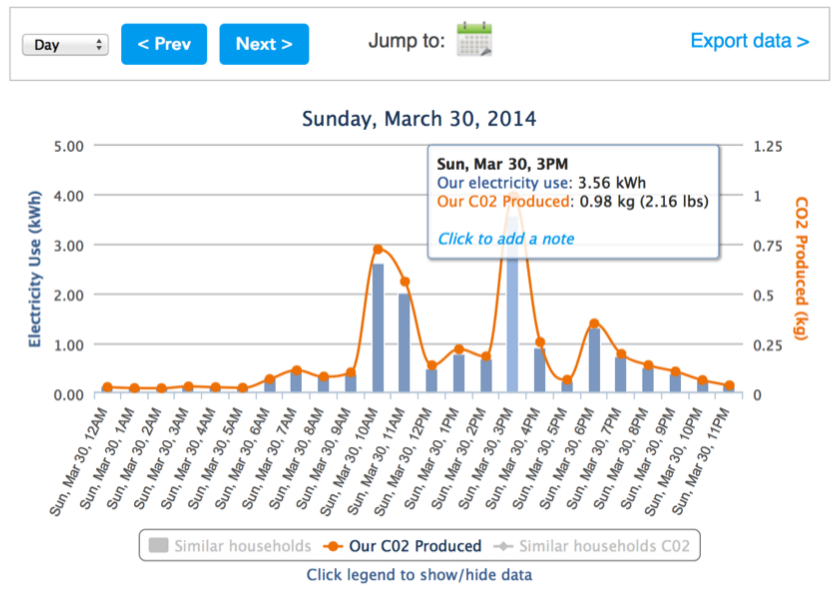
In Q4 2012 GMRI and MMSA staff developed a series of "challenges" (e.g. "How do we use electricity in our house?") and related "investigations" (e.g. "What are the top five energy users in our house?") intended as starter curriculum for teachers to use in conjunction with the *PowerHouse* website. These materials were included in the January 2013 teacher workshop that helped launch the first cohort of program implementation. Curriculum development has been ongoing ever since and has been conducted in collaboration with participating teachers. We have expanded the web site to include 24 additional activities and created a space for teachers to share their experiences and case studies. We are drafting and testing a design process for engaging students in developing an electricity savings plan for their families. We have conducted numerous site visits and have worked directly with 70 students at Massabesic Middle School in East Waterboro, Maine to better understand classroom and home implementation. This work is iterative and on-going. Finally, GMRI and MMSA staff have begun discussions to specify best practices around using online sharing/social networking and student generated content for learning and assessment, especially around engineering process and practices as described in the Next Generation Science Standards (NGSS).

Web Site Development

Web site development activities have had three primary focuses: 1) increasing the number of students with *PowerHouse* accounts connected to CMP Energy Manager; 2) enhancing the informational and educational functionality of the site; and 3) motivating behavior change resulting in reduced electricity use.

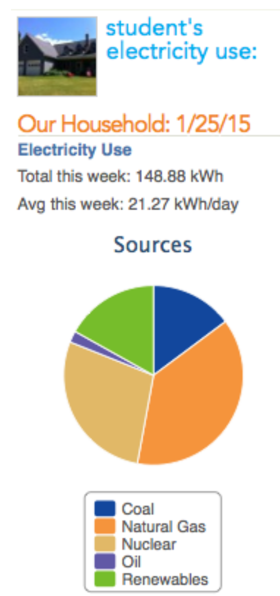
January 2013-June 2014

The project team conducted a full user-experience test in November 2013 to explore remedies to student-family barriers to participation. Participants included representatives from CMP, Tilson, and GMRI. The team concluded that the barriers to adoption could be overcome by allowing participants to opt-in directly using a third party application authorization interface as outlined in the Department of Energy Green Button standard. While CMP currently allows rate payers to download their AMI data directly from the CMP website, there is not currently a facility for powerhouse users to directly authorize that *PowerHouse* receive that data with a single click. Such functionality may be available in the future.



Led by Dana Hutchins, Image Works (GMRI's primary front end web developer and designer) conducted three formal classroom observations during Q2 2013. In addition, GMRI and MMSA staff visited all classrooms and teachers to check in and conduct informal assessments. This first round of classroom observations were compiled into a list of web updates prioritized for (1) ease of account creation, and (2) engagement and understanding of home electricity data.

GMRI and Tilson developed addition Powerhouse functionality at the urging of the state Public Utilities Commission. An important addition to *PowerHouse* functionality—intended to both increase student engagement and more clearly link electricity usage to carbon output—was creating a carbon equivalent overlay that students can use to assess when they are indirectly emitting the most carbon dioxide equivalents during any given time period from within a day, week, month, or year. This work was made possible through access to ISO New England's web service API. The tool correlated student's actual AMI interval data with the energy mix data provided by ISO New England. The tool imputed carbon out to those energy sources and calculated the student's carbon impact per AMI interval. Students are able to compare electricity sources and the relative amounts of carbon each source contributes, and more important, understand when their energy use (or savings) has the biggest impact on carbon emissions, for example on peaking hours or days.



From a teacher's perspective the new carbon overlay assists students in bridging the gap between electricity usage and climate change. Later changes to the carbon overlay included adding an additional spline showing mass CO_2/kWh for clarity. Teachers reported that these combined overlays particularly contributed to student understanding of the "multiplier effect"—the number of kg carbon emitted at a population scale of millions.

The carbon overlay tool was submitted to the DOE Apps for Energy II Challenge with the title, "*How Clean is Your Shirt?*" *PowerHouse* became one of four finalists in the DOE competition. PI Alan

Lishness attended the White House "Datapalooza" event in May 2014 to be recognized for this effort.

July 2014-February 2015

A second round of web development was initiated in summer 2014 to meet teacher needs around site registration process, to bring the site into COPPA compliance such that student accounts could be retained after the close of the school year, to create community building and social norming functionality, and to incorporate data-driven, scaffolded curriculum within each user's site profile. Our specific goals for this work were to:

- Make *PowerHouse* more widely available to our target audience of teachers and students, as well as the general public, specifically by allowing for user account (and therefore savings) persistence. This required a change in our registration process and permission documentation in order to comply with COPPA regulations for children under age 13.
- Build out "communities" functionality (classrooms, etc.) to take advantage of best practices in behavioral science. *PowerHouse's* new community feature allows students to connect online through shared investigation questions, savings goals, and interests. This functionality also encourages peer-to-peer learning and provides a motivation for savings.
- Allow teachers and students to bypass the barriers to students/families connecting their Energy Manager and *PowerHouse* accounts and ensure that all students have access to personal home electricity data. We created a home inventory that incorporates manual entry of devices and appliances and hours used as well as dynamic calculation of total electricity used per device. This home inventory will be incorporated into every user's private profile and simultaneously teach about impacts of lighting, resistive and phantom loads, etc. as the user is guided through data entry and analysis. It will also help users identify areas of behavior change that will have the most impact in reducing their electricity use.

(6) Problems Encountered and Impact/Mitigation

Problems encountered during the span of the project fall in three categories: 1) technical and process barriers to connecting student *PowerHouse* accounts to their family Energy Manager accounts at CMP; 2) difficulties measuring the impact of student/family behavior change due to confounding variables; and 3) inadequate tracking and fidelity of implementation of the *PowerHouse* curriculum in the classroom.

Barriers to Connected Accounts

Despite significant time and effort on the part of all project partners, technical and procedural issues connecting *PowerHouse* and Energy Manager accounts persisted throughout the project. At project launch, Tilson worked with the CMP/API vendor to address technical difficulties accessing and delivering customer data from the AMI system. Unfortunately, AMI data was not available to the project for import until February 2013, at which point CMP, Tilson, and Image Works resolved these issues.

CMP then conducted significant additional work in April 2013 in which they streamlined their Energy Manager signup process from three days to two. Teachers reported that the combined streamlining efforts significantly improved the experience for students and families.

Nevertheless, many of our initial cohort of teachers—most of whom were savvy, early technology adopters—were unsuccessful at engaging students and their families. While 85% of parents agreed to let their children access their own home's electrical data through *PowerHouse*, only 17% actually made the technical connection between *PowerHouse* and CMP's Energy Manager. In classrooms in Bath, Portland, and Windham, Maine where project staff engaged in deeper ways, connectivity improved. A comparison of students' signups from Spring 2013 to Fall 2013 revealed a jump in connection rate from 17% in the spring to more than 30% in the fall. This may be attributed to either teacher/student/family familiarization with *PowerHouse* and/or program ramp-up and evolution over time.

Simplifying and streamlining the registration process will continue to be a focus for project work going forward as it is a significant barrier to scaling and replicating the program.

Difficulties Measuring the Impact of Student Behavior Change

An unanticipated challenge to demonstrating the effect of changes of behavior in families was the relative impact of student experiments compared to the overall energy load in the household. For example, a common intervention by students was to replace all lighting in the house with CFL light bulbs and compare electricity usage before and after the intervention. However, students were unlikely (or unable) to hold all other appliance usage absolutely steady during the before and after periods, which means changes in usage of other appliances had a dramatic impact on student results.

The addition of the Home Inventory feature in our latest round of site upgrades is an initial attempt to mitigate this challenge. The Inventory focuses student attention on the energy "hogs" in the household, allowing them to focus interventions on use of those appliances.

Fidelity of Implementation

Tracking the fidelity of teacher implementation of the curriculum is a persistent challenge in educational research and development. Despite significant effort by GMRI and MMSA staff to visit classrooms throughout the course of the project, it was extremely difficult to determine differences among teachers in the various cohorts in terms of, for example, their effort to launch the program and secure connected student accounts, or the guidance provided to students regarding appropriate and impactful interventions in household energy use.

Going forward, the project will create additional tools for facilitating communication with collaborating teachers and tracking the details of their implementation of the program. This information, in turn, will support future teachers in focusing on practices with the highest impact on student understanding and energy reduction.

(7) Products Developed and Technology Transfer

(a) Publications; conference papers; or other public releases of results.

- GMRI presented a *PowerHouse* workshop at the Maine Science Teachers Association annual conference - October 12, 2012
- GMRI presented a *PowerHouse* workshop at the Maine Science Teachers Association conference - October 11, 2013
- Sea State Lecture, GMRI. Reimagining Education for the 21st Century. GMRI Education Staff. December 5, 2013. Overview of GMRI education programs, including *PowerHouse*. Open to the public.
- *PowerHouse PSAs*. Produced by students at Bath Middle School. Examples of student work products.
- The Coastal Journal (Bath). Bath students create PSAs to reduce Maine's energy consumption. Thursday, December 26, 2013, p1.
- The Times Record (Brunswick). Bath students educate themselves and others on managing energy. Wednesday, December 31, 2013, p1.
- Smart Grid Investment Grant Program – Progress Report II (October 2013), p7. Callout under "The Green Button Initiative".
- GMRI and *PowerHouse* exhibited at the Maine Climate Solutions Expo - March 12, 2013http://www.wcsh6.com/story/news/local/2014/05/22/maine-program-named-finalist-for-national-energy-project/9458149/
- *PowerHouse* was entered and became a finalist into DOE's Apps for Energy II Challenge: http://energy.gov/data/articles/second-round-american-energy-data-challenge-winners-announced and http://energychallenge.energy.gov/a/dtd/PowerHouse-How-Clean-is-Your-Shirt/53038-26122
- Local news networks interviewed GMRI staff and Bath Middle School teachers and students about their *PowerHouse* experience: http://www.wcsh6.com/story/news/local/2014/05/22/maine-program-named-finalist-for-national-energy-project/9458149/
- GMRI and MMSA submitted a paper to the NSTA (National Science Teachers Association) journal on teacher Jenny Galasso's experience with *PowerHouse* in Bath, Maine. It was not accepted, but we are pursuing other publication opportunities.
- GMRI and Bath Middle School teachers co-presented a *PowerHouse* workshop at the Maine School of Science and Math STEM Educators Workshop - August 2014

- GMRI presented a *PowerHouse* workshop at the Maine Science Teachers Association annual conference - October 10th, 2014
- GMRI presented a workshop at the New England Environmental Educators Association annual conference - October 24 & 25, 2014
- GMRI/*PowerHouse* presented at the 2014 Behavioral Energy and Climate Change Conference (BECC) in Washington, D.C.

(b) Website or other Internet sites that reflect the results of this project.

- Updates to http://powerhouse.gmri.org/ based on classroom observations. Username: student, Password: student.

(c) Networks or collaborations fostered.

- Throughout the project, Principal Investigators Lishness and Peake continued to meet monthly with GMRI's *PowerHouse* advisory group populated by members of GMRI's Board of Trustees as well as stakeholders from utility companies and education groups.
- Three times over the course of the project GMRI discussed *PowerHouse* progress with its education advisory group (October 2013, October 2014), international-caliber educators focused on technology and informal learning. They recommended connecting *PowerHouse* with our *LabVenture*! program as a follow-on activity for interested teachers. Though likely not within the scope of this grant period, the idea is interesting as *LabVenture*! reaches 10,000 students per year.
- GMRI is continuing conversations with Iberdrola USA to consider a *PowerHouse* program launch in its New York state service area.
- GMRI has met with members of the Maine Public Utilities Commission and Office of Public Advocate to discuss program extension and impacts. Implementation of ISO New England cost/carbon overlay to address teacher requests around climate was one outcome of these meetings.
- Brown presented to the DECC UK, contributing to their research on Smart Meters in preparation for the UK Smart Meter rollout.
- Brown presented to TNB Malaysia, contributing to their research on Smart Meters as part of Malaysia's Smart Grid program development.
- Lishness spoke at the IEEE Smart Grid Innovation Conference, Feb 2014.
- Lishness served on a three-person panel chaired by Donald MacDonald, DOE, titled *Smart Grid Investment Grant (SGIG): AMI Projects and Customer Education*. Don MacDonald also stimulated an ongoing conversation with Peter Cappers at LBNL to discuss the inclusion of Maine 7th and 8th-graders in the Consumer Research Study to understand the extent to which students influence household electricity consumption behaviors.
- Lishness was recognized for work on *PowerHouse* at the Whitehouse Datapalooza on May 28, 2014.

- GMRI initiated a partnership with the Rochester Institute of Technology (RIT) through inclusion in their pending proposal to the National Science Foundation's Environmental Sustainability program.
- Brown and GMRI presented to National Grid of Massachusetts in preparation for their Grid Modernization effort.

(d) Technologies/Techniques: None.

(e) Inventions/Patent Applications, licensing agreements: None.

(f) Other products, such as data or databases, physical collections, audio & video, software and netware, models, educational aid or curricula, instruments or equipment.

Curriculum and classroom case studies have been posted to the *PowerHouse* website. Curriculum development is ongoing.

The program team has developed a Carbon Overlay tool that provides real-time energy mix information such that students understand time-of-day implications of electricity usage in the context of carbon footprint. While not initially envisioned as a component of this effort, the enhanced product is being developed within the original budget structure.

PowerHouse users now have access to a manually input home inventory of devices and appliances such that users (1) understand how electricity is used in their home and (2) can make data-driven decisions about home electricity usage.

Account registration has been changed from teacher-connected to individual such that accounts can persist following school experience. We expect this will lead to additional engagement and electricity savings.

(8) Conclusion and Goals for 2015

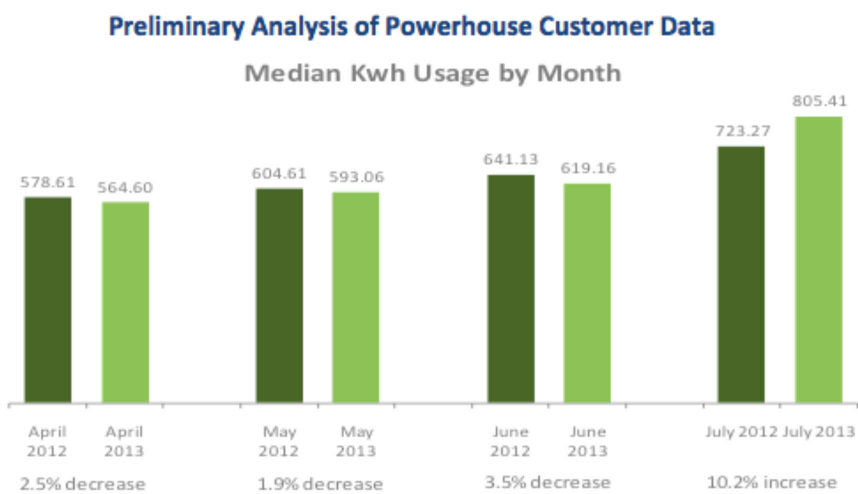
Funding provided by the Smart Grid Data Access program has allowed the project partners to think ambitiously about the potential scale of *PowerHouse* and to wrangle with the barriers to larger scale implementation of the program. To that end, we have created a concise set of program goals for 2015 and are actively recruiting funding to support ongoing program evolution. In addition to mitigating the problems and barriers identified above, two key goals going forward are:

- More clearly understand the connection between student learning and student/family energy savings. In collaboration with MMSA, we are currently developing learning assessment tools focusing on data literacy, evidence-based reasoning, and communication. We will continue refining these tools over the next school year with a subset of our participants, and are aiming for universal implementation in September 2015. Combining the assessment of student learning with evaluation of electricity savings, we hope to clarify whether the acquisition of skills in data literacy, reasoning, and/or communication results in greater home electricity savings. We are also tracking additional metrics such as the number of users, schools, and districts using *PowerHouse*; number of communities created; engagement of teachers and students with *PowerHouse*; effectiveness of teaching methodologies; and total savings of *PowerHouse* accounts connected (or not) to smart meter data.

- Engage whole communities of students, teachers, and the public in collaborative learning and reducing electricity usage as a means to support scale in the program. To that end we will test and iterate the new "community" functionality with teachers, students, and the public; provide curriculum resources to teachers to help them elevate students as energy auditors within their communities; and promote *PowerHouse* with the public through collaborations with businesses and community-based organizations.

APPENDIX A: ELECTRICITY USAGE DATA

After teachers prototyped the connection of student *PowerHouse* accounts to CMP Energy Manager electricity data, CMP analyzed the electricity use of the 181 connected accounts. They compared the total electricity use during the months students were connected to the same months the year prior. Almost half (41%) of connected accounts reduced their electricity use by 5 or more % during April, May, and June. Note that the July data falls outside of the school year, which is our hypothesis as to the significant increase in electricity use that month. This analysis didn't include a control group, which would allow us to draw significant conclusions as to the impacts of the *PowerHouse* program on electricity use reduction.



Key Findings:

Overall - Savings Amount Groups

	Percent	N Value
Saved 5% or More	31%	57
Saved Less than 5%	14%	25
No Savings	55%	101

The chart above illustrates the savings from April - July 2012 to April - July 2013, for those customers who participated in the Powerhouse Program

Monthly - Savings Amount Groups

	April	May	June	July
Saved 5% or More	41%	41%	41%	24%
Saved Less than 5%	14%	12%	9%	9%
No Savings	45%	46%	50%	66%
N Value	184	188	187	188

The chart above illustrates the savings by month comapairing 2012 to 2013, for those customers who participated in the Powerhouse Program

To answer the question, "Have *PowerHouse* participants changed their electricity use?" CMP analyzed data from the 2013-2014 school year for a period of 30 days prior to training and 30 days after. Results, including comparison to a geographically linked control group (within a square mile), are below:

			Participants			Control Group		
School	Start Program	End Program	Customers	Use Per Day Before (kWh)	Use per Day After (kWh)	Customers	Use per day Before (kWh)	Use per Day After (kWh)
Windham Middle School	4/12/2014	4/25/2014	28	27.4	23.3	3661	21.7	17.7
Falmouth High School	6/2/2014	6/13/2014	9	21.7	24.7	2,695	17.9	21.7
Bath Middle School	11/19/2013	12/18/2013	11	27.6	32.4	2,465	16.3	22.5
Portland Breakwater School	3/12/2014	4/18/2014	6	19.0	18.3	2,819	19.2	14.8
All Four Programs			54	25.5	24.8		19.7	19.0
	Percent change in average daily consumption				-2.8%			-3.5%

Numbers of connected families within participating schools continued to be too low to suggest a training effect. The program's initial hypothesis that students engaged with their own home electricity data would manage electricity more wisely may still stand. However, parent connection from *PowerHouse* to CMP's Energy Manager continues to be a barrier. In future analysis, study refinements might include (from CMP study findings):

- Changing time periods before and after *PowerHouse* training;
- Review of internal data to see if load profiles were flattened;
- Modification of the control group to more closely match participant households;
- Use of different mathematical models to estimate training effect, statistical significance

APPENDIX B: AN ENERGY EXPEDITION

An Energy Expedition: Realizing Solutions to Climate Change in the Classroom and at Home

-Gayle Bodge, Molly Auclair, Lynn Farrin, Jennifer Galasso, and Richard McGuire

Abstract:

Integrated science and math classes engaged eighth-grade students in an energy expedition to investigate their home electricity use, develop scientific understandings of how that use impacts the Earth, and use data as evidence to change their families' energy habits. Throughout this experience teachers incorporated the Next Generation Science Standards scientific practices, cross-cutting concepts, and disciplinary core ideas with emphasis on MS-ESS 3.C "…humans have become one of the most significant agents of change in the near-surface Earth system. And because all of the Earth's subsystems are interconnected, changes in one system can produce unforeseen changes in others (NRC 2012)."

Electricity is an integral part of modern life and one that is often overlooked. To make electricity use visible to students, teachers incorporated *PowerHouse*, a newly developed, inquiry-based, virtual learning environment. *PowerHouse* provides families access to their household electricity use data by connecting to smart electrical meters. Engaging students with personally relevant information, like home electricity consumption data, puts them at the center of their learning. Realizing the impact of their household energy usage empowers students to make informed decisions about how they use electricity at home and engage productively in the quest for climate change solutions.

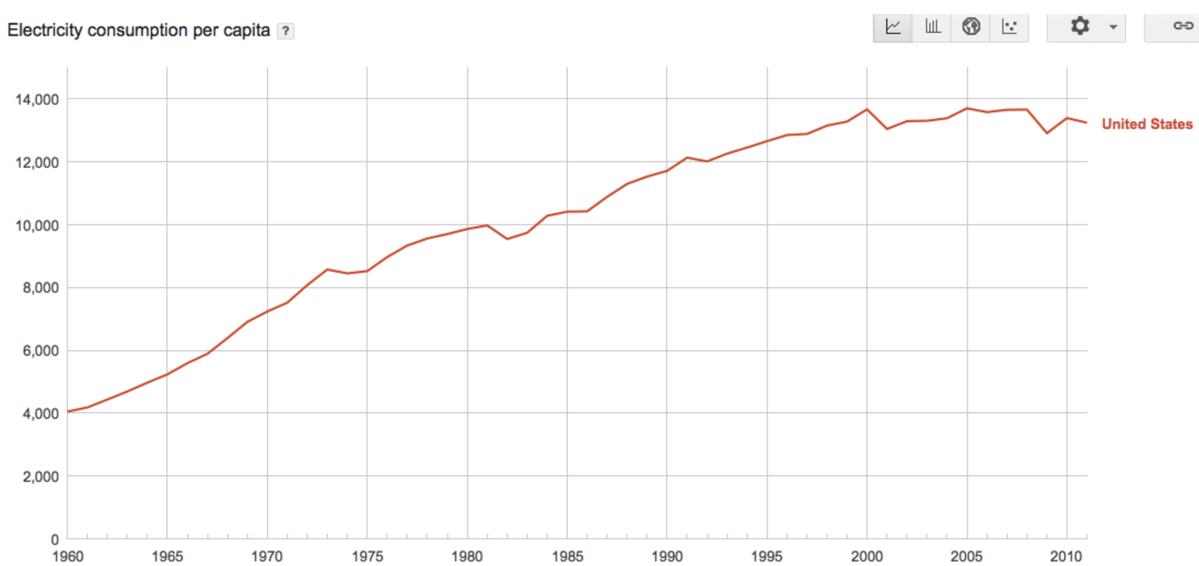
Photo credit: Gulf of Maine Research Institute

Pictures of our earth and large oil rigs roll across the video screen as a student narrator begins this dialogue. "They say our generation is destroying our earth, that the fossil fuels we are using are destroying our atmosphere. To stop this, we need to conserve our energy." The scene shifts to a picture of a *PowerHouse* home electricity use graph. They continue to say that by tracking their home electricity use and visualizing data through graphs, their class was able to save 5% of energy use in their own homes. "As an 8th grader, if we can do this, you can do this! If every household in Maine could save 5% of their energy, Maine could save over $37 million dollars per year!"

This public service announcement (PSA) is one of several student-created videos developed as the culminating experience for an expeditionary learning unit about energy. These messages were created after students had first-hand experience developing and successfully carrying out their own 5% conservation plans for reducing their home's electricity use. Students' plans were carefully designed and implemented in response to investigations students conducted involving the collection of personal household electricity data. This article describes how one team of eighth grade teachers integrated their science and math classes to engage students in an energy expedition to investigate their home electricity usage, develop scientific understandings of how that usage impacts the Earth, and use data as evidence to change their families' energy habits.

Electricity is an integral part of modern life and one that is often overlooked until we're without it. In this modern era, nearly every human task relies on electricity: heating, cooling, meal preparation, cleaning, communication, and entertainment. Over the past 50 years, our personal electricity usage has more than tripled! (Figure 1)

Figure 1: Electricity Consumption per Capita in the United States



Data from World Bank. Last updated: Jul 30, 2014

A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas (NRC 2012) states in Disciplinary Core Idea MS-ESS 3.C "…humans have become one of the most significant agents of change in the near-surface Earth system. And because all of the Earth's subsystems are interconnected, changes in one system can produce unforeseen changes in others." (Page 195) When we use gas in a car it is easy for us to see how our actions and use of energy sources are connected to the complex systems of the earth because we watch the CO2 exit the tail pipe. What may not be as apparent is the impact our increasingly electricity-dependent lifestyles have on the environment. Seemingly simple actions, such as turning on a light or cooking dinner, use electricity but the impacts of these actions are more elusive and our impacts on that system are less readily apparent.

The goal of the energy expedition was to help students make the linkages between their home electricity uses, CO2 production, and climate change while engaging in scientific practices, cross-cutting concepts, and exploring disciplinary core ideas.

Science and Engineering Practices
Asking questions
Developing and using models
Planning and carrying out investigations
Analyzing and interpreting data
Using mathematics and computational thinking
Constructing explanations
Engaging in argument from evidence
Obtaining, evaluating, and communicating information

Cross-Cutting Concepts
Patterns
Cause and Effect
Systems and system models

Disciplinary Core Ideas
MS-ESS3.A Natural resources
MS-ESS3.C Human impacts on Earth systems
MS-ESS3.D Global climate change

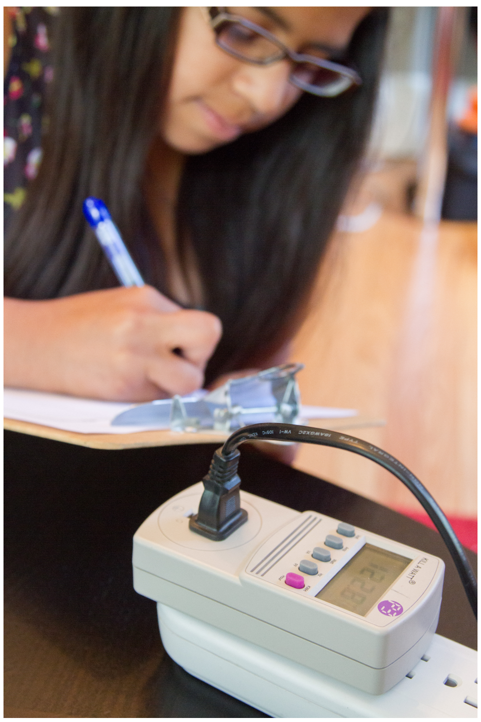
The expedition employed tools and strategies to help students visualize and measure electricity, an essential component of their learning experience. To achieve this goal, teachers incorporated *PowerHouse*, a newly developed, inquiry-based, virtual learning environment. *PowerHouse* provides families access to smart meter electricity data in a format that is engaging, meaningful, and motivating.

Photo credit: Gulf of Maine Research Institute

PowerHouse has two goals, to deepen math and science learning and to reduce household carbon footprints. Engaging students with personally relevant information, like home electricity consumption data, puts them at the center of their learning. Students collect and analyze data, make evidence-based claims about their household electricity use, and gain a meaningful voice in family discussions about energy use at home. Realizing the impact of their household energy usage empowered students to make informed decisions about how they use electricity at home and engage productively in the quest for climate change solutions.

To develop the skills and concepts needed to understand and investigate their electricity usage, students engaged in hands-on classroom activities in both their math and science classes. In science class, students read supporting literature in “Catch the Wind, Harness the Sun” (Caduto, 2011) and completed guided notes to develop a basic understanding of climate science. They investigated types of energy sources used for electricity generation and their impacts on the environment in order to better understand the “why?” for behavioral change at home. Students played the Carbon Cycle Game where they modeled how carbon molecules moved through the carbon cycle during the carboniferous period. They repeated the activity reflecting modern times and current human uses of fossil fuels. At the end of each game students created bar graphs representing the amount of carbon in each source and sink and analyzed how human use of fossil fuels has altered the distribution of carbon in earth’s systems. A class discussion engaged students in describing the carbon cycle while using evidence from their bar graphs to explain where the most/least amount of carbon was in the cycle during both time periods.

A follow up Greenhouse Gas Lab enabled students to observe first-hand the effect of increased carbon dioxide on the temperature of the earth's atmosphere. In small groups students utilized quart sized Ziploc bags to simulate the earth's atmosphere. In one bag (control) they filled a paper cup halfway with water, placed it in the bag, placed a thermometer in the bag, and sealed the system. To simulate the Earth's atmosphere with increased carbon emissions students used the same setup as the control but placed an Alka-Seltzer pill in the cup of water (Alka-Seltzer forms carbon dioxide when it reacts with water) and quickly sealed the Ziploc. Both systems were placed equidistant (6-12 inches) from a heat lamp. Temperatures of both systems were taken and recorded every five minutes for a total of 30 minutes. With this data, students could use evidence to develop an argument on how increased greenhouse gases are contributing to our warming atmosphere and climate change.

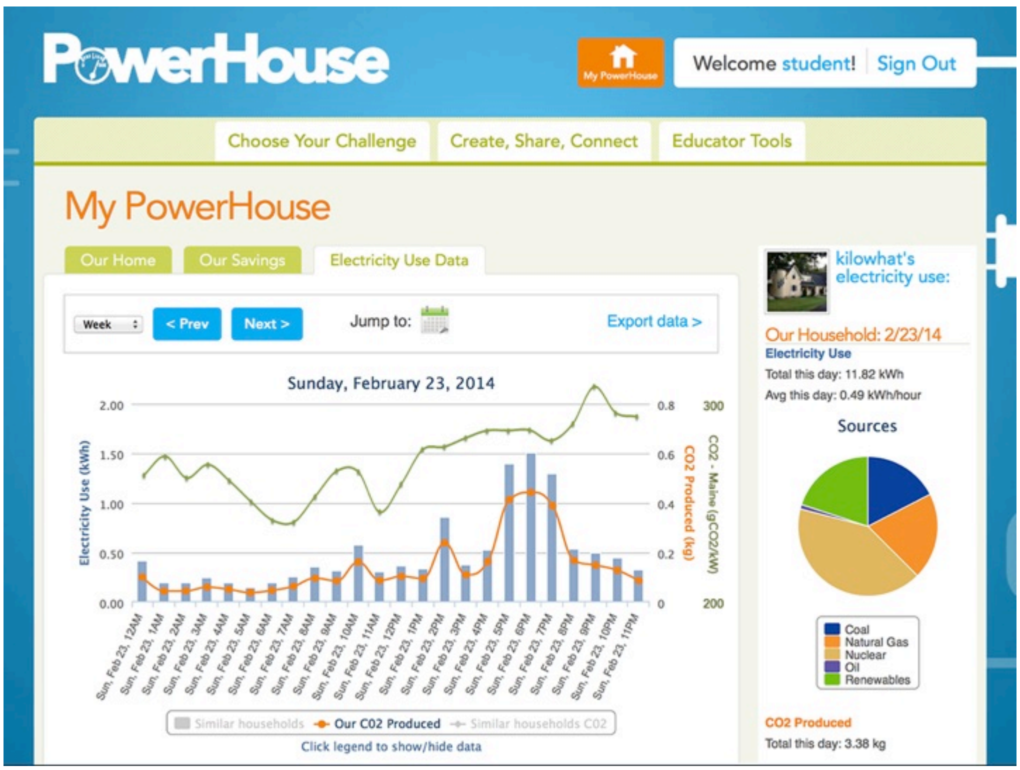


In math class, students focused on collecting and quantifying data from appliances. They conducted a lighting investigation in which they compared the electricity usage of incandescent, CFL, and LED light bulbs. This activity gave students experience with the use of kilowatt meters and reading electrical nameplates. Students also spent time interpreting electricity usage graphs and making inferences from data provided through the *PowerHouse* interface. Students who did not have access to their own home's smart meter data used data from an anonymous home provided through *PowerHouse* to gain a sense of typical home electricity use. They analyzed a week's worth of electricity usage data based on the following questions: "What general observations can you make from the data? At what time of day is your electricity use the highest, when is it the lowest? Why?" and "How does this week compare to other weeks?" After their initial analysis students delved further into their data by comparing their home to aggregate electricity use data of homes similar to theirs; a feature incorporated into *PowerHouse,* by asking the following questions, "When

are there the biggest differences in electricity use between your home and similar homes (days and hours of the day)? Why?"

Students spent time becoming familiar with their own home's electricity profiles. They investigated electricity use patterns through *PowerHouse's* dynamic electricity graphs (Figure 2), adding notes directly to the graphical displays and viewing usage activity in hourly, weekly, and monthly time scales. Completing a home electricity inventory gave students a sense of what they used in their homes that contributed to their electricity consumption. Using this data, students established a baseline pattern for their family's electricity use. These coordinated science and math lessons prepared students to investigate their own home electricity usage and link this learning to the human impacts on the earth system, providing the "Why?" of reducing their home electricity usage and their families' carbon footprint.

Figure 2: *PowerHouse* Electricity Usage Data Graph



Knowing how their family used electricity informed students' choice of a *PowerHouse* investigation question, such as "How can my family reduce the electricity needed to light our home?" Or "What uses the most electricity in my home?" Students' home investigations focused on employing a discrete intervention such as turning off unnecessary lights, line drying clothes, or switching to more energy efficient light bulbs (CFLs or LEDs). The impact of these actions was reflected on their *PowerHouse* electricity use graphs. Students who did not have access to smart meter data used both kilowatt meters and data from electrical nameplates to gather electricity usage information about their home.

Using evidence from their home investigations students developed their 5% home electricity conservation plans to present to their families. Their learning goals were to use mathematics to gather, organize, and present data and structure convincing explanations, describe the importance of conserving energy, and to present an argument using evidence.

> The first week of my investigation, my family went through life as usual, unnecessary lights were on, and we had no idea how much electricity we were using. But, throughout the second week, we monitored our electricity use with *PowerHouse*, and turned off all unnecessary lights. The smallest things can make a big difference. During that week my family saved 26 kWh, that's about 8% by just turning off lights… My carbon footprint was reduced by about 8% in just one week; imagine what a month or even a year could do! That's 1352 kWhs my family could save, about one metric ton of carbon. It is important to continue monitoring electricity use, and turning off lights because our environment needs it… The hardest change for anyone to make, is to be aware. A simple change, and being aware of your electricity use, will go a long way. - *Eighth grade student work example*

Students proved to themselves that single efforts do make a difference; they were able to calculate that simple changes, when viewed collectively, make a big difference. To inspire collective action, students employed behavioral science techniques, such as social norming and modeling, as well as their personal experiences reducing electricity usage to develop public service announcements. This was a collaborative project, working in student teams facilitated by their math, science, and computer teachers. Green screens, computer applications, and creativity ruled as students developed these video messages. Students felt empowered to share their experience and knowledge with their peers, families, town officials, the Gulf of Maine Research Institute, and Central Maine Power Company by hosting a presentation of their public service announcements and conservation plans. They knew the work they did, in their classrooms and at home, made a difference.

There is an increasing trend to digitize our lives and to provide us with data to inform decisions. This is evident in new technologies such as smart light bulbs, wireless thermostats, and the use of smart meter data by power utilities worldwide. What makes the approach that *PowerHouse* uses stand out is that it puts this personally meaningful data into the hands of students to engage them in authentic math and science investigations. Research shows that American homes have a 20% savings potential (Opower, 2013) in household electricity just by changing how they use that electricity. Kids have long been the drivers of cultural shifts in behavior that impacts environmental or personal health, such as recycling (McMakin A. et al, 2002). *PowerHouse* aims to replicate this student-driven movement with electricity efficient behavior changes by partnering with teachers and equipping students with science and math skills needed to make evidence based decisions, engage in persuasive conversations, and bring that learning home. This integrated approach to understanding the complex connections of human actions to climate change shows that data can do the convincing that students and adults need in order to realize the why of behavior change. What if everyone saved 5%?

Acknowledgements

Funded in part by the Department of Energy, Smart Grid Data Access Pilot Program and made possible by partnership with Central Maine Power Company, Maine Math and Science Alliance, and Maine's middle school teachers.

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Opower (2013) New McKinsey study finds that small behavioral changes can slash home energy use by 16-20%. http://blog.opower.com/2013/11/new-mckinsey-study-finds-that-small-behavioral-changes-can-slash-home-energy-use-by-16-20/

World Bank Data (2014)
http://www.google.com/publicdata/explore?ds=d5bncppjof8f9_&ctype=l&strail=false&bcs=d&nselm=h&met_y=eg_use_elec_kh_pc&scale_y=lin&ind_y=false&rdim=region&idim=country:USA&ifdim=region&hl=en&dl=en&ind=false&icfg

Resources

Bath Middle School PSAs: http://bms.rsu1.org/for_students/powerhouse_p_s_as/

PowerHouse: https://powerhouse.gmri.org/about-powerhouse

Catch the Wind, Harness the Sun - Michael Caduto (2011): http://www.amazon.com/Catch-Wind-Harness-Sun-Super-Charged/dp/1603427945

Links to *PowerHouse* activities:

Carbon Cycle Game http://powerhouse.gmri.org/carbon-cycle

Energy Conservation Plan http://powerhouse.gmri.org/energy-conservation-plan

Greenhouse Gas Lab http://powerhouse.gmri.org/green-house-gas-lab

Home Electricity Inventory
http://powerhouse.gmri.org/sites/default/files/content/devices_and_appiances_blank.xlsx

How to Read Electric Nameplates http://powerhouse.gmri.org/how-read-electric-nameplates

Lighting Investigation http://powerhouse.gmri.org/lighting

PowerHouse Challenges https://powerhouse.gmri.org/challenge

Public Service Announcements Activity https://powerhouse.gmri.org/public-service-announcements

Using a Kill-A-Watt Meter http://powerhouse.gmri.org/using-kill-watt-meter

Authors

Gayle Bodge, MSc (gayle@gmri.org) is the Science Education Program Manager for *PowerHouse* at the Gulf of Maine Research Institute in Portland, Maine.

Molly Meserve, MSc (mmeserve@gmri.org) is a Science Education Specialist at the Gulf of Maine Research Institute in Portland, Maine.

Lynn Farrin (lfarrin@mmsa.org) is a Science Education Specialist at the Maine Mathematics and Science Alliance in Augusta, Maine.

Jennifer Galasso (jgalasso@rsu1.org) and Richard McGuire (rmcguire@rsu1.org) are 7th and 8th grade looping science and math teachers, respectively, at Bath Middle School in Bath, Maine.