GOODMAN RESEARCH GROUP, INC.
Program Evaluation • Consultation • Market Research

Evaluation of the CA-CP/MTC Clean Energy Climate Solutions Project

Submitted to
Clean Air-Cool Planet

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INTRODUCTION

The Massachusetts Technology Collaborative funded Clean Air-Cool Planet to implement the Clean Energy Climate Solutions Project. This project involved the use of educational kits to educate science center visitors and classroom teachers about clean energy as a solution to climate change. Three such kits were implemented: Solar Energy, Wind Energy, and Fuel Cell Energy in three science centers in Massachusetts. These included the Museum of Science, Boston; The New England Aquarium, Boston; and the Ecotarium, Worcester.

This project was an extension of the Clean Energy Climate Solutions Project implemented by Clean Air Cool Planet and funded by the Connecticut Clean Energy Fund. This Connecticut-based two-year initiative began in 2006. For this project, ten science centers from the Connecticut Science Center Collaborative were chosen to test, evaluate, and develop the above-mentioned educational kits.

Goodman Research Group, Inc., (GRG) a research firm that specializes in evaluation of educational programs, materials, and services, was contracted by Clean Air-Cool Planet to conduct external evaluation of both the projects. The purpose of the evaluation was to test and evaluate existing kits and curricula to identify materials that would be appropriate or adaptable for a variety of venues in Massachusetts. This report presents data collected from the three science centers in Massachusetts.

METHODS

Early in 2008, the three centers in MA participated in a training session. A total of 30 educators from the three science centers attended this training.

GRG developed a Web-based survey designed to collect information about how the three science centers used each of three kits. Specifically, the survey collected the following information:

- Logistical information about when sessions were held and who attended
- Activities preformed using the kits
- Ease/difficulty using the kits
- Audience reactions to the kits
- Challenges using the kits and suggestions for improvement

GRG explained the purpose and the methodology of the proposed evaluation study to the three science centers. Data were collected by each science center via the GRG survey from May 2008 to September 2008. Each science center was instructed to complete at least nine surveys after using a kit during at least nine different sessions. If a science center conducted more than nine sessions, they could complete more surveys or select nine sessions on which to provide feedback. Reminder emails with a link to the survey were sent to science centers periodically.

Educators at the three science centers completed 26 tracking surveys. Table 1 indicates the number of surveys completed by each Science Center.

Table 1
Number of Surveys Completed by Science Centers

	Type of Kit Used			Total # of surveys completed
	Wind	Solar	Fuel Cell	
Ecotarium	13	2	0	15
Museum of Science, Boston	3	3	3	9
New England Aquarium	2	0	0	2
Total Number of Kits Used	18	5	3	26

*Note: All of the Fuel Cell Kits were conducted by one individual, therefore all information and recommendations come from one source for this kit.

RESULTS

The results from the evaluation study are presented in the following subtopics:

- Educator training
- Demographic information about the museum audiences
- Format of the sessions
- Materials
- Perceived audience reactions
- Challenges of implementation and suggestions for improvement

Educator training

For a majority of the sessions the educators (n=11) indicated that they had attended a formal training by Jonathan Craig or Karin Jakubowski or were trained by a co-worker who attended one of these trainings (n=7). For six sessions, the educators indicated that they used other forms of trainings. These included self-training using manuals, using guided inquiry, and as a part of a science/technology teacher course. For two sessions, the educators indicated that they did not receive any training at all.

When asked if they required more training than what they had already got, only on five occasions out of the 26 total sessions, the educators indicated that additional training was required. For three sessions the educators indicated that they needed more assistance around the use of the materials in the kit and one educator required help with the vocabulary associated with the topic of clean energy.

Demographic information about the audience

Half of the groups (n=13) attending the sessions at the three science centers were adults-only groups. Adult women were the primary audience of these sessions. A little over a third of the sessions were conducted with family groups (n=9) which were evenly split between males and females for both the children and adults.

Only one center, the Ecotarium, conducted an activity with a school group. This session was a demonstration and no demographic information was recorded. Two sessions were categorized as "other" and the educator's notes indicate that these sessions were both one-on-one with a child interested in the activity. See Table 2 for a breakdown of group attendance by center.

Table 2
Type of Attendees by Center

	School group	Family group	Only adults	Other
Ecotarium	1*	3	10	0
Museum of Science, Boston	0	6	1	2
New England Aquarium	0	0	2	0
Total # of sessions	1	9	13	2

*This group was a demo and no demographic information was recorded about it.

Format of the sessions

On average, sessions were 1.65 hours long and ranged from 15 minutes to 6.5 hours. Several of the longer sessions were part of the Museum Institute for Teaching Science's program for Massachusetts teachers. The median length of the sessions was one hour.

During any one session, the bulk of the time was spent doing hands-on activities. Demonstration of the activity was conducted for a short while at the beginning of the session and experimentation and self-guided exploration were used later for short intervals (See Table 3).

Table 3
Time Spent on Various Instructional Methods

	# of sessions that included this format	**Average time spent on format**	**Range of time spent on format**
Demonstration	16	5 min	5 to 10min
Hand-on Activities	20	38 min	5 to >90min
Experimentation	14	10 min	5 to 55min
Self-guided exploration	10	7 min	5 to 75min
Other	9	10 min	5 to 10min

The most commonly used kit (18 out of 26 sessions) was the Wind Energy kit, followed by Solar Energy kit (5 out of 26). The remainder three sessions used the Fuel Cell kit. Examples of various activities performed with these kits included:

Wind

- Calculating the energy output at different blade angles and blade numbers

- Designing and exploring the use of a wind turbine
- Generating electricity with a fan

Solar

- Using solar cells to power a small motor
- Teaching parallel and series circuits
- Lighting a bulb using solar energy

Fuel

- Demonstrating electrolysis of water using batteries
- Running a fuel cell car

Materials

Usefulness of the materials

The educators believed that the materials were quite helpful in teaching the concept of clean renewable energy. They were helpful to a lesser degree in explaining the concepts of how clean energy relates to their lives or how clean energy is a solution to climate change (See Table 4).

Table 4
Educator ratings of helpfulness of kit materials in explaining concepts*

	Not at all	Only a little	Moderately	Quite a bit	A great deal
Concept of clean renewable energy		1	10	11	3
How clean renewable energy relates to their lives	1	5	9	9	1
How clean renewable energy is a solution to climate change	4	5	6	9	1

*Frequencies
** N = 25 sessions

Audience engagement with the materials

The educators gave high ratings regarding the extent to which the materials engaged the audience. For 15 of the sessions, educators indicated that the materials were "*quite a bit*" successful at engaging the audience; for another seven sessions, educators indicated that they were "*a great deal*" successful. The educators further elaborated on their ratings by giving examples of ways in which the materials caught and sustained the attention and interest of the audience. These examples brought out the following themes:

- Inquiry-based activities – Participants enjoyed the materials because they included hands-on inquiry-based activities. The materials provided the participants with opportunities for experimentation.

- Design and redesign opportunities – The materials included in the kits encouraged the participants to learn through design and redesign as they manipulated the various components in each kit.

- Specific examples of the interesting activities – Some educators also indicated that specific activities got the audience engaged with the materials. For example, the participants were fascinated to see a car that runs on water. They also found it interesting to learn how a turbine's blade angle is extremely crucial to produce maximum energy output.

Adaptations and suggested modifications to the kits

Five respondents adapted the kits they received: two adapted Wind Kits, three adapted Solar Kits, and no one adapted the Fuel Cell Kit. The most common adaptations involved using additional materials or using the kits for demonstrations only.

- Educators who modified the Wind Kit provided an LED for the kit and carried out the activity as an informal demonstration.

- Educators modified the Solar Kit by connecting the cells before they were used by visitors so as to ease visitors' frustration. They also connected the cells to motors that required less energy than the one provided in the kit, so that visitors could better see the effect of the solar cells. In the actual words of the educator:

  > "[I] *had eight cells connected in series, eight cells connected in parallel so that visitors could see difference in power output without having to connect the cells themselves (it is time-consuming and frustrating since the pieces are so small).*"
  >
  > "[I] *had eight cells connected in series, another eight connected in parallel provided small motor (motor in kit had energy requirements too high for the power output we were getting)* [and] *also had ice packs available (a volunteer who worked with solar cells as a career said that colder cells had higher output).*"

Ease of using the materials

Educators rated the ease with which they used the kits and how comfortable and prepared they felt in doing so. Overall, educators indicated that the kits were not difficult to use. The educators felt quite comfortable and prepared to carry out the kit activities (See Table 5).

The educators indicated it was a little difficult to use the kits to explain the relationship between clean energy and climate change (See Table 5). This was particularly true with the Wind and Solar Kits. Various reasons cited for this included:

- Children did not know enough about electricity in the case of the wind kit and so they didn't understand how that affects the climate. Because they don't know where their electricity comes from, they don't see the advantage of renewable sources. In the words of an educator,

  > *"The kit in and of itself is pretty straightforward, but I don't think that most children know or understand where their electricity comes from in the first place, so they don't see the difference between electricity from PV cells vs. electricity from the electric grid. To them, both sources are clean."*

- Moreover, participants were more interested in experimenting with the Wind Kit than in learning about real-world applications. Sometimes this was because the participants were too young to understand the science underlying the activity.

With regard to the Fuel Cell kit, the participants made connections between the fuel cell, clean energy, and climate change because they could easily see that no pollution was created by the process. In the words of the educator,

> *"They understood that no pollution was created in getting the energy for the car to run; I also explained how the size of the carbon footprint of the H_2O fuel depends on how the H2 was generated and that it is possible to get H2 using solar or wind energy."*

Table 5
Educators' ratings of ease of using the materials

	Not at all (1)	A little (2)	Moderately (3)	Very (4)	Extremely (5)
In general, how difficult was it to use this kit?* (Mean = 1.54)	15	7	3	1	0
How difficult was it to use this kit to explain the relationship between clean energy and climate change?* (Mean = 2.12)	9	12	3	1	2
How comfortable were you conducting this activity? (Mean = 3.69)	0	2	4	12	7
How prepared did you feel to conduct this activity? (Mean = 3.42)	0	4	5	11	5

N=26; *For these items, a lower number indicates it was *less* difficult to use

Climate change backpacks

Only the educators in the New England Aquarium used the climate change backpack and provided feedback about the materials and activities included in

the backpack. The New England Aquarium offers teacher trainings on climate change and they use the backpack and the clean energy kits when running these workshops. It also lends the backpack and clean energy kits to other teachers once they are trained on these materials.

The educators were asked to describe three things in particular that they liked about the climate change backpack and/or activities. Educators' responses indicated the following themes:

- Activities – the activities included in the back-pack are hands on activities that are creative, useful, and represent real themes. These activities demonstrate a creative approach to teaching climate change.

- Format of activities – the backpack activities offer opportunities to brainstorm with others in the group. These interactive group discussions provide a good learning experience to the audience.

- Materials – the materials in the backpack which included a clear and complete teacher guide, hand-outs for activities, implementation tips, and all the props required for the activities, made it easy to implement the activities.

Based on the experience of using the backpack, the educators made the following suggestions for changes/additions to the activities and materials in the backpack:

- Diversifying the activities – educators would like to see examples of how activities can be geared towards different populations of students. They would like more guidance about carrying out the activities with younger age-groups.

- Additional audio-visual material – educators would benefit from additional resources such as a list of websites available on the topic of climate change, as well as a list of organizations and businesses dedicated to the cause of climate change. They would also value a CD-Rom with power point presentation to use in classroom and posters and other display materials to hang on walls.

- Additional informational material – the backpack could also include a section of teacher-generated activities. A more in-depth introduction on the science behind understanding climate change would help the teachers introduce the topic at hand.

Overall, educators indicated that the activities in the backpack were a good start for the dissemination of information on the topic at hand. However, adaptations and changes to the activities indicated above are necessary to give educators more varied and diverse material to teach solutions to climate change.

Perceived audience reactions to materials

The educators believed that the kits were quite successful with the audience. Of the three kits, the Wind and Fuel Cell Kits received an average rating of 4 and the Solar Kit received an average rating of 3 (on a scale from *1* was "*not at all successful*" and *5* was "*extremely successful*" See Table 6).

Table 6
Educator ratings about the success of the activities

How successful was this activity with the particular age group?	Not at all (1)	Only a little (2)	Somewhat (3)	Very (4)	Extremely (5)
Wind Energy (Mean=4.00)	0	0	2	13	2
Solar Energy (Mean=3.00)	0	1	3	1	0
Fuel Cell (Mean=4.00)	0	0	0	3	0

N=25 out of 26 sessions

With regard to ease of conducting the activities for the audience, educators indicated that audience needed *a little* to *some* help completing the activities. Most commonly, educators needed to provide:

- Background information. For example with the Fuel Cell kit, the participants could get the car to run on their own, but needed the educator to explain the functioning behind it.

- Assistance in putting materials together. For example, for the Wind Kit, the audience needed an explanation of the multimeter (which settings to use, where to put which cords, etc).

Challenges of implementation and suggestions for improvement

The challenges faced by the educators during implementation were related either to the audience or to the kit materials. Educators mentioned difficulty in sometimes reaching their audience. They reported difficulty in explaining the concepts to young children and providing enough background or explanation of the activity. In the words of an educator who used the solar kit,

> *"Visitors were not interested in simply connecting the cells in different ways to see the difference in power output (and connecting the cells was actually difficult to do) it was hard for young children to understand what was going on, although older children and adults were certainly intrigued by the technology."*

Some of the difficulties with the kit materials revealed challenges with instruction, kit components, or location of the experiment.

Wind Kit

Educators indicated that explaining the concepts underlying the functioning of the wind energy kit was often a challenge. Some of the possible reason cited by the educators for this difficulty included lack of understanding on part of the audience about where electricity comes from, age of the children (too young to grasps the concepts), and lack of adequate time to address the conceptual issues. Some actual quotes from the educators:

> *"I think that most people don't understand where their electricity comes from, so it's hard to get them to see why renewable resources like wind are an advantage."*
>
> *"It's tough to get children to understand the pros of renewable energy sources."*
>
> *"We didn't have enough time to really talk at the end about the implications for clean energy, but they understood where we were going with it."*

Some more specific challenges voiced by individual educators while using the wind kit were:

- The instructions for the wind kit were hard to follow.
- Setting up the circuit for the wind kit was difficult.
- Ends of propeller blades wore out after a while and they flew out of the spinning hub.

Suggestions for improving the Wind Kit included changes to instruction and background material and adjustments to the turbine blades. Specific suggestions based on educators' responses were:

- Provide a detailed presenter's guide of FAQs that highlights the background information that all groups will want to know.
- Add some material to instruct audience in traditional ways of generating electricity. This will give them an idea about where their electricity comes from.
- Add an easier measuring tool for the blade angle.
- Make changes to the propeller blades.
- Use an LED or a low power light bulb to show how the windmill can provide power to the light bulb.

Solar Kit

A common challenge faced by multiple educators was that it was hard to power the solar kit indoors. The amount of sunlight available to the educators while

conducting the activity varied, leading to difficulty implementing the activity. Moreover, educators also commented that it was hard for them or for the visitors to connect the cells together for the Solar Kit. In the words of an educator,

> *"Components are simple: shine light and produce electricity; however, it is difficult to connect the cells to each other, so I provided already-connected cells so that visitors could see the difference without having to spend a long time doing it themselves."*

In terms of the suggestions for improvement, the educators indicated that the instructions about setting up the demonstration need to be clarified. Specific suggestions involved providing different electrical devices in the kits:

Compare power outputs of cells that have been cooled down to some that were at room temperature. This suggestion was made because comparing cells connected in series to cells in parallel did not seem to be very interesting to visitors. Also, it was hard to make the connections (bolts were very small and easy to lose).

Add electrical gadgets (radios, lights, or small motors) as challenges for visitors to try to generate power. Have different battery powered devices so that visitors can compare which ones need higher current or higher voltage.

SUMMARY OF RESULTS AND RECOMMENDATIONS

Educators' experiences with the three alternative energy kits were generally positive. Overall, the kits were fairly easy to use and educators felt prepared and comfortable using them. Most also thought the materials were quite helpful in teaching the concept of clean renewable energy. The materials, in the opinion of the educators, were helpful to a lesser degree in explaining the concepts of how clean energy relates to their lives or how clean energy is a solution to climate change. Most of the educators indicated that the materials were quite a bit or greatly successful at engaging the audience. Overall, educators rated most sessions as at least *somewhat successful* (rating 3 out of 5).

The educators seemed satisfied with the training they received for the implementation of the kits; only five educators felt that they needed extra training. Out of these five, three indicated that they needed more assistance around the use of the materials in the kit and one educator required help with the vocabulary associated with the topic.

All the sessions included some demonstration, while the major part of each session was devoted to hands-on activities and experimentation. Because session lengths varied and educators used different types of instructional methods, audience members may have received different information depending on the session they attended.

Educators mentioned that the challenges experienced in implementation of the activities were related either to the audience or the materials. They mentioned difficulty in sometimes reaching their audience, especially explaining the concepts to young children. They also had specific suggestions about modification to the Wind and Solar Kits.
With regard to the Climate Change Backpacks, only one science center used and evaluated them. Overall, the educators at that center indicated that the activities in the backpack were a good start for the dissemination of information on the topic at hand. However, they also recommended specific adaptations and changes to the activities in order to make the Backpacks a better source to teach about solutions to climate change.

Of the three kits, the Wind Energy kit and the Fuel Cell kit were rated slightly higher overall than was the Solar Energy kits. Educators indicated that audience needed *"a little"* to *"some"* help around the background information and in putting materials together for completing the activities.

Based on the feedback from the educators at the three science centers in Massachusetts, GRG recommends that Clean Air-Cool Planet continue to expand and improve upon the kits. The educators have made specific suggestions to improve upon the materials used within the kits. Clean Air-Cool Planet should also consider producing additional instructional materials for science center educators as well as materials for audience members and teachers. For example, the educators indicated that the audience had difficulty in making connections between the alternative sources of energy and climate change. Additional educational and instructional material with regard to this topic could help the educators assist the audience in making those connections.

This program involved the use of the materials at three fairly large science centers in Massachusetts. Based on the success of the program with the participants of this evaluation, GRG recommends that once the enhancements to the kits have been made, Clean Air-Cool Planet disseminate the kits and the related materials to appropriate venues such as other science centers and children's museums across the country.

APPENDIX