National Water Research Institute

Presents

The 2018 Clarke Prize Lecture

Getting Water Research into Policy and Practice (GRIPP for Water)[1]

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Abstract

Human welfare has benefited greatly from advances in science and technology. Despite this, a disconnect between the scientific enterprise and the people it benefits hinders the adoption of scientific and technical knowledge for implementation in policy and practice. The goals of getting research into policy and practice (GRIPP) can best be achieved by *engaging stakeholders* in the framing and design of problem-driven or solution-oriented research projects and then *investing in accessible communication* of project results. GRIPP requires *long-term commitments* on the part of both research institutions and people.

Eawag's research provides many examples of problem-driven and solution-oriented research projects that can help to improve human welfare and safeguard aquatic environments and their ecosystem services. Sustainable management of water supplies, water resources and aquatic ecosystems requires that Eawag's research is leveraged with other research and implementation activities world-wide and that knowledge is shared and made accessible outside the scientific community. The roles of all actors and their contributions – not only to research but also to framing questions, sharing and implementing research results and promoting adoption – must be valued and appropriately acknowledged.

Despite the many improvements in human welfare, much work still remains to achieve the vision of a sustainable future that is expressed in the Sustainable Development Goals. This remaining work poses a huge, but also very motivating, challenge for all of us engaged in water research.

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1. Introduction

Today's scientists and engineers face a paradox. World-wide, daily life has been dramatically improved by advances in science and technology. Mortality for children younger than 5 years old is 15 times lower today in the United States than it was in 1930. Over the same time period, childhood mortality in Nigeria decreased by over a factor of 4 and is about the same today as it was in the United States in 1930 (Gapminder). The target for access to safe drinking water set in the United Nation's Millennium Development Goals was achieved by 2015 and the Sustainable Development Goals set even more ambitious targets for water supply, sanitation and protection of water resources to be reached by 2030 (Vörösmarty et al., 2015).

Access to basic infrastructure and services is taken for granted in high income countries and even by significant segments of the population in low- and middle-income countries (LMICs). And yet, on Earth Day in 2017, people felt the need to participate in marches and rallies for science in over 600 cities around the world – especially in the United States. This year, the web platform "Let Science Speak" was established to combat the politicization and censorship of science and scientists (Generous Ventures, 2018).

As scientists and engineers, we must be concerned about the profound disconnect between the scientific enterprise and the people it benefits because:

- It hinders the adoption of scientific and technical knowledge into public policy and practice and thus limits the impact of our research;
- It decreases the willingness of the public and their elected representatives to provide the funding that our research depends on; and
- It compromises the basis for policy and decision making that affects the lives of all citizens.

Here, I focus on the need to facilitate the adoption of water research as a basis for policy and decision making and the implementation of water research in practice. In the fields of health and development research, this is referred to as "getting research into policy and practice" or GRIPP (Uzochukwu et al., 2016). Many of us who are active in water research feel strongly that our work is in the common interest of society. We believe that our work has the potential to improve human welfare and safeguard ecosystem function and services. Many funding agencies and some academic research institutions have stated that scientific research should have demonstrable benefits for society. This raises several questions:

- How can we promote GRIPP for Water?
- What can we do as individual researchers?
- What changes are needed in our institutions?
- How can we leverage the interests of funding agencies?
- How can we engage stakeholders as partners not only to implement and disseminate our findings but also to help frame and design applied research projects?

2. My Path to the Interface of Science with Policy and Practice (SP^2I)

My education and professional development in academia have led to my current engagement at the interface of science with policy and practice (SP^2I). Policy implications and practical applications seemed far removed from my education and research in chemistry (Bachelors and Masters), chemical oceanography (Ph.D.) and geochemistry (post-doc). My perspective changed when I took up my first faculty position in the Department of Civil and Environmental Engineering at the University of California, Los Angeles (UCLA) in 1991.

In California at that time, there was considerable interest in the anticipated changes in the drinking water standard for arsenic and the implications of those changes for drinking water supply and treatment. My early work on arsenic focused on water treatment technologies and benefited greatly from collaboration with my UCLA colleague Menachem (Meny) Elimelech and his contacts at the Metropolitan Water District of Southern California (MWDSC). As I learned more about arsenic in the Los Angeles drinking water supply, I realized that the Los Angeles Department of Water and Power (LADWP) was facing even greater challenges because of geothermal inputs of arsenic to the water delivered by the Los Angeles Aqueduct (LAA). My research group began studying the geothermal inputs and biogeochemical cycling of arsenic just before I moved, in 1996, from UCLA to the California Institute of Technology (Caltech).

Based on my experience with the technical and scientific aspects of arsenic in drinking water, I had the opportunity to serve as a consultant in 1997 and 2000 to the U.S. Environmental Protection Agency (USEPA); in 1997, for the Board of Scientific Counselors (BOSC) Ad Hoc Subcommittee on Arsenic Research and, in 2000, for the Drinking Water Committee of the Science Advisory Board. Through these activities, I was exposed to policy and regulatory issues. I also had the opportunity, in 2001, to participate as a fellow in the Leopold Leadership Program, which was originally launched as a "media literacy training for mid-career scientists, teaching them how to interact with journalists, translate their research for popular audiences, and speak with policymakers on Capitol Hill" (LLP).

Throughout my time at UCLA and Caltech, my engagement with practice and, to a lesser extent, with policy was closely linked with my own research and scientific expertise. This changed when, in 2007, I moved to Switzerland to become the Director of the Swiss Federal Institute of Aquatic Science and Technology (Eawag).

At Eawag, I was confronted with two types of questions related to policy and practice that extended well beyond my own scientific expertise. The first type of questions concerned Swiss national policies of water resource management. I had a crash course in these issues through Eawag's participation in the Swiss National Research Program on Sustainable Water Management (NRP 61), which ran from 2010 through 2014 (Hoffmann et al., 2017b). I took advantage of this education to write a paper on "Moving Targets, Long-Lived Infrastructure, and Increasing Needs for Integration and Adaptation in Water Management: An Illustration from Switzerland" with 10 Eawag co-authors (Hering et al., 2012a). This paper was published as a feature article in *Environmental Science & Technology* (EST) despite the rather disheartening comment from an anonymous reviewer who wrote that "…not too many readers of EST might be interested in learning about Switzerland…".

The second type of questions concerned Eawag's contributions to society, mainly in Switzerland since Eawag is supported by Swiss taxpayers. Over the nearly 12 years that I have served as Eawag's Director, I have come to realize how well we have been positioned, throughout the organization's history, to influence policy and practice.

Here, I will use some examples to illustrate what I believe to be the basis for Eawag's success with GRIPP. Of course, the prosperity and culture of Switzerland have contributed to Eawag's success. But I hope to identify success factors that are also relevant in other contexts, as Eawag researchers have shown in their work in LMICs.

3. Contributing to Society through Research

Eawag addresses a wide range of topics in water research, with a focus on water quality. Legally-mandated topics include:

- The chemistry, physics, biology and microbiology of water;
- The ecology of aquatic systems;
- Drinking water and wastewater treatment technologies; and
- The sustainable management of water supply and resources and of the water environment.

Eawag's activities span the continuum from curiosity-driven to problem-driven to solution-oriented research and also extend to implementation (Figure 1). In the domains of curiosity-drive research and implementation, we collaborate with a variety of partners. For research, key partners include the Swiss Federal Institutes of Technology (ETH) Zurich and Lausanne (EPFL) as well as other national and international universities. For implementation, Eawag's partners include federal and cantonal authorities, utilities, industry, and our own spin-off companies.[2]

Figure 1. Eawag's research and key partners for curiosity-driven research and implementation. The Swiss Center for Applied Ecotoxicology (Ecotox Center) is a unit hosted by Eawag that provides expertise, education and tools for the assessment of the environmental effects and risks of anthropogenic chemicals (Werner, 2018).

Many of Eawag's research topics are directly relevant to society. Such topics include: antibiotic resistance in wastewater effluent and the environment, biofilms in household plumbing and on bath toys, contaminant monitoring on the Rhine, geogenic contaminants in groundwater, biodiversity and invasive species in freshwater systems, illegal drug monitoring in sewers, methane extraction from Lake Kivu (which lies on the border between Rwanda and the Democratic Republic of the Congo), solar disinfection of drinking water (SODIS), source separation technology for water reuse and nutrient recovery, and wastewater treatment for micropollutant removal. I will use two of these topics – contaminant monitoring on the Rhine and source separation technology for water reuse and nutrient recovery – to illustrate key aspects of our research that contribute to its impact.

3.1 Monitoring Contaminants in the Rhine

In 1986, a fire at the Sandoz chemical storage facility in Schweizerhalle led to severe contamination of the Rhine and a massive fish die-off (Giger, 2009). Subsequently, Switzerland joined with its neighbor Germany to establish an international water monitoring station at the border in Basel. This station, financed by the Swiss Confederation and the German Federal State of Baden-Württemberg, celebrated its 20th anniversary in 2013. The station extends the tradition of water quality monitoring that is coordinated by the International Commission for the Protection of the Rhine.[3] With long-term and

[2]https://www.eawag.ch/en/consulting/knowledge-and-technology-transfer/spin-offs-of-eawag/

[3]https://www.iksr.org/index.php?id=58&L=3

intensive participation by Eawag researchers, the station has been used to monitor target contaminants and also to develop non-target screening (Ruff et al., 2013). Non-target screening has enabled the identification of previously undetected substances (Ruff et al., 2015).

Through collaboration and close communication with regulatory authorities and utilities, an industrial spill that was detected in Basel could be reported to downstream users quickly enough to interrupt water intake while the chemical pulse moved down the Rhine (Ruff et al., 2013). For such cooperation to be possible, it is important that findings from Eawag research are accessible to local stakeholders through articles in trade journals of Swiss professional associations and through reports of the Swiss Federal Office of the Environment (which are published in German and/or French).

3.2 Source Separation Technology for Water Reuse and Nutrient Recovery

Eawag's research on source separation technology began with discussions about sustainability after the 1992 United Nations Conference on Environment and Development in Rio de Janeiro (Keogh, 2018). The separation of urine from "black water" (fecal matter and contaminated flushing water) was envisaged as a key process to recover the nutrients nitrogen and phosphorus and reduce the treatment burden on centralized wastewater treatment plants (Larsen and Gujer, 1996). The concept of nutrient and resource recovery was later applied in the LMIC-context to develop economic opportunities based on the use of excreta as a resource and to promote user acceptance of source separation. Today, the technology for producing fertilizer from urine is installed in the modular, experimental NEST building[4] located on the Eawag-Empa campus in Dübendorf. The urine-based fertilizer Aurin has been licensed by the Swiss authorities for use on all plants, including food crops.

In the course of over 20 years of inter-linked projects, several key technologies were developed and/or applied in novel ways. For example:

- Gravity-driven membrane (GDM) filtration uses commercial ultrafiltration membranes not under the conventional pressurized regime (which uses energy and requires back-flushing) but rather under low-pressure conditions that allow a functional biological layer to be maintained and for stable (albeit lower) water flux (Peter-Varbanets et al., 2010).
- A process for urine stabilization by nitrification (Fumasoli et al., 2016) was developed and patented and is the basis of the Eawag spin-off Vuna Ltd.
- A commercial machine developed by the Swiss cheese industry to produce pellets from dewatered waste was applied to fecal sludge in Uganda (Ward et al., 2017) and is now installed in the NEST building.

These technological developments have been closely coupled with research that takes into account the "enabling environment," which includes financing and socio-cultural acceptance (Tilley et al., 2014). For example, field-testing of the Blue Diversion toilet (which incorporates GDM technology) in Uganda included user surveys to assess people's experience and expectations (Tobias et al., 2017).

A key driver for the development of Eawag's source separation technologies was funding from the Bill and Melinda Gates Foundation (BMGF). Interactions with the BMGF team served to push the research toward rapid implementation and provided tremendous visibility for Eawag and its projects.

[4]The Swiss Federal Laboratories for Materials Science and Technology (https://www.empa.ch/) pioneered the NEST building (https://www.empa.ch/web/nest) to develop and trial innovative building technologies, materials and systems.

3.3 Institutional Embedding of Applied Research at Eawag

Problem-driven and solution-oriented research projects are central to our research portfolio (Figure 1) and many of these projects are supported in part by internal funding. Eawag also makes considerable investments to ensure that the results of applied research projects are accessible to stakeholders (Figure 2). Several outreach platforms are hosted and partially supported by Eawag. The staff of these outreach platforms maintain close contact both with stakeholders and researchers. This allows them to be effective as knowledge brokers, who can link the needs and challenges encountered in practice with research-based solutions (Hering, 2016). Eawag researchers participate in continuing education courses for practitioners. Our Communications Department produces press releases for local media outlets as well as electronic newsletters and annual reports that are designed for audiences beyond the scientific community. Even with the support of Eawag's Communications Department, our researchers must also invest their own time to publish in venues that are read by practitioners and other stakeholders.

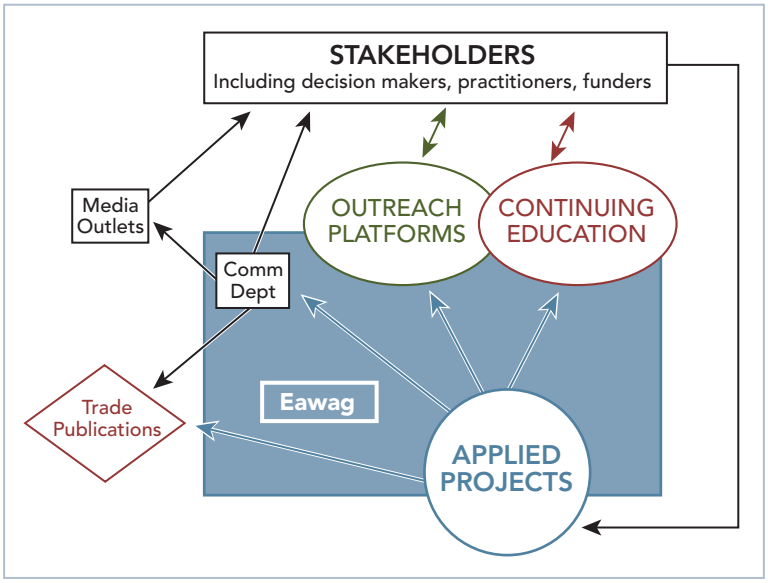

Figure 2. Schematic illustration of Eawag's institutional measures to support the adoption of applied research.

3.4 Success Factors

These examples illustrate three key factors that promote the successful adoption of research into policy and practice. *Long-term commitment* is necessary to carry research through the full value-chain from ideation (which is often curiosity driven) to implementation. It is also needed to develop and maintain trustful relationships with stakeholders. Early *engagement with stakeholders* (including regulatory authorities, utilities, and funders) at the project framing and design phase can lead to research results that are better aligned with stakeholder needs and thus more likely to be adopted. *Investment in accessible communication* is vital for maintaining visibility with stakeholders and lowering barriers to the adoption and implementation of research results.

Success in research adoption and implementation is a strong motivator for researchers at Eawag. This creates a virtuous cycle in which researchers become increasingly motivated to support activities (such as participating in continuing education) that promote adoption. Another important motivation is the opportunity to use real-world problems to help identify new, challenging and ultimately meaningful research questions.

4. A Push-Pull Model for Problem-Driven and Solution-Oriented Research

Eawag has a long tradition of problem-driven and solution-oriented research and our researchers have strong networks with stakeholder communities. New projects benefit from and build onto this tradition and often develop in an ad hoc manner rather than through a systematic approach. Although successful in the past, this model is challenged by changes in the demographics of Eawag's research staff as well as by increasing demands on their time.

In recent years, reflection on inter- and transdisciplinary (ITD) research at Eawag has provided insights into the advantages and disadvantages of various approaches (Hoffmann et al., 2017a, b). This reflection has stimulated efforts to support such activities. For example, we established a Community of Practice to promote exchange among colleagues with a strong engagement in SP2I activities (Hering et al., 2018). Such exchange facilitates the adoption of concepts and methods for implementation that have been developed in other application areas (Hering, 2018).

ITD research at Eawag benefits from continuity in the employment of our research staff and in our funding. These factors allow us to develop research initiatives that reflect goals that are shared by knowledge producers and users (Figure 3). Shared goals, continuity in personnel and stable, flexible funding have been identified as key success factors for the implementation of environmental research (Campbell et al., 2015; Cvitanovic et al., 2016; Reed et al., 2014).

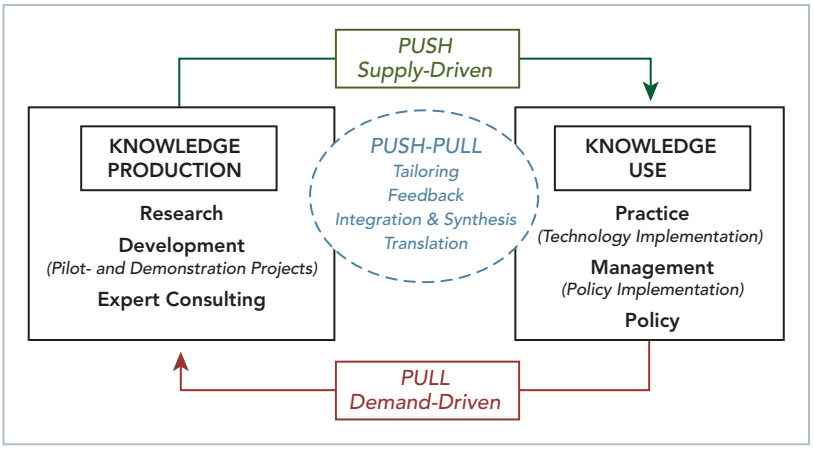

Figure 3. A schematic view of the iterative and interactive exchange of knowledge between those who produce knowledge through research, development and expert consulting and those who implement knowledge in practice, management and policy. Supply-driven knowledge exchange (green) is usually embraced by knowledge producers, who tend to resist the demand-driven knowledge exchange (red) preferred by knowledge users. A push-pull model (blue) has the potential to accommodate both knowledge producers and users. This graphic was published previously (Hering, 2018) and is reused under a Creative Commons Attributions BY 4.0 license.

Problem-driven and solution-oriented research requires cooperation among people with widely varying experience, expertise, capabilities and interests. Such research entails unavoidable transaction costs. In addition, researchers who engage in such projects must also maintain their standing in the scientific community and are not immune to conventional incentives (such as recognition for publications in high-impact journals). The tensions between the values of academia and real-world impact and competing demands on researchers' time should not be ignored (Boaz et al., 2018; Hering, 2016). Mutual respect for different types of contributions to projects and appropriate attribution to contributors are necessary to sustain productive collaboration. Engaging external partners to complete the value chain from ideation to implementation can allow people to play to their strengths and increase the effectiveness of their collaboration.

5. Water Research that Matters – Ways Forward

A substantial amount of water research that is relevant to future sustainability has either already been conducted or is on-going around the world. Integrating new knowledge and synthesizing existing knowledge are necessary to gain the full benefits of past investment (Hering et al., 2016). Access to knowledge from past and current projects is a prerequisite to leveraging advances and combining efforts (Hering et al., 2018). Cross-referencing and appropriate attribution can promote the amplification of "small wins" so that positive momentum can be channeled and aggregated and thus lead to transformational change (Termeer et al., 2017).

It is undeniable that some changes in the incentive structure of academic research are long overdue (Hering, 2016; Hering et al., 2012b). Stakeholders, including funding agencies, can be important allies in initiatives to include the impact

of research in the assessment of projects and careers. At the same time, research institutions must find ways to allow their researchers to engage with stakeholders without compromising the institution's ability to maintain its standing as a trusted provider of objective, evidence-based information (Hering, 2017).

None of this will be easy but it is sorely needed if society is to create a sustainable future. It is also exciting, challenging and motivating. If we can avoid re-inventing the wheel, value different types of roles and contributions and focus on positive examples and small wins rather than wasting our efforts on overcoming resistance, we can move "Over! Under! Through!" (Fey, 2011) toward a sustainable future.

6. Acknowledgements

I would like to express my appreciation to the Irvine Family and the Joan Irvine Smith and Athalie R. Clarke Foundation for establishing and supporting the NWRI Athalie Richardson Irvine Clarke Prize for excellence in water research. It is a great honor for me to receive this award and join the company of past Clarke Prize Laureates, which includes many colleagues and friends.

Throughout my career, I have benefited from collaboration with my former students, postdocs and many colleagues, especially my faculty colleagues at UCLA, Caltech, ETH Zurich and EPFL and the researchers at Eawag. I owe a special debt of gratitude to my Ph.D. supervisor François Morel and my postdoctoral advisor, the late Werner Stumm. Most of all, I would like to thank my friends and family for their encouragement and support.

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The 2018 Clarke Prize Honoree

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Dr. Janet G. Hering received the NWRI Athalie Richardson Irvine Clarke Prize in 2018 for her outstanding achievement in water science and technology. Dr. Hering has been instrumental in advancing access to safe drinking water in the United States and abroad. Early in her career, she focused her efforts on understanding the chemistry of drinking water treatment.

While receiving a Ph.D. in Oceanography from the Massachusetts Institute of Technology-Woods Hole Oceanographic Institution Joint Program, she conducted "elegant work on the surprisingly slow kinetics of some reactions between trace metals and organic complexing agents in natural water," said her former Ph.D. advisor, François Morel, now Professor of Geosciences at Princeton University. Morel noted that she carried out "cleverly designed experiments" and created a theoretical framework to document and quantify the previously unknown phenomenon. Her insights continue to inform studies of the behavior of trace metals in natural waters.

Hering initially joined Eawag as a Research Fellow after receiving her Ph.D. and began making significant contributions to the field of mineral/water interfaces. Recognized for her leadership skills, she successfully performed duties beyond those of the traditional postdoc position, including organizing scientific exchanges with researchers at other institutions and managing international conferences.

In 1993, she and Morel co-authored a textbook, titled Principles and Applications of Aquatic Chemistry, that – according to Dr. David Sedlak of the University of California Berkeley and one of Hering's longtime collaborators – is "a masterpiece that has influenced the way in which water chemistry is taught to environmental engineers, geochemists, and environmental scientists around the world."

Hering returned to the United States to teach at the University of California, Los Angeles, and later at the California Institute of Technology, where she focused much of her research on arsenic removal in drinking water treatment. Hering's research was critical to the efforts of the Los Angeles Department of Water and Power to treat naturally occurring arsenic in its watershed. She also served on various expert committees on arsenic, including as a panel member for the U.S. Environmental Protection Agency (EPA) Ad Hoc Subcommittee on Arsenic Research and as a consultant to the Drinking Water Committee of the EPA Science Advisory Board. For her outstanding work on arsenic, she was elected to the National Academy of Engineering in 2015.

Hering's current investigational efforts at Eawag focus on advancing research in the areas of water quality and management, as well as on promoting collaboration among universities worldwide. For example, she has helped establish interdisciplinary and international collaboration by inviting professors from the United States for guest professorships and lectureships.

In addition, Eawag is an international partner with the National Science Foundation's Engineering Research Center for Re-inventing the Nation's Urban Water Infrastructure (ReNUWIt). Hering also balances water science with water policy, supporting the synthesis between academic research and its real-world applications.

She advocates that water researchers focus on the broader impact of their studies by addressing issues related to the well-being of the public, while also creating benefits for governments and funding agencies. A thoughtful and prolific writer, she has written for various scientific journals and her works have been cited extensively; a 2004 article for the journal *Environmental Science & Technology* has been downloaded over 19,000 times.

The
ATHALIE RICHARDSON IRVINE
Clarke Prize

for Outstanding Achievement
in Water Science and Technology

The 2018 Clarke Prize Lecture, *Getting Water Research into Policy and Practice (GRIPP for Water),* was prepared by Janet G. Hering, Ph.D., the Director, Swiss Federal Institute of Aquatic Science and Technology (Eawag). She presented the Lecture on Friday, October 26, 2018, at the Twenty-Fifth Annual Clarke Prize Award Ceremony and Lecture, held at the Lyon Air Museum in Santa Ana, California.

The National Water Research Institute (NWRI) of Fountain Valley, California, established the Clarke Prize in 1993 to recognize research accomplishments that solve real-world water problems and to highlight the importance of and need to continue funding this type of research. Dr. Hering was the twenty-fifth recipient of the prize, which includes a medallion and $50,000 award.

The Clarke Prize was named after NWRI's co-founder, the late Athalie Richardson Irvine Clarke, who was a dedicated advocate of the careful stewardship and development of our water resources. The Joan Irvine Smith & Athalie R. Clarke Foundation provide funding for this award.

More information about the Clarke Prize can be found at WWW.CLARKEPRIZE.COM.

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