BILL & MELINDA GATES foundation

REINVENT THE TOILET CHALLENGE

REQUEST FOR PROPOSALS FOR THE FIRST YEAR

The Bill & Melinda Gates Foundation announces a new challenge aimed at concept development, design, and prototyping of a means of dealing effectively and cost-efficiently (less than $0.05 per person per day) with human waste for the 2.6 billion people on earth who currently lack access to safe and affordable sanitation.[1]

The Bill & Melinda Gates Foundation

Guided by the belief that every life has equal value, the Bill & Melinda Gates Foundation works to help all people lead healthy, productive lives. In developing countries, it focuses on improving people's health and giving them the chance to lift themselves out of hunger and extreme poverty. In the United States, it seeks to ensure that all people—especially those with the fewest resources—have access to the opportunities they need to succeed in school and life.

We concentrate on areas with the potential for high-impact—sustainable solutions that can reach millions of people. We work closely with our partners to support innovative approaches and expand existing ones so they reach the people who need them most. We also support policy and advocacy efforts to accelerate progress against the world's most acute poverty.

Global Development

Nearly 2.5 billion people live on less than $2 a day. For one person in eight, hunger is a constant, potentially deadly companion. The vast majority of the poor also lack access to the most basic financial services, and only a tiny minority have access to the Internet. The foundation's Global Development Program is working with motivated partners to create opportunities for people to lift themselves out of poverty and hunger. Our strategy is focused. Because most of the world's poorest people rely directly on agriculture, we support efforts to help small farmers improve crop production and market access. Because loans, insurance, and savings can help people weather setbacks and build assets, we facilitate access to financial services for the poor. In addition, information can change lives, we support free public access to computers connected to the Internet. The newest Global Development program area — Water, Sanitation & Hygiene—focuses on sanitation that works for the poor.

[1] World Health Organization and UNICEF. (2010). Progress on sanitation and drinking-water: 2010 Update. Retrieved from http://whqlibdoc.who.int/publications/2010/9789241563956_eng_full_text.pdf.

The Sanitation Challenge

A large share of the solids and liquids people eat and drink are passed on in urine and feces. Human waste contains potentially valuable and recyclable resources such as water, energy, urea, salts, and minerals. But it also consists of large amounts of useful as well as harmful microorganisms, mostly bacteria, as well as pathogens ranging in size from viruses to helminthes. Many diseases are passed on from person to person through the fecal-oral pathway—pathogens in one person's waste end up ingested by another. For some diseases this is the primary transmission pathway, for others it is one of several. Human waste also contains residues of the many complex engineered chemicals people use, such as food additives, antibiotics, hormones, and nutritional supplements, some of which remain in the environment and result in unsafe accumulation in waste sinks.

The dominant solution to dealing with human waste is still the 19th century water closet, linked to sewerage intended to flow to centralized wastewater treatment plants, but often terminating in cesspits or similar "local" storage, or is discharged without treatment. It is questionable whether using ever more scarce potable quality water to flush and transport waste is a wise solution for anyone. Even this solution continues to be inaccessible for 40 percent of the world's population, compelling them to use dump-points such as cesspits for bodily wastes. Indeed, more than 1 billion people defecate out in the open for want of any form of sanitation, while another 1 billion people only have access to ineffective forms of latrines, or "saturated" outhouses that are functionally equivalent to open defecation.[2] The result is a very high prevalence of diseases transmitted through the fecal-oral pathway, such as frequent and serious cases of diarrhea that cause the death of more than a million children every year and result in the permanent mental and physical stunting of several times as many more.[3] The cholera outbreak in Haiti in 2010 that caused thousands of deaths is another potent reminder of the consequences of poor sanitation in conditions precariously endured by hundreds of millions of people. For tens of millions of children, poor sanitation, poor personal hygiene, and lack of access to safe drinking water leads to a chronic situation characterized by poor nutritional status, gross loss of gut function, and stunting, with lifelong impacts on the victims and the societies in which they live.

In addition to the direct health impacts of poor sanitation, other impacts include the risk of violence against women, as they are often forced to defecate out in the open after dark. Poor sanitation also negatively impacts school drop-out rates for girls who cannot attend school during menstruation for lack of adequate, separate sanitation facilities.[4]

In the words of HRH Prince Willem-Alexander of the Netherlands, chair of the United Nations Advisory Board on Water and Sanitation, "The lack of sanitation endured by 2.6 billion people is a hidden international scandal. It is the principal reason for the spread of diarrheal diseases and the toll they take on human lives."[5]

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[2] World Health Organization and UNICEF. (2010). Progress on sanitation and drinking-water: 2010 Update. Retrieved from http://whqlibdoc.who.int/publications/2010/9789241563956_eng_full_text.pdf

[3] Pruss-Üstun, A., Bos, R., Gore, F., & Bartram, J. (2008). *Safer Water, Better Health: Costs, benefits, and sustainability of interventions to protect and promote health*. Retrieved from http://whqlibdoc.who.int/publications/2008/9789241596435_eng.pdf

[4] World Health Organization and UNICEF. (2004). Meeting the MDG drinking water and sanitation target: A mid-term assessment of progress. Retrieved from http://www.unicef.org/publications/files/who_unicef_watsan_midterm_rev.pdf

[5] Black, Maggie and Fawcett, Ben, "The Last Taboo", February 2008

The challenge presently posed to humanity's best and brightest is to develop practical ways and means for giving the "bottom billion" people access to safe and affordable sanitation that is pleasing to use and effectively removes human waste from the environment while recovering components that can be recycled.

The Reinvent the Toilet Challenge

The initial phase of the Reinvent the Toilet Challenge involves offering grant support to exceptionally qualified, highly focused, innovative individuals and teams at selected universities with recent records of extraordinary engineering excellence in pertinent areas. The challenge is to commence the prototyping, conceptualizing, and designing of highly innovative ways and means of disposing of human waste in the high-value-engineered circumstances demanded by potential widespread, near-term adoption in the developing world. ***Note that this Challenge is a separate process from the open calls for proposals issued by the Foundation as part of its "Grand Challenges Explorations" grant process.***

Capabilities of primary interest to this challenge include acceptably disposing of the bodily wastes of a typical human adult for a total cost (capital and operating) of less than $0.05 per day. This "stretch goal" represents a large advance in cost-efficiency over contemporary "best available means" (e.g., those of life-support systems in underwater or space-going vehicles) even after taking credit for plausibly steep learning curves and mass production on indicated scales. Nonetheless, they represent the levels of economic efficiency that must be attained in order to have real potential for major favorable impacts on the human condition in the developing world during the next few decades.

The initial phase of the Reinvent the Toilet Challenge has a "pilot" character. Its more successful approaches and features may be carried into subsequent program phases, which will involve more academic centers of engineering excellence. ***The underlying program has no fixed duration, no circumscribed budget, and no immutable form or structure.*** All of these will be adapted as programmatic progress indicates, as the engineering community rises to the challenge set out here. The program anticipates making grant commitments totaling several million dollars during the first year of the Reinvent the Toilet Challenge.

Exemplary Efforts and Goals

Ideally, the Reinvent the Toilet Challenge will yield a facility that is suitable for a single-family residence in the developing world; takes in the bodily waste of an entire family; and outputs useful waste-fractions—water, urea, salt, minerals—immediately and safely in usable forms. This would be accomplished without reliance on piped-in water, with no connection to any type of sewerage (including one terminating in a local cesspit, septic tank, or a municipal sewage-line, etc.), and with no electric utility connection. It would be a stand-alone, bathroom-equivalent module that includes a lavatory, is microprocessor supervised, and operates with energy derived from the combustion of dried feces. Furthermore, this facility would have a total cost (i.e., capital, operation, and maintenance costs) of a few pennies per day times the number of adults which it serves. The foundation has been advised that creating and operating such a facility may well be technically feasible at the present time, but the economics of such a solution remain uncertain.

While it may not be economically feasible in the near term to realize a facility that serves only a single family, due to problematic unit costs, it may be substantially more practical to create and operate one based on the same or similar set of technologies that serves a few dozen or a few hundred users. Such a facility would certainly be of great interest in the context of this challenge as an urban neighborhood asset. Modest amounts of utility electricity usage may be acceptable in many urban areas, provided that

associated electricity bills do not consume an excessive portion of the entire facility operating budget. While rural users would not be able to be served initially by such a facility, extension to rural use might be accommodated through other economical energy sources (e.g., energy scavenged from the environment via wind or solar converters) or to energy efficiency improvements deriving from experience with more urban systems.

The basic goal of the Reinvent the Toilet Challenge is obviation of the widest feasible spectrum of bio-threats to human health and well-being, focused on fecal-oral pathway transmission, all while being practical under the economic constraints of the developing world.

The foundation contemplates extending support in most scales and degrees of ambition of effort, ranging from descriptions and analyses of brilliantly innovative concepts to full-scale functioning hardware. However, we will give some preference to proposals that aim to deliver tangible, prototype-grade products or even detailed designs of such, presumably supported by performance-oriented modeling. Among these, some preference will be given to ever more complete systems over modules or components of systems, (e.g., a fully functional toilet vs. a key component of one, or a processor of both urine and feces rather than one or the other).

Technical Specifications

The "envelope specification" of the challenge is the rendering of the bodily wastes of an adult human into water, CO_2, and mineral ash; at a *per capita* daily total cost not to exceed $0.05; in a safe, enduring, environmentally satisfactory manner that is adequately human-engineered; in a way that it will be widely acceptable by the world's poorest people.

Key Requirements

- Acceptance at essentially unrestricted rates of mixed-content (urine and feces) human waste streams, as well as "sanitation incidentals" (e.g., toilet paper, feminine hygiene waste, diapers).
- Reasonably prompt (single-day time scales) rendering of inputted wastes into a water stream suitable for rejection to the ambient environment, a CO_2 stream suitable for injection into ambient air, and a mineral-ash stream suitable for packaging and eventual zero-hazard disposal, e.g., as agricultural mineral fertilizer.
- Unqualified freedom from inputted water and output sewerage connections of any type.

Key Desires

- Provision of a toilet/lavatory facility suitable for hygienic deposition of human bodily wastes that is well-lit and self-maintaining in all critical respects, including freedom from insects, odors, stains, and unhygienic surfaces.
- Sustained operation without any inputting of wired-in electricity (e.g., utility mains-derived).
- Scalability down to a single residence scale without loss of developing world practicality
- Conversion of recovered water into potable-grade water, e.g., via polishing, to address considerations of color, odor and taste, and achieve assured sterility.
- Recovery of urea in at least "technical grade" form, suitable for packaging and subsequent use as agricultural fertilizer.
- Recovery, sterilization, and packaging of minerals for subsequent uses as food condiments, dietary micronutrients, and/or mineral fertilizer.

- Production (e.g., via electrolysis) of modest quantities of hypochlorous acid salt (e.g., NaOCl; CaOCl) solutions for general-purpose sterilization, e.g., in facility surface cleaning and in preparation of possibly superficially contaminated foodstuffs for human consumption.
- Robustness of operations via optimally implemented redundancy, including smart supervisory control system, wireless connectivity with a central maintenance/support point, and vandalism and misuse suppression features.

Valuable Intermediate Solutions

- A facility that has the mixed content (urine and feces) processing capabilities of the previously described facility without the toilet-lavatory itself, but can accept delivered waste (through pumping trucks, buckets, etc.) for processing at a local-scale treatment facility without input or output connections.
- A treatment facility described above that can handle the waste of 1,000-5,000 people per day (many useful technologies have been implemented at a larger processing scale, and their reliable, cost-effective function at family scale is an existing engineering challenge).
- A treatment facility described above with external electrical power and with the cost per user within the prescribed limits.
- Cost-effective implementation at single-family scale of necessary subsystems that currently exist primarily at large throughput scales.
- Self-maintaining toilet-lavatory with user experience and durability specifications as above but without the full set of capabilities for efficient mixed content processing specified for the full system.

Proposing Scopes

It is anticipated that several distinct types of organizational structures may be able to contribute in this initial phase, ranging from a solitary effort by a committed individual, to a team of students at the upper division or graduate level, to groups including multiple faculty members. But in all cases, there will be overall supervision by a member of the proposing university's faculty (usually an academic senate member) who must act as the proposing Principal Investigator PI) and carry all of the usual PI responsibilities for both the university and the foundation.

While support of small-scale "paper studies" of limited scope and duration but of exceptional promise is certainly within the ambit of this phase of the challenge, endeavors aimed at and reasonably likely to attain a prototype system or at least major subsystem modules in the course of fast-paced, highly innovative efforts will receive primary emphasis. In addition, all organizational structures, even smaller teams of students proposing as self-assembled or "class project" entities, must feature execution plans that will lead with reasonable likelihood to a nontrivial product of manifest significance to this challenge, even if it's just a detailed paper design of high quality and programmatic salience. All efforts proposing to develop prototypes of any kind or degree of completeness must be willing and prepared to support their operational evaluation to explicitly declared extents, both on campus and in the field, including timely documentation and publication of results.

The foundation expects that proposals for the first phase of the challenge may be placed into three tiers. The top tier would consist of "full system" or "whole solution" approaches that respond to all aspects of the challenge.

The second tier would consist of "partial solutions" that miss one or more key features of the challenge, albeit in a non-absurd manner. The lowest tier would consist of "key modules" or "major capabilities" that comprise substantial building blocks of a notional "whole solution" but that are quite incomplete in themselves.

For instance, a second-tier proposal might be for a system that could perform as challenge-specified in all respects except that it would use a few kW-hr of electricity per user per day rather than the few tenths of a kW-hr that is the upper-bound under challenge techno-economic specs. It might employ this additional electrical energy for low-complexity rendering of human waste components into water, CO_2, and mineral residue and be suitable for use in natural disaster situations where electrical power might be comparatively available (e.g., the recent Haitian post-earthquake situation). A third-tier proposal might contemplate demonstration of a fully operational prototype for automatically cleaning an entire sanitation facility within challenge parameters so that it is unendingly free of odors and stains and has clean and sterile surfaces. Or, it would be able to pre-process a mixture of urine and feces into two distinct streams—one liquid and one solid—for simplification of subsequent processing into water, CO_2, and mineral ash within challenge parameters.

It is expected that lower tiers of effort will ask for correspondingly lower levels of support and/or provide nearer-term attainment of major programmatic milestones, e.g., demonstration of full working prototypes at the culmination of the challenge's first phase in August 2012.

Proposal Preparation, Submission, and Work-Up

Short proposals (about ten pages, including Annexes – with detailed guidelines to be provided online for those interested to submit) are due to the Foundation through online submission on ***March 11, 2011***. Each proposal shall begin with a cogent summary of the basic idea, concept, or effort plan. This shall be followed with a more extensive characterization of the work to be done and the product(s) to be generated as deliverables at the conclusion of each phase of the proposed work, as well as at the conclusion of the proposed work. Each component must be sufficient in scope and detail to enable its feasibility evaluation by an expert reviewer in the foundation's service. Proposals may address extended durations of contemplated effort, but this initial proposal should focus on the first phase of effort, with sketches of linkages into subsequent terms of effort.

This shall be followed by brief sketches of the pertinent professional background, qualifications, and accomplishments of the principal performers of the proposed work, including all faculty members who may be involved in any substantive manner.

A budget, including justification of sufficient detail to enable evaluation of its reasonableness and necessity, must also be included. ***As the foundation contemplates making grant awards in the range of $200,000 to $400,000, "complete system" proposals can be made for awards up to $400,000 for the first phase of effort, nominally commencing no earlier than June 1, 2011, and concluding no later than August 31, 2012. The foundation reserves the right to award a grant amount lower than what is proposed, in which case we would ask for revisions of the budget and the technical plan.***

Items proposed for purchase must be clearly tied to the work to be done (e.g., equipment and supplies for actual use in prototyping). No funds will be provided for the purchase of major equipment or furnishings, computing hardware, or software, or for the performance of construction. No support will be extended for faculty salaries in excess of 10 percent during the academic instructional year, but

requests for as much as 100 percent academic summer salary support are acceptable. All reasonable types of student wages and salaries are eligible for grant support, but tuition or academic fees will not be covered except under unusual circumstances. The standard indirect cost policy of the foundation, outlined in the templates supplied by the foundation, must be adhered to.

Because this challenge is at its essence an extreme value-engineering one, grantees are asked to make an *ad hoc* technical-economic argument to consider the likely ability of the proposed effort to ultimately lead to the capability to satisfactorily dispose of a combination of ≤3 liters of human urine and ≥400 grams of human feces for a total unit marginal cost of less than 5 cents. For economic estimation purposes, the cost of money should be assumed to be 6%/year, and facility operational lifetimes should be taken to be no greater than 20 years. Plausible economies-of-scale may be invoked in making this economic feasibility case. This argument should be no more than two pages in total length.

All proposals must be submitted through normal university review and approval channels, preferably in entirely electronic form. Receipt and processing information will be communicated to the proposing PI's e-mail address and that of the institutional Review Officer. No person or unique combination of persons may be the proposing PI on more than one proposal in this initial phase. Foundation staff members or foundation advisers may contact the proposing PIs for clarifications or elaborations in the course of the proposal review process. Delays in responding to these may delay or defeat proposal evaluation without further notice being given. Foundation queries directed to such e-mail addresses that do not elicit a timely response will result in indefinite suspension of processing of that proposal and its automatic rejection without prejudice after posted deadlines have elapsed. Proposals not fully complying with each of these administrative requirements cannot be considered for funding.

Evaluation Criteria and Number of Awards

Evaluation and selection criteria are as follows:

- Quality and pertinent experience of the proposing team.
- Proposed progress to be made on the whole vision or selected elements by August 2012.
- Quality/methodological innovation/technical approach proposed.
- Reasonableness of budget, program cost-effectiveness, and strength of techno-economic justification of the proposed product.

The foundation contemplates funding no less than about two-fifths of all proposals received, and may extend support to half or more.

Challenge Executing Conditions

The foundation aims to inform successful proposers by April 12, 2011. All proposers will receive notification of foundation decisions by April 30, 2011. ***Work may commence only once a grant agreement has been executed between the foundation and the proposing institution, with effort start dates targeted at June 1, 2011.*** As the phase of contracting depends on the complexity of the local situation and fast-paced cooperation between the foundation and the grantee institution, not all grant agreements may be in place by June 1, 2011. In this case, the start date of the work will be delayed until the grant agreement has been fully completed.

The proposed work should be completed and prepared for presentation at a culminating meeting of this first phase of the challenge in August 2012, on a date to be announced. Quarterly progress reports will

be required over all intervals of supported effort, due no later than 30 days after the end of each reporting interval. Cognizant foundation professional staff and foundation advisers will provide guidance as to the minimum essential content of these interim reports, as well as to that of the final report, which shall be due no later than 60 days after the conclusion of any supported effort interval. Depending on the progress made during the first phase, the foundation will decide how best to continue the challenge in a second phase. Successful performers will be invited to submit proposals for this second phase of effort, with awards for the second phase being made contemporaneously with the August 2012 event that culminates the first phase of the challenge.

Competitively Awarded Prizes

At the Reinvent the Toilet Challenge event to be held in August 2012, teams will be invited to present and demonstrate their work, in the form of papers and posters, with strong preference being given to the exercising of working models or functional prototypes. The efforts of the different teams will be evaluated by a panel of reviewers who will award prizes to the teams that in their judgment have made the most outstanding progress in each of the three tiers of endeavor. The "full system" or "whole solution" prize-stipend will be $100,000. The reviewers may award as many as two additional prizes for outstanding progress made on major supporting modules in the two lower tiers of programmatic ambition, in amounts of $40,000 and $60,000. Certificates with appropriate citations will accompany the prize-stipends.

Detailed proposal guidelines, templates and online submission

Universities interested in submitting a proposal are requested to confirm their interest though an email to RTTC@gatesfoundation.org and they will receive a link to a page with guidelines and templates for online proposal submission no later than February 11, 2011

List of universities invited to submit a proposal to this Challenge

1. California Institute of Technology	United States of America
2. EAWAG: Swiss Federal Institute of Aquatic Science and Technology	Switzerland
3. Imperial College	United Kingdom
4. Indian Institute of Technology, Bombay	India
5. Loughborough University	United Kingdom
6. Massachusetts Institute of Technology	United States of America
7. National University of Singapore	Singapore
8. Princeton University	United States of America
9. Stanford University	United States of America
10. Technical University Delft	The Netherlands
11. The University of Tokyo	Japan
12. Tsinghua University	China
13. Universidade Federal de Minas Gerais	Brazil
14. University of California, Berkeley	United States of America
15. University of California, Santa Barbara	United States of America
16. University of Cambridge	United Kingdom
17. University of KwaZulu-Natal	South Africa
18. University of Minnesota, Twin Cities	United States of America
19. University of Texas, Austin	United States of America
20. University of Toronto	Canada
21. University of Wisconsin, Madison	United States of America