Article

Augmented Popperian Experiments: A framework for sustainability knowledge development across contexts

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Abstract: The challenges to sustainability governance across multiple geographical/cultural contexts lead us to the "piecemeal engineering" idea advocated by the philosopher Karl Popper, which explicitly considers context. We argue for adopting the piecemeal engineering approach, augmented by adaptive policies and modern (online) collaboration platforms to maximize the prospects of sustainable practices worldwide. This recommended course is not intended to be a theory in itself. Rather, it is a well-grounded, practical and practicable stop-gap measure in times when complexity and change outpace theories and strategies. We present a philosophical foundation for this "Augmented Popperian Experimentation." Focusing on The Water Network (the largest collaborative platform for water researchers and professionals), we show that sustainability-oriented organizations in the water realm and others are inching toward the practice we advocate. We discuss implications.

Keywords: Sustainability, Governance, Piecemeal engineering, Collaboration, Karl Popper

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1. Introduction

> *"A fact learned from a fragment of one culture can be applied to salve the ills of another."*
>
> \- Andre Norton

The many jurisdictions that are (or should be) responsible for sustainable development are diverse in their local conditions and capabilities. Wishing to advance the UN Sustainable Development Goals (SDGs) and the Paris Accords, they ask, "How?" or, alternatively, bridle at the central direction they perceive as emanating from New York and Paris [1].

Additionally, anyone who travels or watches the news understands that management occurs in many contexts – social, organizational, legal, linguistic, technological, and even geological. In terms of the latter, the Fukushima tragedy illustrated the folly of Japan's nuclear strategy, building an atomic power plant in a locale prone to earthquake and tsunamis, even as nuclear power proves successful in stabler geographies. It is indeed clear that one size, in terms of theories of sustainability governance, cannot fit all contexts. Recently, Moldavska proposed that defining organizational context is helpful to the implementation effectiveness of corporate sustainability [2].

It then stands to reason that diverse regions and contexts must try different policies, tactics, and measures. Many recent articles advocate this "experimentalist" approach to sustainability. Drawing on ideas of Axelrod, Ostrom and others, Sabel and Victor write, "Where uncertainty is high…

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experimentation and learning are better means of advancing" climate change measures [3]. Trencher et al tell of social experiments with students and the elderly [4], as does Kerkhof with Dutch stakeholders [5].

A related stream appears under the banner of sustainability governance. Monkelbaan sets forth these criteria for sustainability governance: Deliberative and participatory; Adaptive; Pragmatic; Pluralistic and diverse; Focused on knowledge sharing and learning; Reflexive; Polycentric [6]. "Postmodern governance theory celebrates multiple epistemologies," Monkelbaan states, "but it does not specify the mechanisms and institutional arrangements for handling multiple knowledges in a way that recognizes the specificity of knowledge claims." We note that Monkelbaan [6] and Ansell [7] (in his *Handbook on Theories of Governance*) defer to the pragmatist philosophers (James, Churchman) in articulating a foundation for experimental governance.

Schot and Geels emphasized the importance of context as the key element of their Strategic Niche Management (SNM) framework [8]. SNM assumes that sustainability technology innovations are "protected spaces that allow nurturing and experimentation with the co-evolution of technology, user practices, and regulatory structures." They continue, "It is not a technology push approach. Instead, SNM scholars argue that sustainable development requires interrelated societal and technical change," which we presume would imply adaptive policies. Schot and Geels summarize three criteria for the successful development of SNM niches as requiring (1) the articulation of expectations, (2) the building of broad social networks involving multiple kinds of stakeholders, and (3) multi-dimensional learning focused on second-order learning.

Taken together, to add knowledge in sustainability and to anchor and operationalize the work of Moldavska [2] and Schot and Geels [8], we propose Augmented Popperian Experimentation (APEX hereafter) - philosopher Karl Popper's "piecemeal engineering" as an alternative framework to one-size-fits-all policy-making. Popper's idea explicitly considers context. Augmenting his idea with two other notions – collaboration platforms and adaptive policies –as a workable and philosophically sound way for jurisdictions, NGOs, and companies to navigate the multi-contextual situation, in the absence of comprehensive theories for sustainability and governance for sustainability knowledge development. We provide a philosophical foundation for policy action, and concrete technological and policy tools to put the framework into practice. Specifically, we show how piecemeal engineering can leverage modern information technology to carry governance through the present era of colliding cultures and rapid change, and toward the possible emergence of new overarching theories.

The paper begins by identifying theoretical gaps. Following by establishing the philosophical foundations, provides greater clarity to, what a growing number of companies, governments, and NGOs are already (partially) doing argues for Augmented Popperian Experimentation as a bridging strategy during a Kuhnian "crisis," with a special focus on managing for sustainability; and shows how today's information/communication technology (ICT) and new managerial ideas make this framework practicable and easily communicated among constituencies.

It then introduces the new information and policy management technologies. Following an in-depth case in water management, the paper gives further examples of practice, and concludes with discussion and policy implications.

2. Theory and Sustainability: Are we 'between theories'?

Theories that address parts of the sustainability problem have predictive power and are more or less operationalizable. An example is cradle-to-cradle design [9]. However, in his review of Espinosa and Walker [10], Jopling [11] states, "The sustainability of a human society is not just about its relationship with the environment: it's a problem concerning the nature of the society and the way it is organized." This makes it clear that creating a complete, overarching theory of sustainability would be a Herculean task, even for a single society. Our global sustainability problem involves multiple, diverse societies.

Indeed, even when a sustainability course or article puts "theory" in its title, the careful authors present their work as a "framework" (Waring et al [12]; Kerkhoff [5]; Buser and Koch [13]) or an "approach" (Espinosa and Walker [10]). A University of Melbourne course, "Sustainable Infrastructure Systems," represents the state of knowledge as a collection of theories from land use, infrastructure (systems engineering), and public policy, plus the Four Capital Model of sustainability (Human Capital, Financial Capital, Environmental Capital, and Manufactured Capital), and the Natural Capitalism of Hawken, Lovins and Lovins [14].

The familiar three-pillars model (E^3 for Equity, Efficiency, and Environment, a.k.a. P^3 for People, Profit and Planet) and the four-capital model are excellent starting points, as is the generalization of cradle-to-cradle known as Circular Economy, though these lack the explanatory and predictive power one expects from a theory [15]. In a 2013 CFP for a special issue of *Sustainability*, Vallance wrote that "much remains to be done, particularly around the reconciliation of the tensions between these [pillars]" [16].

The latter theoretic structures are more conceptual and aspirational than explanatory. Such predictive power as they have, to state the matter fairly, can be made untestable due to public policy impediments or "persistent diplomatic deadlock" [3].

Technological and social changes have already made other theoretical approaches obsolete. The Oxford Reference states, "Theories of sustainability attempt to prioritize and integrate social responses to environmental and cultural problems" [17]. This statement ignores technological responses. More importantly, it ignores recent developments with the UN's Sustainable Development Goals, which were formulated via multi-constituent dialog. As Leitner and Tillemann point out, prioritization proved impractical [1]. All the SDGs are important, at least to some constituencies. A central authority prioritizing the SDGs would vitiate the original reason for multiple-constituent dialog.

The Oxford Reference goes on to decompose sustainability theory into an economic model, an ecological, a political model, and a religious model, but does not note interactions among the models that could create a theory [18,19].

This brings us back to approaches, like our Augmented Popperian Experimentation (APEX), that attempt not to homogenize diversity but to embrace it. Espinoza and Walker, building on ideas of system theorist Stafford Beer, advocate "embedded autonomous social systems with self-organised autonomous units each served by meta-systems using a new family of indicators, real-time measurement systems and appropriate responses thereto" [10]. Waring et al propose "a recipe for how to grow sustainability: groups at the scale of the resource they manage; a population of such groups; learning between groups; high stakes for group failure; and rules to support cooperation" [12]. Kerkhoff notes "persistent concerns over our apparent inability to connect what we know with more sustainable practices and outcomes" [5]. Foxon's critique of economic theory's applicability to sustainability is typical of many such: "Mainstream (neo-classical) economics provides little guidance for understanding long-term industrial change" [20].

In terms of sustainability theories, Allen and Ervin [21] and Espinoza and Walker [10] agree: "One size does not fit all." Section 4, below, includes further review of the literature of experimental governance for sustainability.

What the present paper adds to the diversity-philic sustainability frameworks is, first, a further philosophical foundation – surely needed as humanity faces an existential ecological threat – calling on the ideas of Daniel Denning, Thomas Kuhn, Karl Popper (with whose opposition to centralized control Stafford Beer largely agreed) and Jean Paul Gustave Ricœur.

Second, we provide concrete technological and policy tools to put the framework into practice.

3. Philosophical Foundations: Bridging obsolete and yet-to-come theories

A totally free-market economy cannot fix long-term, global problems [22]; and centrally-directed economies have been among the worst polluters [23]. Yet developing countries under either kind of regime deserve to enjoy a decent level of wealth. These conditions and complexities have destroyed much of the received wisdom of economics. The ideas of the philosopher of science Karl Popper suggest a bridging tool that can help guide policy makers until new theories, spanning (as they must) economics, sociology, and ecology emerge.

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Daniel Dennett sets the stage for this philosophical discussion. Thomas Kuhn's writing further clarifies the context within which we apply Popper's ideas. We elaborate how we build on these philosophical foundations.

3.1. Dennett: Four grades of umwelt

The present-day philosopher Daniel Dennett distinguished four grades of *umwelt*, or organismic experience [24]. Dennett's first two grades are instinctive 'Darwinian creatures,' capable of no adaptive behavior, and 'Skinnerian creatures, who… adjust their behavior in reaction to "reinforcement,"' with adaptive but random behaviors being reinforced. Third and fourth in Dennett's taxonomy are:

3. 'Popperian creatures, who… pretest hypothetical behaviors offline, letting "their hypothesis die in their stead," as Karl Popper once put it. Eventually they must act in the real world, but their first choice is not random, having won [competitive] trial runs in the internal environment.'
4. 'Gregorian creatures, named in honor of Richard Gregory, the psychologist who emphasized the role of "thinking tools"… The Gregorian creature's *umwelt* is well stocked with thinking tools, both abstract and concrete: arithmetic and democracy and double-blind studies, and microscopes, maps, and computers.'

Theories and firm, well-structured knowledge are Gregorian. Experience-based hypotheses and exploratory experimentation are Popperian.

3.2. Kuhn: Scientific paradigms

Popper is well known for proposing that a statement can only be considered scientific if it is falsifiable [25]. Thomas Kuhn set forth the psychological and sociological barriers to falsification [26][1]. Not all scientists are as rational as Popper; they may cling to a troubled but currently prevailing theory due to inertia, investigator bias, greater ease of publishing papers that bow to the theory, or a seeming lack of alternatives. As a result, Kuhn wrote, scientific progress is non-linear, subject to (in his famous phrase) paradigm shifts.

Kuhn (b.1922-d.1996) wrote that *The Structure of Scientific Revolutions* features this standard sequence: (1) normal science; (2) anomaly; (3) crisis; and (4) revolution – establishing a new paradigm [26]. The first, normal science, tends to consolidate a theory. Because no theory is a complete explanation of reality, anomalies arise – and are often denied or explained away by adherents of the theory.

Anomalies accumulate to the point where they can no longer be ignored. In his introduction to the 50th anniversary edition of Kuhn, Hacking writes, "Anomalies become intractable [27]. No amount of tinkering will fit them into established science. But Kuhn is adamant that this does not, in itself, lead to rejection of existing theory"[2].

Kuhn himself put it this way: "The anomaly itself now comes to be more generally recognized as such by the profession. More and more attention is devoted to it by more and more of the field's most eminent men (sic)."

This puts the field into the *crisis* stage of the sequence. Hacking [27]: 'A crisis involves a period of extraordinary, rather than normal, research, with a "proliferation of competing articulations, the willingness to try anything, the expression of explicit discontent, the recourse to philosophy"'. As indeed we are having recourse to philosophy in the present paper. Yet "the willingness to try anything" implies a possibly undisciplined empiricism, unlike the structured Augmented Popperian Experimentation that we propose here.

Kuhn did not specify how long a crisis lasts. His examples from the history of science show crises spanning a couple of decades up to about 1350 years – the latter being the lifetime of the

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[1] We cite the 2012 50th anniversary edition. Kuhn's original book was published (of course) in 1962.

[2] This could be why early reviewers of this paper – which proposes a practical strategy for navigating the interregnum between prevailing theories – commented, "But where is the theory?"

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best-then-available-but-obviously-flawed Ptolmaic astronomy, until it was supplanted by the Copernican. Kuhn's answer to "What do scientists do during crisis?" seemed to be, "Collect and ponder anomalies." There was, to be sure, only one astronomical universe to study. Because we now have multiple, diverse cities and regions experiencing environmental stress, we can propose another task for mid-crisis scientists: Experiment, collaborate, and adjust, according to Augmented Popperian Experimentation.

The experience-based sustainability theories of some traditional societies had predictive power – follow them and the tribe survives – but were not globally scalable. Recent decades represent a gap between the pastoralist theory/ethos and a new, as-yet unformulated comprehensive sustainability theory. In terms of ethos, we now similarly fall between the early-industrialist exploitative worldview and an as-yet unrealized "fulfilling life with small environmental footprint" ethic.

With the help of computers, governments and companies can conduct multiple experiments – piecemeal engineering – across multiple geographies and divisions, sharing information about what works under what conditions, and matching solutions over there with problems back here. This procedure offers the best chance for beneficial and localized practices to emerge, until such time as new social + economic + ecological theories emerge, and Gregorian thinking again becomes practicable.

3.3. Popper: Piecemeal engineering

"Before Kuhn," writes Hacking, "Karl Popper (b.1902–d.1994) was the most influential philosopher of science" [27].

Popper maintained that centralized, utopian planning, which easily slides into static totalitarianism, is to be avoided. "If we plan too much, if we give too much power to the state, then freedom will be lost, and that will be the end of planning." Rather, he wrote, human welfare and social progress are achieved through diverse initiatives and tests – multiple engineering experiments. In Popper's words, "What we need is not holism. It is piecemeal social engineering" [28].

By implication, and by frequent reference to Karl Marx, Popper was criticizing economic theories that led to such monolithic regimes. He was specifically aiming at communism and Nazism, but the current breakdown of neoclassical economic theory also can serve as a case in point of Popper's argument.[3]

Furthermore, Popper understood the difficulties of implementing a policy:

> The social technologist and the piecemeal engineer may plan the construction of new institutions, or the transformation of old ones; they may even plan the ways and means of bringing these changes about; but… they do not plan for the whole of society, nor can they know whether their plans will be carried out; in fact, they will hardly ever be carried out without great modification, partly because our experience grows during construction, partly because we must compromise [29] (pp.131-132).

Because we now address sustainability in multiple cultures and geographies and under technological change, in this paper we will favor the term "multiple engineering experiments," abbreviated as MEE. Popper advocated MEE as a reaction against totalitarian regimes that do not recognize or value diversity in local conditions and cultures.

When Popper proposed MEE, there were no quick mechanisms for sharing (across regions) the descriptions of local problems and the local solutions that might be applicable elsewhere. Now we do have those mechanisms, the online collaboration platforms. We also now have the policy mechanism to deal with MEE, namely, "adaptive policies." These augmentations to MEE transform it into APEX, make it more powerful and useful, and are discussed in the following sections.

4.1. Adaptive policies

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[3] Popper explicitly mentioned that his statement applied not just to governments but to businesses as well (Popper [28], pp.59-60). We will pursue this avenue in a future article.

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Sabel and Victor argue that "this bottom-up approach will only work if it is supported by institutions that promote joint exploration of possibilities by public and private actors" [3]. Exploration, in fact, cannot be prevented. Institutional acceptance and implementation is another story. Indeed, adaptive policies are the most difficult hurdle in the APEX equation. However, we demonstrate by example that adaptive policies are not only possible, but are starting to be endorsed by prominent thinkers and embraced in practice.

The late Bill Cooper, editor of *Kohler's Dictionary for Accountants*, defined a policy as a rule that must be followed 90% of the time.[4] Phillips went on to define an *adaptive policy of the first kind*, in which the 90% figure changes as conditions change over time – going sometimes to zero, either due to a sunset clause or to (constant monitoring and) adoption of policies that are working well in other localities [30]. An *adaptive policy of the second kind* would allow the percent figure to vary by geography, culture, and local conditions.

Swanson et al [31] and Marchau et al. [32] provide rich detail about, and document instances of, adaptive policy-making for innovation in transport and other sectors.

In the context of genetically modified organisms (GMOs), Mitchell remarks [33]:

> The problem with generating "global" GMO policies is that policy-makers are failing to consider the local variations of a particular region. I'm proposing an adaptive policy that's more in tune with the knowledge we've gained about the biodiversity of a specific area.

Mitchell offered as an example Bacillus thuringiensis (BT), a bacterium used as a pesticide on corn and cotton. The 600 strains of BT have different effects on GMO plants. "Reasonable policy needs to take into account such complexities", Mitchell said. "The consequences for biodiversity of introducing a GMO are relevant to successful regulation".

As an alternative to the "predict-and-act" approach that would stem from a fixed policy, Mitchell suggested "multiple, iterated scenario analyses to provide models better attuned to the factual complexity and diversity that GMOs display".

Espinoza and Walker's complex systems approach to sustainability leads them to cite, as an example, the crisis in Colombia's Magdalena River basin, and to argue that supporting the eco-region requires continually "rewriting roles and responsibilities of the various existing public and private institutions." They suggest a recursive analysis to uncover the various levels of complexity in the larger meta-system, which inherently includes consideration of societal and technical contexts. This sounds much like adaptive policy [10].

We now have the information technology (IT) capability to track a multiplicity of small-area policies, solutions and initiatives, and to adapt policies accordingly.

4.2. Collaboration platforms

Noting 'the considerable heterogeneity that is likely to characterize regional, national, and subnational policy efforts," Mehling, Metcalf and Stavins focus on linking regional policies and highlight the economies of scale benefits of partnering among regions having similar problems and similar solutions [34]. Online collaboration platforms seem the most promising way of linking for this purpose.

A collaboration adds broad social networking capabilities to a work process. It generally refers to the system that combines tools and processes to ensure individuals can connect and collaborate with people, information and the resources they require at any time. Typically, a platform includes an email client, Web conferencing, social media sharing, video capabilities, document sharing capabilities, instant messaging and more.

In the past decades, companies have developed various web-based systems for supporting collaborative activities in different life-cycle phases of product development, including marketing, design, process planning, production, distribution, service, etc., and for associating these distributed product development life-cycle activities into a globally integrated environment using internet as well as web technologies [35]. This type of collaboration platform can foster innovation by

[4] Personal communication, c.1990.

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incorporating knowledge management into business processes so task workers in the organization can share information and solve problems more efficiently.

Public platforms, such as LinkedIn and Facebook, are free online platforms that people use to build social networks with other people who share similar personal or career interests, activities, backgrounds or real-life connections [36]. Other commercial public platforms focus on specific subjects such as water, air pollution or food and so on. Members can share and acquire knowledge by raising or answering questions, posting or downloading articles, or participating in discussions, effecting knowledge management on the platform. For example, the Water Network is the largest online knowledge-sharing platform and business exchange for global water professionals. Members are from every country in the world, representing over 10,000 companies [37].

Research-oriented platforms such as ResearchGate and Mendeley enable collaboration and knowledge sharing among academics. While both platforms provide free tools for collaboration through open discussion forums and direct messaging, Mendeley includes further capabilities such as data sharing and ad-hoc groups. For example, a search for "water resources management" on the Mendeley site returned thousands of tabular datasets and images with links to hundreds of slide decks and numerous references to software or code related to published articles.

The opportunity to develop digital services to provide access to expertise, customized research and project solutions through online platforms is estimated at more than $13 billion per year [38].

5. APEX: Linking MEE, Adaptive Policies and Collaboration Platforms

In his seminal work, Drucker emphasized the importance of decentralization in post-capitalist society [39]. Specifically, he indicated, "Organizations must be able to make fast decisions based on closeness to performance, closeness to the market, closeness to technology, closeness to the changes in society, environment, and demographics" [39]. Accordingly, government agencies and NGOs have taken advantage of information technology to get access to knowledge, information and data for developing policy. In this section we offer empirical examples from five sustainability domains – water management, green business development, climate change, smart cities, and environmental cleanup – that show positive impacts from moving toward the APEX orientation.

In his fictionalized account of the 1787 U.S. Constitutional Convention, Best attributes this dialog to the Founding Fathers [40]: "The accidental division of this country into thirteen states gives it thirteen chances to happen upon the perfect system. Copying each other's successes speeds our progress." "Perhaps thirteen chances for chaos." "No, we're unique! No one in all of history has owned thirteen republican laboratories." America's early Popperian experimental laboratory still yields fruit: Zorn writes of other States learning from the failure of Kansas' recent bout of extreme trickle-down economic policy [41].

As we will see in the examples below, opportune political divisions can aid experimentation (India's smart cities) but are not always necessary (the Water Network). We see how far each organization has progressed toward realizing the equation

$$\text{APEX} = \text{MEE} + \text{Collaboration Platforms} + \text{Adaptive Policies}.$$

5.1. Water management

Water is a key resource and cost to all manufacturing and heavy industries, agriculture, oils and gas and of course fundamental to life. With a global water crisis there is a tremendous need for knowledge sharing and valuation of alternative solutions to business, government and utility challenges. The Water Network (https://thewaternetwork.com/) began in 2009 and today is the largest knowledge-sharing platform and business exchange for the $700 billion global water research and business ecosystem, with its estimated 12 million knowledge workers globally.

The Water Network provides a channel for people to connect with one another and share their experience or knowledge in the field. No matter whether one is a water professional, technician, researcher, policy maker or just interested in water-related issues, one is welcome to join the platform to register a free account and exchange ideas. Members can communicate quickly with people from different backgrounds or countries anytime, anywhere through the network. Diverse

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members can post water-related questions on the website. Other members may share a similar experience or provide ideas toward answering those questions. Subsequently, questioners and some respondents may enjoy further contact and discussion. Then, questioners may test the feasibility of solutions derived from the discussion. In this way, water-related problems can be solved by collective intelligence.

One of the most traditional and conservative industries in the world is wastewater treatment. For 100 years the technology solution of choice has been activated sludge. Trying out activated sludge innovations is costly (many tens of thousands of USD), complex, and takes up a lot of space. Decision makers in the industry are risk-averse. The Water Network, subject of this paper's in-depth examination, features an embedded open source tool that creates a complete waste water treatment plant design including process flow, architectural layout, instrumentation lists, etc., and compares this traditional activated sludge process with a modern biological activated sludge solution. The Water Network is a community where members can see hundreds of others with a similar challenge (type of nutrient, temperature, population served, etc.), providing confidence that the would-be innovator is not alone. Virtual experimentation is the first step, followed by confidence by checking viability with peers.

Table 1 demonstrates by example the process of piecemeal knowledge sharing, acquisition and local adaptation via the Water Network platform. In the example about the removal of nitrates, the question received 37 responses in total (see Appendix 1). As shown in the Appendix's Table, there were 21 responses with related solutions, 8 responses with other suggestions and questions, and 8 repetitive responses. Some of those respondents further contacted and joined the questioner's personal network and activities. The questioner is an educator and professional in water engineering.

Table 1 summarizes the experimentation and adaptive policy options reflected in the lengthy Appendix.

Table 1: Summary of APEX aspects of Appendix 1 - Reaching recommended nitrate levels in Zambian drinking water

MEE suggestions	11 suggestions to use biological denitrification with artificial wetlands 1 suggestion to use reverse osmosis 1 suggestion to use reduction with aluminum powder 2 suggestions to use blending
Adaptive policy suggestions	1 suggestion for adaptive policy targeted at protecting bottle-fed infants through an information campaign focused on mothers

A more recent Water Network post by Trudi Schifter asked the community to share "news/government projects/laws/NGO efforts/technologies that have successfully reduced/prevented plastic pollution in natural water bodies around the world" [42]. The post garnered 13 responses from stakeholders around the world including individuals representing private companies, academia, and industry experts. Localities represented include Japan, India, Australia, Algeria, and the USA. Responses ranged from supportive comments and anecdotes to relevant policy suggestions. One respondent posted a link to a complete report describing a "Sustainable Plastic Waste Management Plan" implemented in Himachal Pradesh. The report outlines the rationale, objectives, key stakeholders, implementation strategy, and impact assessment for an entire plastic waste management project. The report can be found online [43]. This post, and the responses shown in Table 2, demonstrate that APEX principles of adaptive policy and engineering experiments are being actively applied in many parts of the world and that online platforms such as the WaterNetwork are an effective means for collaboration and knowledge sharing.

Table 2: Summary of responses to "Which Laws/Initiatives are Successfully Reducing Plastic Pollution?" [42].

Creative solutions	Making bricks from plastic
Company/technology reference	www.baleen.com [Engineered Sewer Solutions] www.urbanstormwater.com.au
Policy reference / suggestion	Plastic ban fact report from Himachil Pradesh, India, including link to PDF report describing the result of a local initiative to cleanup plastic waste Recommendation for the "6Rs concept" – Reduce, Redesign, Refuse, Re-use, Recycle, and Recover, with references to four relevant on-line articles
Helpful materials (pictures, slides, etc.)	two posts
Anecdote / supportive comments	five posts

In still another Water Network example, one expert asked for the best solution to control bromate in his process water. All fifteen answers from his peers have come from the results of experiments at plants around the world with similar problems.

Where a community of experts generates trust and respect, so that answers can be challenged, is where insights about the problem, and therefore grist for adaptive policies, can emerge [44].

At the Network level, those engaging are not typically working together on a project, but rather answering questions, and sharing knowledge and information to those who need it in scalable structured way. Up until this point in time at The Water Network, the quality is maintained through active moderation, akin to Wikipedia. The next step in the evolution of the ecosystem is to provide peer ranking as a means to identify trusted, reference-able sources and rank products, expertise, services and even professionals.

5.2. Diverse applications of APEX

Examples from sustainability areas other than water show successes of APEX, and instances where obstacles have prevented organizations from fully realizing APEX and from completing their missions. The obstacles include political regime change, competition for profit, ambivalence about devolving authority to local governments, lack of local imagination, and organizations caught between too much central direction and no direction at all. This section looks at four such initiatives.

Technology-based economic development (TBED) initiatives, of which there are now hundreds worldwide, aim to increase the wealth of a local region by encouraging the launch and growth of innovative, sustainable businesses.

For some decades now, organizations such as the World Technopolis Association[5] and the IC² Institute of the University of Texas at Austin[6] have networked people and institutions for the sharing of best practices (and failure stories) in TBED. The networking has taken the form of online collaboration, conferences, study missions, and the exchange of students and visiting scholars, and has led to the formulation of many national and localized technology policies and strategies worldwide.

A common obstacle has been turnover in elected and Ministry officials. In many countries, new Presidents push their own initiatives. Politically, these may have to look different from the initiatives of the previous administration, which belonged to the opposition party. New cabinet Ministers may not share their predecessors' enthusiasm for TBED. Policies are therefore fluid, but neither adaptive nor evidence-based.

Sustainable innovation in SMEs. The European Commission's Smart Specialization Platform (Bröchler and Lewis) embodies online collaboration and attempts adaptive policy in the European

5 www.wtanet.org

6 www.ic2.org

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Union [45]. The Platform provides policy guidance while enabling regional entrepreneurs to network and discover technology and supply chain linkages across Europe. In addition to providing cooperative platforms at the European level, the Platform makes a variety of locale-specific data available to entrepreneurs and policy makers. For example, the Benchmarking Regional Structure tool (http://s3platform.jrc.ec.europa.eu/regional-benchmarking) is an interactive database that allows identifying reference regions based on structural similarity [46]. The organization publishes a number of relevant technical reports citing evidence for and providing guidance related to implementing the platform at a local level (Navarro et al [46]; Rodriguez-Pose et al[47]; Mariussen et al[48]).

However, Bröchler and Lewis point out that "players in the [innovation] ecosystem compete for funding and clients," implying that it is challenging to induce companies to collaborate in the way Popper put forward, and to forgo unproductive duplication of offerings [45].

Climate change. After the Deadline 2020 report[7], which revealed the carbon emission reductions cities would have to make to meet target warming limits, "many city leaders had one critical question: How?" [49]. The Cities Climate Leadership Group (C40)'s steering group appointed a leadership team—New York, Paris, Mexico City, Durban, and others—to prepare and share detailed climate roadmaps.

Some of these cities' plans were not delivered on schedule, according to Rogers. One can imagine the authors' dilemmas: Needed green technologies cannot be developed "on a schedule," and the relevance of Paris' experience for Peoria, for example, is not just a matter for Paris to decide unilaterally. Sender and recipient must interact.

Cleanup. Eight post-industrial cities, including Essen, Pittsburgh, Cincinnati, and Beijing, comprise the Urban Transitions Alliance, dedicating their metropolises to move "from green to grey to green again" [50]. The Alliance's 2017 meeting focused on the "common challenges to making their cities both sustainable and economically viable at a time when climate change dominates local agendas."

Their press statements seem ambivalent about diversity and two-way communication with non-member cities. "It's about bringing together different ways of thinking because of the different background that each city has," says the chief resilience officer of Pittsburgh. Yet he continued, "We can replicate [the Alliance's 'blueprint' for teaching other cities how to tackle climate change] in cities across the world."

It is good that the cities are collaborating. Yet it appears from press accounts that a small number of cities, in an anti-Popperian manner, will fall into the central-direction trap, showing insufficient interactivity and policy flexibility.

6. A world of multiple contexts and fast change

We are living in a world of multiples. Phillips mentioned the multiple products, markets, countries, cultures, careers, stakeholders, idea sources, and ideologies every enterprise now deals with [51]. In this paper we have suggested that Popperian multiple engineering experiments ("MEE"), when combined with adaptive policies and collaboration platforms to form APEX, are the appropriate way to pursue sustainability under conditions of multiple contexts and fast change. In effect, governance becomes knowledge management.

We do not mean to imply that this schema could replace theory in the long run – only that in times of extreme policy failure, or in times of Kuhnian paradigm transition, APEX is a viable way to carry on until matters again stabilize.[8]

Our APEX scheme has much in common with "open innovation," as open innovation implies attracting and collating ideas from multiple and sometimes unfamiliar sources (Scarbrough and

[7] http://www.c40.org/researches/deadline-2020

[8] We distance this paper's thesis from ideas of "adaptive strategy" (Richardson [63]; Martin [64]) and "evolving strategy" (Reeves et al [65]). The first of these too often manifests as no strategy at all. The second removes the human element from policy, unrealistically trying to make the organization work like a machine.

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Amaeshi[52]). However, APEX, unlike open innovation schema, implies ongoing two-way exchange of ideas with all involved parties, and consequent evolution of policies.

International environmental resolutions are often finalized under the false pretense of consensus among the delegates and their respective constituents. Avery drives home this point [53]:

> Utopian engineers have to proceed without the consent of the majority because it is very difficult to get a majority to support a blueprint for the whole of society. They will therefore, [Popper] argued, have to rely on the centralized rule of one person or a few persons. This criticism, Popper contended, does not apply to piecemeal social engineering since it needn't be difficult at all to get a majority to support a particular reform aimed at alleviating an easily identifiable source of human suffering.

APEX can ameliorate this situation. We follow Avery's words with Popper's (emphasis is ours),

> The piecemeal engineer knows, like Socrates, how little he knows. He knows that we can learn only from our mistakes. Accordingly, he will make his way, step by step, carefully comparing the results expected with the results achieved, and always on the look-out for the unavoidable unwanted consequences of any reform; and *he will avoid undertaking reforms of a complexity and scope which make it impossible for him to disentangle causes and effects, and to know what he is really doing*.

Mason adds [54]:

> The design of the post-capitalist world, as with software, can be modular. Different people can work on it in different places, at different speeds, with relative autonomy from each other…. Every experiment run through it would enrich it; it would be open source and with as many data points as the most complex climate models.

7. Implications for policy makers

In this paper we put forth Augmented Popperian Experimentation, APEX, as a strategy for bridging, or perhaps better to say surfing the crisis, between two successive paradigms. However, we allow the possibility that the present Kuhnian crisis might last a long time. In that case, APEX could operationalize, and de facto define for the duration, the modular and experimental global regime that Mason suggests.

The suggested combination of multiple engineering experiments, adaptive policies and modern (online) collaboration platforms has important implications for sustainability managers. It suggests managers should aim to develop two mechanisms simultaneously – collaboration platforms and adaptive policies to create synergy with piecemeal engineering experiments. *Speed* is key in the world of irreversible climate change, as evidenced *inter alia* by the leadership of climate-vulnerable Fiji at the COP23. Speed can be achieved digitally (and cheaply and with low risk) via the collaboration platforms. Building and exploring collaboration platforms may allow agencies and organizations to implement and evaluate many more experiments than they have done in the past. Additionally, if the agency or NGO speedily evaluates diverse experiments, discarding unworkable ones and following up on promising ones, it fosters developing new green products and new green industries [55].

Conversely, if an organization fails to build collaboration platform, it is likely to miss an important channel to explore, acquire new knowledge and run experiments, as well as test new ideas. Thus, developing a system that integrates multiple experiments, collaboration platforms and adaptive policies into a whole is critical to effectively reacting to fast change for a governing body or NGO.

Bodin states, "By its nature, environmental governance requires collaboration. However, … various types of stakeholders often lack the willingness to deliberate and contribute to jointly negotiated solutions to common environmental problems" [55]. Like Bröchler and Lewis [45], Bodin investigates what environmental problems collaboration seems best suited for, and finds that more research on this question is needed.

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It is pleasing that a great number of organizations have adopted positive sustainability agendas. However, the usual "annual conference proceedings" seem to presume the conference was held on a tabula rasa, not explicitly building on results of earlier conferences. Unlike online collaboration platforms, proceedings and white papers allow no comments, queries, searches, organization of arguments into threads, or exchanges of data files. They do not allow the accumulation of evidence needed to fine-tune local policies, or formulate adaptive policies. The success of an online platform also depends on there being a critical mass of willing participants.

Writing in the *New York Times*, Plumer agrees with the need for decentralization [56]:

> The real action on global warming does not unfold in international venues. The problem will largely be addressed by governments back home trying to adopt policies to shift away from fossil fuels, by businesses perfecting and deploying clean energy technologies, by city planners reworking their local transportation systems.

It follows that these "governments back home" would do well to share data on their successes, their failures, and what they're trying next.

It is similarly urgent to move toward adaptive policies. Plumer notes that COP23 "negotiators sought to write a 'rule book' that will govern this process, laying out guidelines for how emissions from each country should be measured," but that most "hard decisions" about its content were postponed. Negotiators must realize that one of the countries will soon invent a new instrument that will provide better measurements [57]. The temptation to seek continuity in measurement (even when the measurements are of poor quality) is strong. However, we live in a world of multiples and of big data, and we have the ICT capability to utilize multiple measurement streams. Even science and technology policy experts are still defining policy making as a process of "compromise," implying that all affected constituents must regress to the mean [58]. This is no longer necessary; APEX implies that policy making can and should be a dynamic process.

8. Conclusions

APEX is an easily remembered acronym that, rather than highlighting the complications of recent sustainability thinking, brings together much of it in a summary that is palatable for policymakers and the media, as well as for researchers. Resting on a clear philosophy and fitting with today's technology, APEX presents, we hope, a way of quickly advancing policy discussions at a time when action is urgently needed.

The 20th-century philosopher J.P.G. Ricoeur introduced the concept of "distentio-," "the stretching of consciousness through simultaneous attention to memory and expectation"[59]. Sarpong and al. built on this idea, putting forth "distentive capability" as an organization's capacity for this kind of time-binding [60].

The APEX approach proposed in the present paper encompasses past, present, and future: As Satell notes, the 1943 experimental development of antibiotics would not have happened without reference to the earlier (1860s) germ theory of disease [61]. Similarly, experimentation implies there will be failures, and that failures are unavoidable. A greater total number of experiments will produce a greater number of successes, even if also a greater number of failures. Failures – even when they occur elsewhere and are communicated via the collaboration platform – offer learning opportunities that can ultimately increase the local ratio of successes. We conjecture that both qualities – integration of past, present, and future, and institutional acceptance of failures – are healthy tactics for governance.

Risks of the APEX approach, relative to global/holistic strategies, include information overload, and possible suboptimization. Modern information technology helps manage both risks. The combination of MEE, Adaptive policies and Collaboration platforms does not try to reduce complexity. Rather, as Boisot put it, it "absorbs complexity" [62]. It can equal a way to conceive of sustainability governance in multiple contexts and turbulent times.

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APPENDIX 1. Example of Nitrates removal technology for bore well water

Questioner	ET	In my project area, we use bore wells as a water source, but recently the water is contaminated by nitrates. Could you please let me know which low- cost technology can be used to removes nitrates in borehole water in rural areas of a developing country? Conventional processes for nitrate removal - ion exchange, reverse osmosis and electro dialysis - are quite expensive and pose a question of subsequent disposal of generated nitrate waste brine. By the Zambian Drinking Water Standard (ZDWS), recommended nitrate levels are 10 mg/l NO3- N equaling 44.3 mg/l NO3. We would like to reach these levels so any advice is helpful.
Respondent		Related Solution
1.	PM	Nitrate is the indication of microbiological in the water, the best way is disinfection by using chlorine. Abstracting water from borehole to the reservoir/tank and disinfect water into the tank/reservoir with chlorine. This is the first option and the second option is iron exchange, reverse osmosis, and package plant.
2	HA	I think that you should try to treat the water by passing the water on a film of a Seaweed mounted on cement base then the water influent treat it by activated carbon to adsorpe any unwanted taste in that way you are going to elimenat all Nitrogen and phosphate from water beside the COD and BOD are going to be decrease.
3	LT	Hmm. Reverse osmosis requires costly, energy intensive and requires skilled labour. Biology process requires carbon source for denitrification, not to mention that it also have to have a basin, technology elements, and a little bit more skilled staff. I would try to use some wetland-like technology, or deal with the source.
4	LT	I agree with Mr. Mann and Mr. Lauenstein. I would recommend a shallow, watertight pool which is populated by duckweed or water hyacint (Lemnoidae and Eichhornia crassipes -take care, the second is considered to be highly invasive and dangerous, especially in Africa). If possible use local surface or underwater floating water plant species, the ones growing the fastest. Let the water flow through slowly the pool. The size/ volume of the pool, the flow and harvest intensity should be tested first with a pilot. I would start with 15- 20 cm depth, a few square meters, 2 day contact time (flow/volume) and a biweekly harvest of 25%. I would measure effluent NO2 daily, starting from the seventh day, and I would set the parameters (flow, depth) based on the result. Temperature might influence plantal growth, if the water is cold, they grow slower. If

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		this works: it is cheap but requires labour to harvest the yield intermittently. Also, the pool have to be cleaned regularly to produce adequate water. Pumping needs at least a windmill wheel, so this one could be installed without electricity.
5	PM	The easy method it will be blending, just pump water from different borehole and blend it. Make sure that the pumping took place at night in order for reaction to take place.
6	HH	Denitrification by biological treatment is the most effective and cheapest way
7	TM	You can use aquaponics; the plants in an aquaponics system will see your nitrates as "fertilizer", and clean them out of the water. You'll then have to put the water through a secondary process to get any bacterial contamination out, but this will solve your first problem. For more, see http://www. friendlyaquaponics . com/ for tons of free information about what aquaponics is, what it does, and what it costs.
8	JW	Biological treatment can help in not generating waste brine but needs more control in the disinfection process after treatment. Depending on the flow rate of the well biological treatment may be or may not be more cost effective than IX, RO or EDR.
9	PB	Nitrate is a compound that is formed naturally when nitrogen combines with oxygen or ozone. Nitrogen is essential for all living things, but high levels of nitrate in drinking water can be dangerous to health, especially for infants and pregnant women. Nitrate contamination of ground water resources has increased in Asia, Europe, United States, and various other parts of the world. This trend has raised concern as nitrates cause methemoglobinemia and cancer. Several treatment processes can remove nitrates from water with varying degrees of efficiency, cost, and ease of operation. Safe & Economical Process Biological denitrification exploits the ability of certain naturally- occurring bacteria to use nitrate for respiration under anoxic conditions (absence of oxygen). The overall process is the reduction of nitrate to nitrogen gas and proceeds as follows: $NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$ Denitrification can be achieved using both heterotrophic and autotrophic bacteria. In heterotrophic denitrification an organic carbon substrate, such as methanol, ethanol or acetic acid, is required as a food source for the bacteria. In autotrophic denitrification an inorganic energy source such as sulphur, reduced sulphur species (e.g. thiosulphate) or hydrogen is required; the carbon needed for bacterial growth is obtained from bicarbonate in the water. Trickling filter followed by flash aeration may do the trick. Algal turf scrubber. Electrolytic reduction method
10	CBB	You have covered all of the typical ways to reduce nitrate in drinking water. Another way requires some chemistry and biology. I have seen some biological processes that reduces nitrate to nitrate and eventually de-nitrification. I think there is some research published on the microbiological reduction of nitrate. I hope this leads your research to find a low cost and SIMPLE solution.
11	TA	Depending on the volume of water to treat, you could possibly use biofiltration. Under anoxic conditions, bacteria can remove, "digest" the

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		nitrates. You would need enough residence time to do the appropriate removal. Usually another vessel is added after the sediment filter and used as the biofilter. The biocidal treatment is done after the biofiltration. To determine how much removal can be done, you would need to do preliminary bench work. This is, by far, the least expensive way to treat water. If you need more info, feel free to ask.
12	BP	If no low nitrate well water sources would be available to replace or blend the nitrate rich well water, then nitrate shall best be reduced to inert nitrogen gas as applied at full scale over at least 30 years. This nitrate reduction can be achieved in various ways but - as always - the most sustainable and cost-effective solution for a specific case depends on the design flow rate (m^3/h) and on the nitrate concentration (mg/l). Also the raw well water composition, pH and temperature would be important. Please specify as to advise more specifically for your case.
13	HC-C	The cheapest option is by blending but this relies on an alternative source of low nitrate water and a vessel where blending can occur. Dependent on the nitrate levels, the amount of low nitrate source may be minimal. Targeting the water for consumption against any used for washing may also reduce the volume of quantity of water you need to treat.
14	BJ	You may have realised from the replies that treatment of nitrates is difficult and neither practical nor affordable in rural Zambia. I have done a little research and recommend the following websites to substantiate my suggestions. They are: http://www.who. int/water sanitation health/diseases/ methaemoglob/en/ and https://en. wikipedia.org/ wiki/Methemoglobinema and http:// pediatrics. aappublications. org/content/116/ 3/784 . A key concept is as follows: " The current EPA standard of 10 ppm nitrate-nitrogen for drinking water is specifically set to protect infants" i.e. to protect bottle-fed infants under 6 months. So in rural Zambia, if mothers habitually breast feed their infants beyond 6 months then it is fairly safe to allow other humans to consume the non- standard water. Where bottle-feeding is unavoidable you should advise mothers to seek other sources that have lower nitrate content, e.g. rainwater harvesting for babies' bottles. (Admittedly it is not easy in rural Zambia to harvest, store and keep clean.) The other issue is the source of the nitrates. In Europe and USA it comes mostly from widespread use of fertilizers. In Rural Africa it is more likely from nearby pit latrines, cattle kraals etc. So, in general do not allow householders to site their pit latrines close to the borehole, or site boreholes near to latrines and kraals. Alternatively, if there are many such latrines and the borehole is surrounded by them, you may need to propose a borehole further away from habitation. Not ideal but may be a solution. Also users can learn to differentiate between sources and the specific source for a particular activity. Hope this helps.
15	SA	A trickling filter followed by flash aeration may do the trick. Though this may require some electrical energy and tanks to be constructed, the water post this treatment will definitely have acceptable levels of nitrates. Just need to initiate a nitrification denitrification cycle. Also, if the water requirement is 20 - 40000 liters, the RO units cost quite less. In India, we provide an RO of that capacity for approximately 5 - 6 lakh rupees. It

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		comes to around $10000 USD. And its worthwhile if you want to use the water for drinking.
16	BM	Is it possible for you to build a tank / pond to store the water from the borewell for a few days before use. If so treating the water in the tank / pond would be possible. We have a solution to grow Diatom Algae in such tanks / ponds. Diatoms would consume the Nitrate and some of it would escape into air as N2 gas.
17	EM	Depending on the aquifer, bore water may also cause scaling issues. Take a look at our website for a maintenance free, chemical and salt free water conditioner that does not require electricity. www.softerwatercondioners.com
18	ECJN	I suggest you try a chemical process in which aluminum powder reduces nitrate to ammonia, nitrogen and nitrite. [Consequent Control of pH and concentrations of dissolved aluminum, nitrite and ammonia might be possible at a realistic cost]
19	DM	Can design a low cost 2 stage bio filter. Need flowrate, full water analysis, seasonal change / ranges. System would require one low head pump or utilise existing pumping head. Is power supply available? Options can be considered to tailor. Is there more than one system / How Many? d_marioni@yahoo.ca
20	ER	It is tricky to remove nitrates as they are so stable, and I expect that management of water quality in a borehole will bring with it many other challenges! Depending on the amount of water needed daily, you could consider looking into an algal turf scrubber where water is abstracted and passed through conditions optimised for algal growth (i. e. lots of sunlight) to remove nutrients and various pollutants. Algal productivity essentially strips nitrates from the water, and you simply have to harvest the algae at times to maintain healthy continuous growth. There is quite a lot of literature on this method, but I have only used this approach for my marine fish tank at home. It is scalable though. However, the best (and most direct strategy) perhaps would be to identify the direction of groundwater flow to the borehole, and trace this back to the source of the nitrates (overuse of artificial fertilisers? septic tanks? agricultural practices?). You will then need to work with the various stakeholders to put in place some measures to reduce input of nitrates to the groundwater. Good luck!
21	SB	Try something like Coal made from bamboo. That if easily available must work.
		Unrelated/ Other Suggestions and Questions
1	JA	This question is best answered with a fairly good paper that addresses the issue from its many sides and approaches. - http:// groundwaternitrate . ucdavis.edu/ files/139107. pdf A careful consideration of these options will guide you to your particular best case scenario since each well should be considered as a unique case.
2	DH	We have same problem here in the uk. We have started to drill deeper and seal out the top water and have had great results. As always start with a good borehole that has been drilled correctly and has a good grout seal and this should reduce any contamination
3	DM	I agree that minimum cost segregates the end users. Make a small bottled water plant for mothers of young infants and find a way to fund this minimum cost approach. Minimum cost technology for this minimum

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		flow can be designed if you define the flowrate and water quality parameters fully / completely. Purpose driven funding might be available for the identified target group.
4	ST	There are not quite expensive water treatment technology-if interested-please send the amount and composition of the water-will send the cost of the equipment
5	DF	Hmmmm .... i wuld instal a natural garden with many diferent water cleaning and nitrat's infiltrating cultures ... what is with solar energy preheatig water systems ?
6	PL	How about running the high-nitrate water through an artificial wetland, and possibly cultivating value-added crops in the process?
7	PL	Have you considered looking for and dealing with the source of the nitrate? Would it be possible to use trees or plants to take up the nitrate before it gets into the groundwater?
8	DDT	Hello, please explain what debit / hour you need and how level you have in water in mg/l of NO3 ?

Source: https://thewaternetwork.com/question-0-y/nitrates-removal-technology-for-bore-well-water-tQJS Km3Xi-joqbI9vPKVng