Introduction of New Process Technology into the Wastewater Treatment Sector

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ABSTRACT: Innovative wastewater treatment technologies are developed to respond to changing regulatory requirements, increase efficiency, and enhance sustainability or to reduce capital or operating costs. Drawing from experience of five successful new process introductions from both the inventor/developer’s and adopter’s viewpoints coupled with the application of marketing analysis tools (an S curve), the phases of new technology market penetration can be identified along with the influence of market drivers, marketing, patents and early adopters. The analysis is used to identify measures that have increased the capture of benefits from new technology introduction. These have included funding by the government for research and demonstrations, transparency of information, and the provision of independent technology evaluations.

To reduce the barriers and speed the introduction of new technology, and thereby harvest the full benefits from it, our industry must develop mechanisms for sharing risks and any consequences of failure more broadly than just amongst the early adopters. WEF and WERF will continue to have the central role in providing reliable information networks and independent technology evaluations. Water Environ. Res., 83, 483 (2011).

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Introduction

New technology creates interest in the municipal wastewater treatment sector because it serves a new or existing need in a creative manner and is therefore deemed innovative. In fact, the definition of new technology is synonymous with technological innovation. Innovative wastewater treatment technologies are developed to respond to changing regulatory requirements, increase efficiency, and enhance sustainability or to reduce capital or operating costs.

The latest U.S. Environmental Protection Agency (Washington, D.C.) (U.S. EPA) needs survey (U.S. EPA, 2010) establishes total needs for wastewater treatment (secondary and advanced) over the next two decades at $105 billion out of the total for wastewater (all categories) at $298 billion, a staggering amount.

New technology introductions can mitigate the costs of wastewater treatment for the wastewater industry. However, new wastewater treatment process introduction faces significant obstacles in the North American marketplace. The risks involved with these introductions means that many municipalities will not participate in them, waiting instead for others to be “first.” Municipal officials and consulting firms generally are not rewarded for assuming such risks, and often they will be resistant, even if the risk of catastrophic failure is small. This slows the pace of new process introduction and reduces the aggregate benefits of new technology development.

In this paper, the writer draws on his and Brown and Caldwell’s experience with new technology introduction, both from the point of view of the innovator/developer originating the technology, as well as from the point of view of an adopter, when evaluating and recommending new technologies to others. Beyond the use of personal knowledge and observations, marketing theory is applied to the analysis.

Finally, the assessment is extended to identify measures that have increased the capture of benefits from the introduction of the new technology. It includes recommended measures that will reduce the risk involved in new technology applications, such as increased transparency of information, provision of independent evaluations of technologies, and mechanisms for sharing risk more broadly.

Theories of New Technology Introduction

About a decade ago it struck the writer that wastewater treatment innovations followed a life cycle that resembles an S curve, as shown in Figure 1.

Here the new process life cycle focus was on its technology development aspects, as it moved from pilot to demonstration scale, its first full-scale applications, and its subsequent refinement, until a plateau of mature technology status was reached. The writer applied the curve to several applications he knew intimately, while a colleague contributed others. Indeed, it was found that the S curve seemed a reasonable fit for all of those cases for which there were no marketplace disruptions. The theory was first presented at an MBR conference focused on industrial applications (Melcer and Parker, 2003). The concept of a product life cycle is well known in business in the sales of products and services (e.g., Rink and Swan, 1979), although its focus has not been on the stage of technology development. Instead of an S curve, it has been presented as a plot of sales per reporting period (see Figure 2).

A different type of S curve for new technology penetration had earlier been discovered by social scientists. Developed from the purchaser’s point of view, it was found that new technology diffusion followed an S curve. This was first observed in the forties where the rate of hybrid corn seed adoption was followed in two Iowa farming communities. It has since been used in many applications. The full development of the concept can be found in the widely-used text by Everett Rogers first published in 1962 (the current fifth edition is Rogers, 2003). Figure 3 shows Rogers’ conceptualization of the diffusion of technology. The curve is

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different than that presented previously, as the focus is not on the state of technology, but rather on the characteristics of those adopting the technology. It was found that adoption times allowed Rogers to place adopters into classes and that characterization statistically fit a bell shaped curve representing a normal distribution.

Of most interest to our sector are those found in the earliest phases of diffusion, because if there are no innovators or early adopters, then the introduction of the new technology fails. As described by Rogers, innovators tend to be venturesome with an interest in new ideas. They have access to significant resources and can withstand the consequences of occasional failures. Moreover, they have the ability to understand and apply the complex technical knowledge needed to make an application a success. Rogers points out that occasionally they are the actual inventors of the process improvement or new technology, and once it is proven, seek means to facilitate its wider introduction.

Innovators play a central role in the launch of any new technology and serve as gatekeepers. On the other hand, early adopters tend to be opinion leaders in an industry to which potential adopters look for advice and information. Thus, they have a major role in accelerating the penetration of technology. Early adopters give an innovation a “stamp of approval” to others considering it. They have a greater ability to deal with abstractions, a favorable attitude towards scientific outcomes, and tend to be more highly educated than later adopters. Most importantly, they have access to networks and influence the decision making of others. Access to opinion networks is a critical point in technology diffusion, according to Rogers.

In this paper, five case histories are presented from the experience of the writer and Brown and Caldwell. The two different viewpoints of the S curve are used to analyze available statistics on the process market penetration, to examine the pace of diffusion and the stage of technology development, and how it was shaped by the events that influenced it.

**Case Examples**

The examples presented in this section show the general applicability of the S curve, and identify key elements to the success of the technology penetration and events that impacted it. The focus is on municipal applications in North America.

**The High Purity Oxygen Activated Sludge Process.** Figure 4 shows the HPOAS flow sheet. This innovation involved the use of pure oxygen in covered stage reactors, instead of air diffusers or mechanical aerators in uncovered basins. Three or four stages were used to ensure a high utilization of the applied oxygen. The process was introduced and developed by the Union Carbide Corporation (UCC). For a contemporary history of the technology and its development program see the book by the process inventor (McWhirter, 1978).

Figure 5 shows the S curve for the technology. Included are plants placed into service first by the process originator, Union
Carbide Corporation (UCC), and by its competitors, mainly Air
Products, and ultimately by the firms of Lotepro and Mixing &
Mass Transfer Technologies, which successively assumed the
rights to the original UCC technology. Key developments that
impacted the observed high rate of technology adoption in the
seventies were:

- A pilot study was conducted in 1968 at Batavia, New York,
  that proved workability of the concept.
- U.S. EPA funded a demonstration project in 1970 at Batavia,
  New York that again showed process feasibility. A U.S. EPA
  report was issued on the project. In Rogers’ terms, the U.S.
  EPA has to be viewed as the “innovator” amongst the
  adopter population.
- At the critical early stage of product introduction in the early
  seventies, the U.S. EPA sponsored a technology transfer
  seminar program across the US that included presentations
  on the new HPOAS process. While there was no formal
  endorsement, having the government provide the process
  developer a forum added tremendous credibility to the
  process.
- Throughout the seventies, UCC made many claims about the
  processes advantages in a comprehensive marketing cam-
  paign that included print ads, brochures, presentations to
  consulting engineers and direct marketing to municipal
  clients.
- UCC constructed several trailer mounted pilot plants and
  offered on-site testing at low cost to municipalities and their
  consultants. Many such studies were conducted and a number
  of these municipalities selected the process for implementation.
- UCC was quite open with its research results, a kind of
- To deal with the difficulty with sole sourcing in the
  municipal marketplace, UCC licensed a competitor, Air
  Products, to also provide the technology. As municipal
  utilities seldom sole-source technologies, this provided the
  necessary competitive element to ease the technology’s
  introduction.
- Starting in the early seventies, the U.S. EPA construction
  grant program provided funding for many secondary
  treatment plants, and the HPOAS process introduction was
  fortunately timed to catch the beginning of this construction
  wave.

Because of the speed of process introduction and the
acceleration provided by UCC’s effective marketing campaign,
the typical project jumped directly from a pilot study to design of
a full-scale facility. Since many of the projects were moving
simultaneously in step, almost all the plants in the seventies to
early eighties could be viewed as early adopters and first
generation technology plants.

UCC’s marketing claims were expansive: it was asserted that
the HPOAS was superior to the conventional air activated sludge
process in economy, sludge production, sludge settleability, and
ability to be designed for stable operation at high food/biomass
ratios (F/M) and low solids residence times (SRTs). Engineers
finally questioned some of these claims and Water Environment
Federation (WEF) provided a forum at its national conference for
achieving an industry consensus. This turned into a debate which
proved to be so informative that WEF immediately published
articles capturing it in its journal. UCC’s claims were examined
and found to be overstated (Chapman et al., 1976; Kalinske, 1976;
Parker and Merrill, 1976). There was a limitation to this
assessment, however, in that it was primarily based on pilot study
data rather than on full-scale plants and had limited information

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**Figure 4**—Typical high purity oxygen activated sludge process. Reactors are covered but secondary clarifiers are
typically uncovered.

**Figure 5**—S curve for North American HPOAS plants put
into service (all providers). Gray squares show installa-
tions per year, while black diamonds show cumulative
installations.
on process limitations of the competitive technology, conventional air activated sludge.

The debate about UCC’s claims spawned a positive development: research on the influence of system loading and dissolved oxygen (DO) on bulking in the activated sludge process. This was equally applicable to both the conventional air activated sludge process and the HPOAS process (Palm et al., 1980; Sezgin et al., 1978). This work put into better perspective what DO levels were appropriate for each process to prevent high F/M and low DO bulking. What followed were two decades of work on progressive improvements to bulking control in conventional activated sludge systems with improved reliability through the use of selectors (see Jenkins et al., 2004; Parker et al., 2003a, 2003b). This indirectly muted the argument that the HPOAS process produced mixed liquor with significantly better compaction and settleability.

A decline in marketing momentum no doubt impacted sales, when UCC sold its interest in the HPOAS process to Lotepro in 1979. The environmental business was sold as a whole with the profitable HPOAS process packaged with some other lines that had less market potential (Warakomski, 2010).

By the early eighties, a large number of new HPOAS plants came on line with the emergence of issues that had not been apparent at pilot scale. Most significant was the development of nocardioforms and the resultant nuisance foams; this has been a difficult problem to resolve due to the foam trapping that occurs at each reactor stage of the system. This has resulted in the need to lower the operating MLSS concentrations from much higher design targets, causing the systems to operate at higher F/M values than designed, which impacted the settleability and compaction of the mixed liquor. Oxygen utilization was seldom as high as claimed and turn down for energy management was limited in some systems. This meant many of the original claims promised in the seventies were not realized. These problems negatively impacted the perception of the process by the wastewater industry and diminished its sales in the eighties and nineties.

There were a number of second generation refinements to PSA design, cryogenic design, and aeration mixer improvements made after 1980 that improved the energy efficiency of the process, but most of these came too late to impact the majority of HPOAS plants constructed. Also, other process issues arose that impacted further market penetration of the HPOAS process after 1980. Due to the low pH and low SRT of the process, achieving nitrification was not practical for many systems. It was not until much later that a bioaugmentation scheme was found that could allow nitrification within HPOAS reactors without the use of excessively long SRTs (Riska et al., 2004). The resolution of identified settleability problems by selector enhancements also came too late to reverse perceptions of the HPOAS process. Both anaerobic and classifying selectors (Parker et al., 2003b; Pettit et al., 1997) were tested and found effective, but this happened quite late in the development of the HPOAS process. Confirming work showed that an anaerobic selector seemed quite effective for nocardioform control, when combined with SRT control and with sufficiently low SRT (Jolis et al., 2005). Due to the high level of foam trapping in the compartmentalized HPOAS system, a classifying selector was only partly successful at Sacramento in its first HPOAS application (Parker et al., 2003b), but proved to be quite reliable when combined with other measures in a later San Francisco trial (Jolis et al., 2006).

In terms of the two versions of the S curve presented in the theory section, the HPOAS process is considered a mature technology, and given that there have been no new plants initiated since the late nineties, at the end of the final stage of Rogers’ curve for diffusion of technology.

**The Flocculator Clarifier.** Before the seventies, little thought was given to optimizing flocculation of the mixed liquor in activated sludge plants prior to secondary clarification. Research conducted at UC Berkeley by the writer (Parker et al., 1970, 1971, and 1972) in the late sixties at bench scale showed the importance of providing a slow stirring step to optimize flocculation and minimize floc breakup, thereby enhancing supernatant quality after settling. It was found that the competing reactions of flocculation and breakup led to an optimum mixing time and turbulence intensity that resulted in minimization of effluent suspended solids in activated sludge plants. It should be noted that this basic research was supported by the U.S. EPA via an activated sludge process optimization research grant.

The first successful full-scale applications of the optimized flocculation concept in secondary clarifiers in North America were mid-seventies designs by Brown and Caldwell, which were placed in service at Corvallis, Oregon and Santa Rosa, California in the late seventies. It is of interest that the Corvallis application was in a plant that could be run as activated sludge alone, coupled trickling filter/activated sludge (TF/AS) process, and as a trickling filter/solids contact (TF/SC) process. These plants used circular clarifiers with large flocculator centerwells equipped with mechanical mixers. The Corvallis plant was designed to meet an average monthly effluent SS concentration of 10 mg/L. At the time, it was believed by most consultants that effluent filtration was needed for this requirement. Brown and Caldwell had experience with secondary clarifier designs that achieved effluent suspended solids concentrations at that level most of the time, so it was believed that the addition of an enlarged flocculation centerwell would suffice, rather than committing our client to the large expense of effluent filtration. The Corvallis application met this requirement in all three operating modes (Norris et al., 1980, Norris et al., 1982). Staff from the local office of a different national consulting firm maintained their belief that effluent filters were required to meet the monthly requirement and requested that the state regulatory agency sample the plant; the state’s independent testing confirmed the results obtained by the City under its self monitoring program.

These results were indeed a breakthrough, and as a consequence, once the full-scale results were available, Brown and Caldwell designed many new circular secondary clarifiers with large flocculator centerwells. It is notable that another firm (Black and Veatch) also placed full-scale circular clarifiers with enlarged centerwells into practice soon after (Stukenberg et al., 1983), also based on the original basic research at UC Berkeley. The flocculator clarifier design built upon the secondary clarification concepts already employed by Brown and Caldwell, such as the use of in board launders to minimize the impact of density currents (based on the early work of Anderson, 1945). The firm continued to use an energy dissipating inlet well based on an original design of the Walker Process Equipment company. Early in the eighties, the firm shifted the type of suction sludge removal from an “Organ Pipe” concept originally developed by Dorr Oliver to a design allowing more precise RAS and sludge blanket control, consisting of a pipe with orifices, marketed by Envirex.
under the name “TowBro.” The TowBro mechanism was an Envirex modification of a sludge removal device originally developed in Milwaukee by Townsend and Brower (1930).

Optimization of flocculator clarifier design concepts continued by Brown and Caldwell. Deeper tanks (up to 18 ft or 5.5 m sidewater depth) were found to produce consistently better effluent quality (Parker, 1983) because sludge blankets had very little impact on effluent quality. It was found by testing at Corvallis and Santa Rosa that the mechanical mixers were not needed to provide mixing within the flocculator centerwell needed for flocculation of dispersed particles (Norris et al., 1982). The flocculator clarifiers were stress tested and evaluated as to loading capability, and they were found to support very high surface loading rates and solids loading rates, compared to conventional designs (Parker and Stenquist, 1986; Parker et al., 1996). And a comprehensive evaluation of the flocculation and breakup kinetics of a large number of conventional activated sludge plants allowed confirmation of standardized flocculation zone residence times (Wahlberg et al., 1994). Computational fluid dynamics modeling and field testing allowed simultaneous optimization of flocculator center well diameter and depth, sidewater depth and effluent launder position, as described in a paper describing the history of the flocculator clarifier development (Parker et al., 1996). Typical features of the flocculator clarifier, as designed by Brown and Caldwell, are shown in Figure 6. Differences from these features found in our designs largely reflect client preferences.

Up to 1990, the vast majority of installations of flocculator clarifiers were by consultants providing custom designs. Between the two consultant firms specializing in the use of flocculator clarifiers, they were incorporated into perhaps 50 plants in operation or design by 1990.

In the late eighties, a major marketing program by WesTech with its own clarifier design under its “Clarifier Optimization Program” or COP significantly accelerated the use of enlarged flocculation zones in circular clarifiers. Since no research reports with field data obtained with standard protocols were published to support the superiority of the design features, one might surmise the COP was configured by picking and choosing successful elements from previous designs and investigations. Those elements included:

- An energy dissipating inlet well similar to that previously employed by Walker Process (also employed by Brown and Caldwell in its custom designs).
- An enlarged flocculator centerwell that was pioneered by the writer’s research and published field experience with Brown and Caldwell designs.
- Baffled peripheral launders. This is the same type of launder that was pioneered by Crosby at Stamford, Connecticut (Crosby, 1984) as a retrofit method for improving effluent quality.
- A spiral sludge scraper removal mechanism following the precedents of German designs (see the review in Ekama et al., 1997).

While there have been no side-by-side testing of the COP unit versus Brown and Caldwell’s design, there have been tests of clarifiers with similar features. That testing indicates that the COP was not the superior unit. Side by side testing of a clarifier with a spiral scraper versus a unit with a TowBro mechanism showed the latter produced lower effluent suspended solids in one study (Parker et al., 2001). Similarly, Moreno and Reed (2007) compared two parallel flocculator clarifiers, one with spiral scrapers and the other with TowBro suction sludge removal. The latter had lower sludge blanket levels and lower effluent suspended solids.

The writer views the situation of commercial success of the COP clarifier versus the original flocculator clarifier design by Brown and Caldwell as one akin to the situation of the VHS recorder versus the Betamax recorder. The latter was considered by many to have been the better technology, but the former was marketed as superior to other clarifier designs and was correspondingly rewarded by a superior market share. In the case of flocculator clarifier designs, consultants usually are not (nor should be) in the position to market processes, rather they offer their services as a trusted advisor and offer advice on the relative merits of various alternatives. In the latter role, the consultant does influence process selection, and on a one-to-one basis, the use of experience and process data from their designs operating in other plants usually wins over marketing claims, but not always.

Figure 7 shows the remarkable growth trends of the flocculator clarifier sold by WesTech. The numbers do not include those sold

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**Figure 6—The flocculator clarifier as designed by Brown and Caldwell.**
by Eimco, who soon followed with their own almost identical unit. Leveraging off the research by others and without the coverage of patents for the COP features, WesTech by dint of their substantial advertising program achieved quite a substantial market penetration for their version of the flocculator clarifier. In fact, the market penetration was far greater than would have ever been achieved by the two consulting firms which had pioneered the use of the flocculator clarifier. Moreover, there seems to be no slowing of sales with time. Thus, even though the technology was introduced into the market in the late seventies, it could be classified as being in the “early adopter” phase in terms of potential customers. The lack of an approach to a point of saturation of the market is due to role of the flocculator clarifier as a part of a process, and when new variants of the activated sludge process are introduced, it remains a logical choice. This prevents it from occupying a limited niche in the marketplace.

Given the fifteen year long technology development program by Brown and Caldwell and the lack of major changes in the COP design for some time, either form of the flocculator clarifier has to be viewed as a mature technology. However, competitive technologies which make claims about their flocculation performance have begun to enter the marketplace. The current Manual of Practice (MOP) 8 (WEF and ASCE, 2009) summarizes them, but also notes that there are no comparative testing results to validate them relative to the existing clarifier technologies. Thus, as a general category, flocculator clarifiers could be viewed as being in the beginning of their third generation, since new designs have begun to appear.

**The Trickling Filter/Solids Contact Process.** Figure 8 shows the two commonly used variants of the TF/SC process. A trickling filter is followed by a small aerated tank and the flocculator clarifier described in the previous section. The key innovation was the use of bioflocculation to incorporate dispersed solids into biological floc. The basis of the floc structure is the sloughed solids from the trickling filter. The anaerobic portions of the sloughed solids must be retained long enough under aerobic conditions such that they can contribute to bioflocculation and not subsequently disperse in the secondary clarifier. As there is little net new growth, the viability of the process is dependent on the efficiency of the bioflocculation process. The process was introduced initially to provide a means of upgrading rock trickling filter plants which had difficulties in meeting the U.S. EPA’s secondary treatment requirements.

![Figure 8](image-url)
requirements mandating a monthly average of 30 mg/L for both BOD₃ and TSS. The process was shown to be capable of equaling the performance of the activated sludge process for those parameters (Norris et al., 1980; 1982). A history of the process development along with process design considerations and their evolution with time within Brown and Caldwell can be found in Parker and Brathy (2001).

The process idea was based on the research at UC Berkeley by Parker et al. (1970) described previously, whereby mild stirring of activated sludge prior to secondary clarification had been shown to lead to improved effluent quality. A trial of the process at a pilot plant at Seattle did not prove successful (Brown and Caldwell, 1978); while clarifier underflow solids were returned to a contact zone and mixed, the tank was not aerated. As described earlier in the development of the flocculator clarifier, an upgrading project at Corvallis, Oregon resulted in a flexible design whereby a TF/AS plant could be operated in three modes; one of these was the TF/SC process. The difference in this test was that the suspended growth portion of the process was aerated (it was un aerated at the Seattle site) and of course the test was at full-scale rather than pilot scale.

Given that the plant could always operate in the TF/AS mode with all of its aeration tanks in service (it had been anticipated that the plant would have to nitrate in the future), there was no risk in this first trial for the plant’s owner as to startup, as the need for nitrification had been postponed. Once the TF/SC mode was proven, the Corvallis plant operated with its aeration tanks out of service, using the aerated distribution channels for solids contact and sludge reaeration (this first TF/SC plant used the solids contact/reaeration configuration). The success of the TF/SC process in a full-scale plant allowed Brown and Caldwell to design a number of additional TF/SC plants with confidence, both for upgrading rock trickling filter plants and with synthetic plastic media in greenfield applications. At least for the first applications with plastic media, pilot studies were used to establish design criteria. Ultimately over 30 plants were designed by Brown and Caldwell.

The U.S. EPA played a key role in the wider use of the TF/SC process during the eighties: they funded two detailed studies of the process first at Corvallis, once the benefits of upgrading rock trickling filter plants were realized (Norris et al., 1982) and then for a broader set of TF/SC plants (Matasci et al., 1986). Progress was reported in WEF publications, as the U.S. EPA in the eighties chose to use the publication of technical articles rather than reports as its primary vehicle for publicizing results. The U.S. EPA also provided enhanced construction grant funding for the process at 17 sites across the U.S., under an “innovative and alternative” grants program (described later). These efforts were key to establishing broader acceptance of the process by plant owners and consultants and deeper diffusion of the technology was achieved.

Figure 9 shows the S curve for the technology in North America. The curve shows only a few discrete data points as only two surveys by Brown and Caldwell were available (1989, 2000) and therefore the curve is not as accurate as for the other case examples. It is suspected that the surveyed numbers may be low, as the writer continues to hear of applications that were not counted. This undercount occurred because the process users were not under an obligation to inform the inventors, given the process had been placed in the public domain (it was not patented).

A potentially depressing influence on the market penetration of the process in the nineties and in the first decade of the twentieth century were shortcomings in the WEF MOPs, which kept the TF/SC design criteria at the first generation levels, rather than reflecting the changes in the second generation and third generation designs that had been developed by Brown and Caldwell. Not having more up to date (and cost effective) criteria available to the design community meant that the TF/SC economics would suffer in comparison to other alternatives considered by consultants not having an in-depth knowledge of the process. The most recent MOP 8 (WEF and ASCE, 2009) more accurately portrays the process, but the changes have come far too late to impact process decisions over the last twenty years. The more accurate portrayal may stimulate resurgence of interest in the process.

Since 2000, new applications have leveled off, as indicated by the firm’s involvement in fewer new applications. However, the process still finds applications for carbonaceous only applications (Slezak et al., 2010) and in cases where high peak wet weather flows must be treated (Parker et al., 2005). From the point of view of the two versions of the S curves presented in the theory section, the technology is approaching maturity and is in the last region of the curve defined by Rogers.

The Moving Bed Biofilm Reactor and Integrated Fixed Film Activated Sludge Technologies. The Moving Bed Biofilm Reactor (MBBR) was originated in the mid-eighties by Professor Hallvard Ødegaard’s basic research at the Norwegian University of Science and Technology and was further developed by a small Norwegian company, Kaldnes Miljøteknologi (KMT) with funding support from the Norwegian government (Royal Norwegian Council for Scientific and Industrial Research). It was initially oriented to obtaining nitrification and nitrogen removal from cold wastewaters on constrained sites. The first MBBR was installed at Steinholt, a small village in Norway in 1989.

The history of process developments for the technology can be found in Rusten et al. (1995a, 1995b) and Ødegaard et al. (2004). KMT subsequently merged with the Anox company of Sweden to form ANOXKALDNES (AK). Very recently, that company was purchased by Veolia Water Systems. For convenience, the company in the municipal marketplace is referred to as AK regardless of the time period.
The MBBR process, shown schematically in Figure 10, has been sold for both carbonaceous removal only, and for nitrification and nitrogen removal, and there are many possible flow schematics (Ødegaard et al., 2004).

The Integrated Fixed Film Activated Sludge (IFAS) process was an earlier development than the MBBR process, and its origins and variants are described in a WERF technology review (Sen et al., 2000). The first applications were for floating sponge media and fixed hanging web media. However, Jones et al. (1998) successfully placed floating media of a type similar to AKs in an aeration basin to enhance nitrification, and AK was quick to seize the opportunity and offer an IFAS technology of their own. This allowed them to use media and equipment they had developed for MBBRs into activated sludge systems. A typical IFAS flow sheet is shown in Figure 10.

Most sales in the municipal arena by AK have been with MBBRs, although IFAS applications are a growing percentage of the sales. Figure 11 shows the S curve for this technology for North American sales.

WEF has provided a forum for evaluations of the MBBR and IFAS technology to be presented in technical sessions and workshops at its annual conference.

By the year 2000, AK became the dominant market player in North America. In the writer’s observation, this was due to AK’s twofold approach to technology introduction: (1) willingness to create true partnerships with companies and vendors in each of their various marketplaces, and (2) full openness or transparency with their partners and potential users of their technologies as to the status of their research, both in terms of its strengths and weaknesses. This transparency served them well, particularly in North America, where generally consultants and municipalities do not respond well to “black box” marketing methods, but instead appreciate transparency, considering their need to manage risk with new technologies in project implementation.

In terms of technology development, the writer would consider the MBBR and IFAS processes at the point of development of second generation (with more developments to come) and in the “early adopter” category with respect to Rogers’ technology diffusion curve.

The Membrane Bioreactor Process. The MBR process was developed to provide high quality effluents on constrained sites. It can be tailored to provide reuse quality effluent or adapted specifically for nutrient removal. A short history of the early days of the development of the Membrane Bioreactor can be found in Stephenson et al. (2000). Dorr Oliver originated the process in the sixties and later licensed the Sanki Corporation in Japan who ultimately built 39 MBRs with membranes external to the process. Zenon (now known as GE Water and part of General Electric Company), a Canadian corporation, continued the development of MBRs starting in the late eighties and early nineties, with primarily industrial and small municipal applications. The first municipal application for Zenon was a plant serving a shopping center. Zenon received some basic research funding from the Canadian Federal Government for membrane development. In terms of the North American market, Zenon played a pivotal role in introduction of the technology, particularly when they introduced in the mid-nineties their hollow fiber membrane system, with placement of many fibers in cassettes within the aerated environment, rather than external to it. The space they created in the marketplace for MBRs allowed many vendors to follow, including those with well established technologies from abroad (e.g., Kubota from Japan) as well as new market entrants. Figure 12 shows a typical MBR flow sheet for biological nutrient removal.

The system was aggressively marketed by Zenon who also supported the process with extensive in-house research as well as indirect support of research or application testing by utilities.
through a large program of providing low cost rental pilot units. This was an essential element of getting process acceptance and the program was bootstrapped off the profits of sales of municipal MBRs (Benedek, 2010). Initially, Zenon took the approach to the marketplace as offering the process as a black box, whereby they would supply the system, do all the process engineering, and be responsible for the end result. However, as the projects moved beyond very small projects, they offered instead to support consultants providing custom MBR designs suited to larger plants. During this phase (which continues), the process moved out of the black box and into a much more transparent phase, where research results were shared with the engineering community. This has increased acceptance of the process and allowed Zenon access into the larger plant market.

WEF has provided technical sessions and workshops on MBR technology at its annual conference as well as sponsoring biannual specialty conferences on the technology.

Figure 13 shows the S curve for Zenon’s North American sales of the MBR process for municipal wastewater treatment. In terms of Rogers’ theory, the inflection in the curve indicates the process appears to have passed into the late majority phase, in terms of number of sales. In terms of membrane development, there have been many refinements and economies. But whether Zenon’s hollow fiber membrane is the last type of membrane configuration to be offered remains to be seen; in fact there is much ferment in this arena as new materials and configurations are frequently offered by competitors. Only time will tell what the next generation will bring to MBRs as providers try to reduce the main disadvantages of the process (membrane flux rates, energy usage and fouling). In terms of technology development, MBRs have not reached the mature technology phase.

Lessons Learned from Successful New Technology Introductions

All of the cases examined have to be considered successful market introductions, since they captured significant market share in a difficult and competitive arena: the municipal wastewater treatment market. In this section, common elements in successful market introductions are described.

Time for Process Introductions. Discussions with process vendors almost uniformly note the long times for new process introductions into the municipal wastewater treatment market. One representative of a process vendor noted that the North American municipal wastewater market was the most difficult market and attributed this to the many decision makers involved before a project was authorized (consultants, municipal utilities, regulatory agencies, the public, etc.). Another noted that it took seven years to see a return on investment in research in the municipal wastewater sector, while in the industrial sector, three years was more the norm. Still another indicated that on initiating sales of a new process technology in the US, the first industrial wastewater sale was achieved within a year, but the first municipal sale took six years of steady marketing investment. This is reflected as well in the time scales of the S curves presented in this paper. The duration between the first full scale application and the inflection point on Roger’s S curve can be used as an indication of the rate of process adoption and is termed herein the new process half-life. Recall, the inflection point is the time when a process passes from the early adopter to the late adopter phase. The
HPOAS process took 4 to 5 years, the TF/SC process took 10 to 12 years, and the MBR process took 28 years to get to the inflection point. The MBBR and the COP version of the flocculator clarifier have not reached the inflection point, meaning their half-lives exceed 12 and 18 years, respectively. The HPOAS case example can be considered to have the minimum half-life achievable and with this perspective the others are all quite long. The problem with long new process introduction periods is that the benefits of new technology cannot be fully gained when new regulatory initiatives are put into place with short compliance time frames.

Extended times for new process technology introduction are in part due to the fact that major municipal projects can take 5 to 8 years from the start of master planning to plant startup. For new process technologies to be relevant they must be considered early in a project cycle; this alone extends the time for process introduction. This also lengthens the time between successive generations of each technology.

Major capital facilities such as wastewater treatment plants are expected to have decades of useful life, so adoption of new technologies has additional barriers of inertia to overcome than say low cost disposable consumer products, which may have short product cycles (e.g., laptops and cell phones). This difference has been recognized previously by economists, who note that durable products used in the industrial sector have long time spans for introductions and more conservative market responses (Rink and Swan, 1979).

**Government Support of Research and Process Evaluations.** National government research funding of either basic or applied research was an important element in the development of all five of the new technologies introduced. Often, the research was initially funded at bench scale and in a university environment. This seed money was essential to the inventor as it leveraged later funding from both private and other public sources. In the earliest cases (the first three), the support came from the U.S. EPA. In the last two cases the support came from foreign governments and subsequently the technology was introduced into the U.S. Unfortunately, in the recent past, government funding in the U.S. has been very limited.

**The Role of Marketing in New Process Introduction.** Three of the new technologies examined were introduced to the marketplace by commercial companies marketing a process and were heavily advertised (HPOAS, MBBR and MBR) and this supported relatively high rates of growth while they received that support. In contrast, the TF/SC process was not introduced by an equipment company. Decisions to adopt the technology were uninfluenced by advertising, and the pace of introduction was somewhat slower. The flocculator clarifier had a slow introduction, until the technology was adopted and aggressively marketed by an equipment company; then the adoption rate markedly accelerated.

**Role of Patents and Competition in Technology Introduction.** The HPOAS, MBBR and MBR processes, while patented processes with companies having significant (often dominant) market shares, all have had significant competitors. This has eased the new technology introduction, as utilities in North America are leery of sole sourcing technologies.

Neither the TF/SC process nor the flocculator clarifier was patented, and because of this no sole sourcing was required. While it is often asserted that patents are necessary for new process introductions, this is not always the case, as evidenced by the experience with these two technologies. While the nonproprietary TF/SC process was not marketed in any conventional sense, considering the likely undercounting in the surveys it achieved similar market penetration to the heavily marketed and proprietary HPOAS process.

Decisions to adopt new technology introduction are made on a case by case basis regarding cost and performance benefits of the new technologies compared to conventional technologies in the municipal marketplace. And the relatively high penetration seen for each of the technologies reviewed is evidence of the cost and performance benefits at the time of process selection.

**Influence of Innovators and Early Adopters.** Rogers emphasizes the importance of innovators and early adopters in the introduction of new technologies. These five successful new process introductions had the innovators and early adopters essential for the introduction of the new technology.

**Transparency of Information.** The inventors and developers of the five technologies examined provided in-depth information about their technologies to potential users. In some cases this was delayed, but once more complete information was provided, consultants and municipalities had better bases for evaluations and designs relying on these technologies. And the new technologies have been aided when the assessment of process efficacy is at least partly based on independent assessments. New technology introduction can also be slowed down by such assessments, if less than favorable.

Transparency of information is necessary for consultants and plant owners to make fair evaluations of new technologies relative to existing technologies, as well as to manage the risks involved when new technologies are selected for project implementation.

**WEF as a Forum for New Process Introductions and Technology Evaluations.** WEF has played an important opinion maker or gatekeeper role using Rogers’ terms. The case histories show WEF played a key role in the introduction of new processes, making available assessments of the various processes. In one case identified, a flawed assessment hindered technology diffusion: for the TF/SC process, WEF provided a forum in its journals for evaluations of first generation TF/SC plants, but in the case of its treatment of the process in its MOPs of the nineties, WEF essentially ignored information on second and third generation designs that had improved the process’s economics.

**Influence of Market Drivers.** For at least three of the technologies, the implementation of U.S. EPA secondary treatment regulations and construction grant funding provided opportunities in the seventies and eighties for new technology applications. From the nineties to date the following have been influential in creating opportunities for new technology introduction: (1) ever tightening effluent regulations; (2) growth; (3) constraints on urban treatment plant sites driving a need to intensify treatment (more capacity or greater degree of treatment); (4) rehabilitation and replacement of plants reaching the end of their useful lives; (5) the need for increased economic and energy efficiency and conformance with other sustainability indices of community import, and (6) the need “to do more for less” in response to stress on utility budgets. The MBR and MBBR/IFAS technologies were particularly developed to respond to the need to intensify treatment while meeting more stringent effluent requirements.

**Risk Management.** No one gains if new technologies are introduced without proper supporting research and as a result a
new treatment system fails. The critical stages in technology introduction are as follows:

1. Basic research (usually in the laboratory)
2. Pilot scale research (usually in the field)
3. Demonstration scale research
4. First generation applications with evaluations and lessons learned
5. Additional generation applications with evaluations and lessons learned
6. Final generation (mature) technologies

The progression path shown above can be viewed as nothing more than an application of the scientific method, whereby more is learned at each step and informs the actions of the next step. All of the five technologies examined followed these steps. Of course, some technologies may stop at the second generation (e.g., HPOAS), some pass through three generations (e.g., TF/SC) and some seem to be destined for many generations (e.g., MBRs). Steps 3 and 4 seem to be the most critical steps, as the greatest risks are in scale up of a new process, as there are many unanticipated findings when reaching “full-scale” in municipal wastewater treatment plants. In the writer’s experience, failures have occurred at full-scale because of skipping steps.

Skipping steps can truncate technology development. Heavy marketing and the resulting compression in the HPOAS development cycle meant that the majority of the projects moved at nearly the same pace; the result was that what was learned from the first generation of plants was slow to impact the design of the next generation. On the other hand, the more leisurely pace of the TF/SC process diffusion into the marketplace allowed at least three generations of development before process maturity. As noted previously, both processes received similar market penetration by quite different pathways.

The U.S. EPA provided a mechanism in the eighties for mitigating the risk of new technology introductions into the municipal marketplace (U.S. EPA, 1980). It allowed for an increase in federal construction grant share from 55 to 75 percent if municipalities installed “innovative and alternative” (I/A) technologies that had the potential for cost savings or performance enhancements. More importantly, it mitigated the risk in the adoption of the new technologies, by providing for 100 percent replacement if the technology failed. This spurred new technology adoption. As noted earlier, the U.S. EPA provided I/A funding for 17 TF/SC plants under the construction grants program, which eased owner’s and consultant’s concerns about new technology adoption.

While most of the new technology applications were in fact successful, of course there were a minority that failed. By 1987, the U.S. EPA had a five percent failure rate for the 1,350 I/A projects then in operation (U.S. EPA, 1988). Despite the relatively low failure rate, the risk insurance aspect was a significant element of the program, as the failures were significant in financial terms to the adopters with failed projects.

**Technology Innovation in the Future**

**Need for New Treatment Technology.** The U.S. EPA 2008 Clean Water Needs survey estimates costs for secondary and advanced treatment for the next twenty years at $105 billion; this value is low because it does not account for regulatory trends that are on the horizon but were not completely accounted for at the time of the survey. We are in an era where the regulatory goal or endpoint is approaching that sought under the original goals of the Clean Water Act, but instead of zero discharge it is zero pollutant concentration. One focus has been micro-constituents or contaminants of emerging concern. Much research has been completed on their presence in receiving water and effluents, but their impacts on the ecosystem as well as on mankind are still being defined. As a result, there are not many regions with effluent requirements in place as yet (e.g., see the review of Reeves et al., 2010). It seems a certainty that advanced treatment of some type will be required once impact issues are resolved. We will need to optimize existing technologies and develop new ones to meet this challenge.

Another area needing development are technologies that allow reduced reliance on external energy sources and that minimize (or eliminate) the carbon footprint of our treatment plants (see the research priorities identified by an expert panel in Crawford et al., 2010).

Certainly one of the greatest challenges facing our industry over the next decade will be the implementation of new nutrient removal plants, and upgrading existing ones. Because of pending changes to require low effluent requirements across broad regions of the U.S., our nation will likely go from hundreds to thousands of nutrient removal plants in a relatively short span of time. Yet it has been shown that there is significant risk of violations for existing technologies for the range of effluent limits being proposed (Parker et al., 2009). Nitrogen removal technologies in particular need reevaluation, as many were developed in the seventies and eighties (e.g., Barnard et al., 2006) with a focus on eliminating carbon addition requirements rather than seeking the lowest possible nutrient concentrations. Yet processes that use external carbon either for the entire job of nitrogen removal or to supplement wastewater carbon appear to do marginally better when seeking very low nitrogen limits (e.g. Parker et al., 2009). However, not even the best performing processes can meet some of the proposed limits, leading design professionals to indicate that they will need to be followed by high cost tertiary processes, such as microfiltration and reverse osmosis. We clearly need to develop less expensive alternatives and that will require both basic and applied research.

Another reason for reassessment of nitrogen removal technologies is the propensity of some nitrification and denitrification technologies to produce troubling amounts of Nitrous Oxide ($N_2O$) emissions relative to the values typically used by the US in its reporting to the UN (e.g., see the results from a WERF survey reported in Ahn et al., 2010). With the data currently at hand, it is not possible to conclude which flow sheets will produce the lowest emissions, but some trends are beginning to emerge. Emissions of $N_2O$ have been proven to be highly variable and subject to the influence of diurnal loading variations; this is because nitrifiers and denitrifiers are never at a steady state. Dynamic models will need to be developed that describe this phenomena sufficiently well to allow designers and owners to proceed with confidence in new plant designs so as to limit the emissions of nitrogen in both the liquid and gaseous “effluents.”

Given that all existing nitrogen removal technologies will need to be assessed from an emissions point of view, there will most certainly be technological change. We need those new technologies, and we need them as soon as possible, as the cost of broader nutrient removal will have significant financial impact on our industry.
With all of these needs identified on the horizon, now more than ever we need to take the steps that will break the barriers to new technology introduction so as to broaden the benefits of innovation for our industry.

**Roles and Mechanisms for Encouraging New Technology Introductions.** Risk Mitigation. Identification of means to provide for risk mitigation is vital for accelerating new technology introduction as the risks for new technology introduction are not borne equally amongst the participants. Inventors/venture capitalists can achieve high returns from rapid penetration of new technologies. Their liabilities are usually only limited to the extent of their investment, which is generally not the entire capital investment for projects which include the new technology (e.g., equipment may be provided by the vendor, but the process tanks and ancillary facilities are provided by others). In contrast, innovators and early adopters and the teams supporting them (consultants and agency staff) actually bear a disproportionate risk without a profit motive; the public agency has used public funds to implement the process. Cost recovery tends to be only partial and subject to difficult and litigious processes. Even though guarantees may have been provided by a process vendor, the agency is ultimately responsible for meeting effluent requirements and must move forward in a timely fashion with technology replacements. Thus, our industry needs to identify and implement models of spreading risk amongst a broader set of parties to accelerate new technology introductions and increase the capture of benefits.

**Government’s Role.** A proper role of government (federal and state) is to support research and mitigate the risk involved with new applications. Examples in this paper from the past showed that government research support was essential in all of the technologies examined. The ability to support full-scale process demonstrations and to guarantee replacement technology grants is a proper role for government. The federal government through the U.S. EPA played this role in the eighties and needs to return to a proper role for government. The federal government through demonstrations and to guarantee replacement technology grants is a proper role for government. The federal government through the U.S. EPA played this role in the eighties and needs to return to a proper role for government. The federal government through the U.S. EPA played this role in the eighties and needs to return to a proper role for government. The federal government through the U.S. EPA played this role in the eighties and needs to return to a proper role for government. The federal government through the U.S. EPA played this role in the eighties and needs to return to a proper role for government. The federal government through the U.S. EPA played this role in the eighties and needs to return to a proper role for government. The federal government through the U.S. EPA played this role in the eighties and needs to return to a proper role for government. The federal government through the U.S. EPA played this role in the eighties and needs to return to a proper role for government. The federal government through the U.S. EPA played this role in the eighties and needs to return to a proper role for government. The federal government through the U.S. EPA played this role in the eighties and needs to return to a proper role for government. The federal government through the U.S. EPA played this role in the eighties and needs to return to a proper role for government. The federal government through the U.S. EPA played this role in the eighties and needs to return to a proper role for government.

**Need for Partnerships and Alliances.** In evaluating and selecting competing technologies, engineers need to maintain an unbiased and arms-length relationship with process vendors in order to preserve the integrity of the selection process when using public funding. However, this creates expectations about relationships amongst the parties to a project implementation that does not foster the introduction of new technologies. A challenge will be to rethink and discover new paradigms for the creation and legitimization of partnerships that are often essential in new technology launches. We need models that formalize these relationships for the specific projects that are new technology launches. The default position seems to be “suspecting” the relationships that often develop to implement projects with new technologies. Instead we should be celebrating them, as innovators and early adopters have proven essential to new process introductions. We need to develop ones that honor the alliances that are often the key to success.

**The Role of Universities and Research Institutions.** Researchers at universities and other research institutions are often in the best position to propose and evaluate new technologies, as long as they receive adequate funding from government and private sources. The reason is that basic research by its very definition is not necessarily tied to the immediate needs of any one situation, but is typically more oriented to longer term needs and future priorities. Sustaining this type of “leading edge” research is a fundamental component of any successful research strategy for North America’s environmental needs.

**WEF’s Role.** Networking of information has an important role in harvesting the benefits of new technology introductions. WEF conferences allow innovators and early adopters to share their experiences. Just as important, WEF must provide a forum for independent, fair and comprehensive evaluations of new technologies and their progression through the generations of their development. Both its conferences and its publications, such as *Water Environment Research*, can continue to provide vehicles for innovators as well as for those evaluating the innovations. While WEF does not view its MOPs as “standards,” they have much the same impact in our industry. Given the influence its design manuals have on practice and furthering the use of new technologies, more frequent updating would be in the interest of our industry. The update cycles for MOP 8, its design manual, has extended over an average of eight years (last published in 1999, 1998, and 1992). The concept of electronic updates of individual MOP chapters needs to be explored; this would allow for more flexible production cycles and allow those chapters needing revision to not hold up those ready for publication. This would allow rapidly changing information for newer technologies to be available more quickly to our industry, allowing a greater degree of harvesting of the benefits of new technologies. It would also prevent the repeat of past mistakes (lessons learned) in successive applications. It is notable that the current edition of MOP 8 is the first available in an electronic format, so the precedent is established for this delivery method.

WEF’s annual conferences provide an important forum for technical exchange. At the beginning of the writer’s career in the seventies, he was the beneficiary of both learned and impassioned discussions about the merits of new technologies. This was an important learning experience. Over the last two decades the discussion period has devolved to a question and answer period that is a poor substitute. Recent efforts of the program committee to reverse this and encourage discussions should be continued. Examples are the greater use of moderators in promoting discussion, and devoting time for the use of panels at the end of sessions.

Transparency of information is an essential feature of new technology introduction. Inventors, early adopters, process vendors and research organizations need to provide the detailed information available to encourage potential adopters to consider the process and consider the risks and rewards of potential applications. Nutrient removal is an area of continuing research and ripe with claims and counter claims made about new technologies or about expected future results of new designs seeking low effluent nutrient concentrations. Technology reviews have appeared in WEF workshops and conference proceedings that are often unsubstantiated in terms of references supporting the arguments, partly due to the lack of access to supporting data and underlying research. In order for our field to progress in a logical fashion with a minimum of “recreating the wheel” or preventing unnecessary repeating of
costly mistakes because of unrecognized precedents, a high scholarship standard must be encouraged. It would be useful if WEF continued to emphasize the importance of scholarship in all technical presentations and technical articles in its proceedings while minimizing what are clearly only sales oriented presentations which make claims without proper technical support. WEF already has policies and procedures regarding scholarship and avoidance of conflict of interest in effect for MOPs and workshop presentations at conferences (WEF, 2009; 2010). Expansion of these policies to the technical program and rigorous application of them would materially reduce the risk of new technology applications and increase the benefit capture for new technologies.

**WERF’s Role.** There is an increasing trend for technology assessments to devolve to the advocates of technology. However, it is objective third party assessments of new technologies that will be a key to maximizing the value of new technologies to our industry. WERF has already played a significant role in comprehensive and objective technology evaluations and should continue to play that role. This allows potential technology adopters access to information that would otherwise not be available and to independent judgments about the technology, separate from those available from process advocates or marketing materials. An example of third party evaluations is the WEF/ WERF cooperative study of nutrient removal plants which for the first time has allowed an objective assessment and technology ranking for alternative nutrient removal methods, using statistical methods for performance assessment (Parker et al., 2009).

WERF has played an invaluable role in the development of assessment protocols that have allowed more comprehensive and scientifically based technology evaluations and are now widely used in our industry (e.g., Ahn et al., 2010; Melcer et al., 2003; Wahlberg, 2001). Experience shows the protocols result in significant cost savings and so they have high continuing value. And their use allows independent evaluation of claims made by technology proponents. There is a continuing need for the development of additional protocols, for example in the area of evaluation of biofilm technologies (Parker et al., 2010).

Finally, one of the writer’s visions for WERF remains largely unrealized (Parker, 1988). WERF lacks the financial wherewithal to carry a process idea from bench scale through demonstration scale. Thus, there is a linkage to government support of demonstration projects mentioned earlier, such as those that could be managed by WERF with U.S. EPA funding.

**Summary**

Five case histories of new technology introduction into the North American market were examined. Analysis of them supports the following conclusions:

- Market drivers influence new technology introductions and these include regulatory programs, growth, constrained treatment plant sites, replacement of aging of existing plants and the need for utilities to have increased economic and energy efficiency and to conform to sustainability expectations of their communities.
- Due to a variety of factors, the cycle times for new process technology introductions are excessive and so long that when new regulatory programs are introduced, the full benefits of the technology cannot always be obtained.
- Government research support was an essential element of the each of the histories examined, whether that support was at the initial basic research taking place in universities or at the point of first application, such as in demonstration projects.
- Competition in the marketplace for public sector applications was always a feature of the technology introductions.
- Neither formal marketing programs nor patents were required for new process introductions to be successful.
- Decision-makers require transparency of information for new processes and “black box” sales approaches are typically unsuccessful.
- WEF has provided an essential information forum through its conferences and publications.
- Utility managers’ perspectives on adoption of risk influence new technology introductions. Innovators and early adopters are an essential element in new technology introductions.

Considering the very large projected capital needs of our industry, means must be found to accelerate new technology introduction. One of the most critical needs is to seek means for increased risk mitigation for innovators and early adopters in the municipal sector, recognizing that they are not rewarded by accepting risk in project implementation. Amongst the means available are vehicles that have been used in the past such as government funded demonstration grants, as well as failed technology replacement grants. Other means also could be developed in the future such as new technology insurance pools, as well as the use of partnerships and alliances.

Other key steps for ensuring a robust national research program for wastewater process development include:

- Maintaining active research programs at major universities and other research institutions so that basic research (at bench scale) can provide leading edge directions to longer term needs. This requires a reinvigoration of government funded research in the wastewater treatment sector.
- WEF must continue to provide a forum through its publications and its conferences. This must include encouragement of a high level of scholarship at its conferences and resultant publications, as the current poor level of scholarship leads to significant monetary losses for our industry given that it leads to “recreating the wheel” through lack of recognition of the state of development of technologies and obscures the identification of the logical next steps. And “sales oriented” presentations lacking in depth without sufficient supporting data should be discouraged, as potential adopters are unable to assess both risks and the rewards of new technology adoption.
- WERF should continue and reinforce its provision of third party process assessments of new technologies of potential value to our industry, as it provides potential adopters information that they cannot otherwise obtain with their own resources. WERF’s successful development of process evaluation protocols should continue, as they have served technologists in our industry well. WERF can play an essential role in ensuring that government funded demonstration grants are well executed and evaluated.

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