Why Africa Only Needs Four Pumps

Standardizing complete pumping systems to improve lifecycle cost and reliable water service

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Revised manuscript draft • November 2, 2026

Prepared for consideration by Christian Relief, Development, and Advocacy
The Journal of the Accord Network

This manuscript examines complete pumping system standardization as a practical application of lifecycle costing. It combines an internal East African portfolio screening, published research, and explicitly identified practitioner observations. Technical checks and submission preparation notes remain in the separate author review appendix.

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Abstract

Water service costs connect initial construction, capital maintenance, and routine operation. This paper examines whether four pump models, organized into two standardized system families, could improve lifecycle performance across an East African portfolio. An internal screening yields preliminary coverage of 90 percent when marginal SP applications and assumed-suitable SQFlex records are included. The proposed intervention standardizes motors, drives, electrical protections, photovoltaic configurations, racks, and working procedures alongside pumps. Municipal water practice, packaged treatment, international standards, and energy-sector learning curves establish precedents for combining repeatability, purchasing scale, and accumulated experience. These sources support the mechanisms without establishing savings for the proposed kits. The paper therefore proposes testing complete configurations against service requirements, lifecycle cost per customer, reliability, and maintainability, while retaining engineered exceptions.

Keywords: solar pumping; standardization; component commonality; inventory; water service; lifecycle cost

Water service requires an integrated lifecycle

A pump purchase commits a water service provider to a chain of future decisions. The selected hydraulic assembly determines compatible motors, electrical equipment, operating limits, spare parts, and aspects of installation and maintenance. A decision recorded as a saving in the construction budget may subsequently consume the operator's time, require repeated replacements, or interrupt water sales. The performance of that purchase therefore extends beyond the project and the organization that made it.

Capital expenditure (CapEx), capital maintenance expenditure (CapManEx), and operating expenditure (OpEx) are useful accounting distinctions. They describe initial assets, renewal and rehabilitation, and routine operation and minor maintenance. They do not describe independent systems. IRC's WASHCost framework already establishes the importance of costing sustained services, including support and the cost of capital.[1] This paper applies that lifecycle perspective to the consolidation of pumping equipment and its supply arrangements.

The same interdependence exists among community development, project management, and multidisciplinary design. Community engagement informs demand and willingness to use a service. Design establishes the service that can be delivered and maintained. Project management coordinates the resources needed to realize it. Operational experience should inform all three. Treating these responsibilities as a succession of handoffs without continuing feedback can leave each party meeting its own targets while the customer receives an unreliable service.

Common configurations can also improve cooperation among disciplines. A project manager can recognize an incomplete kit, a community-development practitioner can explain realistic restoration arrangements, and an operator can report a deviation in terms the designer understands. This working knowledge allows each discipline to inform the others without requiring every participant to acquire

[1] IRC. 2011. Life-cycle Costs Approach: Costing Sustainable Services. WASHCost Briefing Note 1a. https://www.ircwash.org/resources/briefing-note-1a-life-cycle-costs-approach-costing-sustainable-service.

the same specialist qualifications. The assembly of repeatable equipment can be standardized while the planning and delivery of water service remain interdisciplinary.

The proposition examined here is that four pump models, arranged within two standardized system families, could serve most recurring applications in a defined East African portfolio. Two SP hydraulic assemblies would share a qualified motor and drive platform. Two complementary SQFlex models would use a compatible motor and control architecture. Electrical protections, photovoltaic modules, rack modules, interfaces, documentation, and maintenance procedures would form complete pumping kits. This is pumping system standardization, extending through procurement and service.

The title states a hypothesis to test. The available analysis concerns an organizational portfolio in East Africa; it does not establish continent-wide coverage. A limited equipment portfolio should serve eligible applications, with deliberate engineering for exceptions. The objective is sustained, affordable water service at an acceptable lifecycle cost per customer. Health protection, reliability, and financial sustainability are connected outcomes, although health effects require their own evidence.

For Christian relief and development organizations, stewardship includes the consequences of initial decisions for the people who will operate and use the service. An organization's responsibility for a particular budget does not eliminate its influence on another organization's future costs. Shared service objectives, technical review, and feedback from operators can make those consequences visible before procurement.

An established practice applied to water service

Interchangeability has a long industrial history. Nineteenth-century firearms manufacture developed precise tooling, gauges, and inspection so that parts could fit across assemblies. This achievement emerged through several inventors and institutions; attributing it solely to Eli Whitney obscures that development. In 1913, Ford combined interchangeable components, divided tasks, and moving materials in automobile assembly. The transferable principle is the reduction of avoidable variation in interfaces and work, supported by verification that parts actually conform.[2]

Water infrastructure has its own history of common specifications. AWWA adopted its first standard for cast-iron water pipes and special castings in 1908. Standardized testing methods and equipment specifications provided shared reference points for an expanding sector.[3] Standardization should not be credited by itself with the health gains of filtration and disinfection. It helps make specified performance reproducible and verifiable. The present proposal extends that practical tradition to a portfolio of source-water pumping assemblies.

Safe water is a service whose value depends on quality, quantity, continuity, access, and affordability. Equipment variety is useful when it improves those outcomes or accommodates a real site requirement. Variety that merely multiplies interchangeable tasks, stock lines, and training burdens needs a different justification. This is compatible with respecting customer preferences about service arrangements and with maintaining diversity in community engagement and local governance.

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[2] Karyl Lee Kibler Hall and Carolyn Cooper, "Windows on the Works," Eli Whitney Museum & Workshop, https://www.eliwhitney.org/windows-works; The Henry Ford, "K–12 Research Guide: Assembly Line," https://askus.thehenryford.org/K12/faq/433848. These histories distinguish the development of interchangeability from the later moving assembly line.

[3] American Water Works Association, "About Us," historical timeline, entries for 1905 and 1908, https://awwa.org/who-we-are/.

The long tail of equipment variety

The 63-record SP evaluation contains 43 distinct model labels after spaces are normalized. Thirty-one labels occur only once. Those one-time labels represent 72.1 percent of the model list and 49.2 percent of the records. The five most frequent labels together account for only 18 records, or 28.6 percent. Figure 1 reconstructs the equipment long tail directly from the study table. These are frequencies of recorded pump models, not measurements of subsequent spare-parts demand.[4]

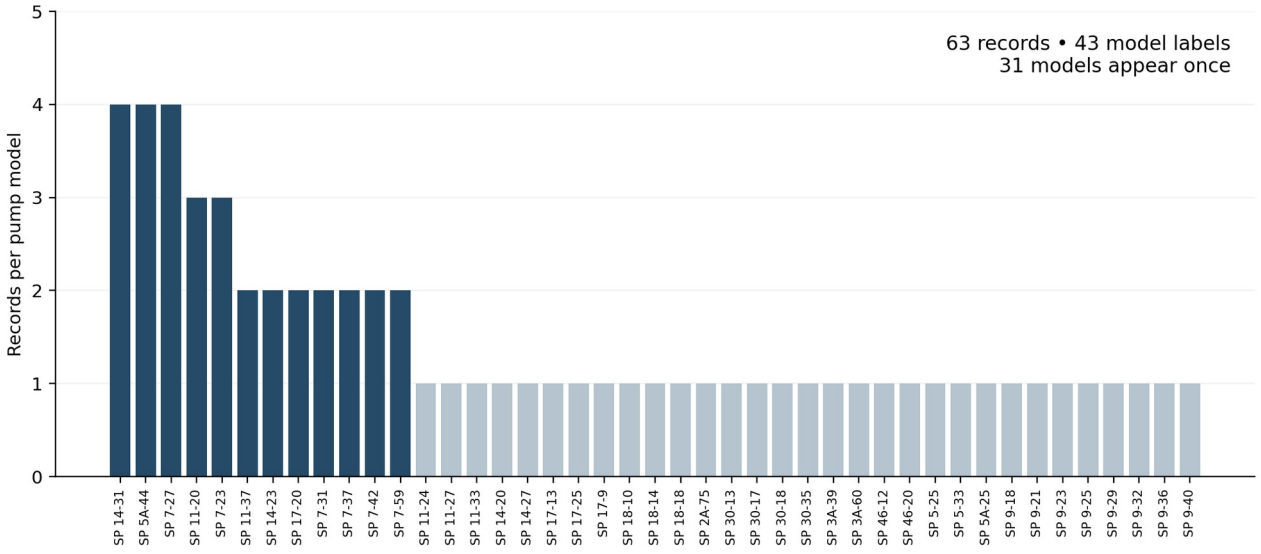


Figure 1. Long tail of SP model labels in the 63-record evaluation. Reconstructed from EA SP Pump Simplification, Curves & Duty Points, G40:G102. Only spaces were normalized; distinct names such as SP 5 and SP 5A were retained. This figure represents recorded equipment frequency, not replacement demand.

A long tail describes a distribution with many infrequently occurring items. In this portfolio, even the most frequent SP model appears only four times. Consequently, a policy of keeping a replacement for every recorded model would spread stock across many items with little individual repetition. Inventory expenditure alone would not show whether the correct replacement was available at the correct location. A warehouse could contain substantial value while a particular community still waited for its pump.

Long-tail items and long-lead-time items are related operational concerns but different quantities. The former are uncommon items in the portfolio; the latter take a long time to obtain. A rarely purchased model may be locally available, while a common model may have a long supply lead time. An inventory policy needs both frequency and lead-time information, together with the consequences of a stockout. The historical pump list establishes variety; it does not by itself establish stock requirements.

Research on component sharing provides a foundation for evaluating this tradeoff. Fisher, Ramdas, and Ulrich examine how organizations can offer different products while using fewer underlying components. Their automotive study treats commonality as a tradeoff involving design costs, variable costs, product requirements, and volumes. The application proposed here is analogous: different water schemes can retain different duties while drawing from a limited equipment architecture. Their results do not quantify savings for African water projects.[5]

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[4] Internal Pump Study. n.d.b. “EA SP Pump Simplification.” Unpublished engineering workbook, supplied by the author. Worksheets: Curves & Duty Points; 50 Hz Options Library. File: EA SP Pump Simplification(1).xlsx.

[5] Fisher, Marshall, Kamalini Ramdas, and Karl Ulrich. 1999. “Component Sharing in the Management of Product Variety: A Study of Automotive Braking Systems.” Management Science 45 (3): 297–315. https://doi.org/10.1287/mnsc.45.3.297.

The practical objective is to concentrate recurring demand on components that can substitute across many installations. A common motor may serve two hydraulic assemblies. A common drive enclosure may support both assemblies. A rack module may recur across several array sizes. This creates repetition at several levels even when the complete site designs differ. The long tail becomes an explicit set of exceptions whose performance requirements and supply arrangements are documented.

The East African screening study

The primary technical analysis selected SP 9-40 and SP 14-31 as complementary candidates and compared them with 63 SP pump records installed or planned during 2017–2025.[6,7] The first candidate provides greater head at lower flow; the second extends the flow range at lower head. The workbook includes duty points, source-yield information, original and substitute daily production estimates, solar-capacity changes, and suitability ratings. It is a retrospective engineering screening exercise rather than a controlled trial.

The presentation summarizes five rating levels. Eleven SP records are rated 0, four are rated 1, twelve are rated 2, eight are rated 3, and twenty-eight are rated 4. Categories 2 and 3 are grouped as requiring additional solar capacity. Category 4 is described as meeting the required demand or more with the same solar capacity. Category 1 can work but is not recommended under the study criteria; category 0 cannot provide the required demand. These categories convey the original analysis and do not substitute for a new site-by-site verification.

The resulting SP-only share in categories 2–4 is 48 of 63, or 76.2 percent. Including category 1 raises the potentially workable share to 52 of 63, or 82.5 percent. A broader worksheet calculation adds 47 SQFlex records to the denominator and places all of them in category 4. Under that assumption, 99 of 110 records fall outside category 0, giving exactly 90.0 percent. Excluding the four marginal SP records gives 95 of 110, or 86.4 percent. Table 1 makes these different definitions visible.

The 90 percent figure therefore has a traceable basis in the supplied analysis. Its interpretation depends on two conditions: the inclusion of marginal SP applications and the assumption that all 47 SQFlex records qualify. The latter has not been established for the particular pair of SQFlex models proposed here. The combined calculation also mixes SP records from 2017–2025 with SQFlex records from 2021–2025. It should be described as preliminary portfolio coverage under stated assumptions.

Population and acceptance rule	Covered / total	Share
SP only, ratings 2–4	48 / 63	76.2%
SP only, ratings 1–4	52 / 63	82.5%
SP plus assumed-suitable SQFlex, ratings 2–4	95 / 110	86.4%
SP plus assumed-suitable SQFlex, ratings 1–4	99 / 110	90.0%

Table 1. Coverage depends on population and acceptance rule. The 47 SQFlex records are assumed suitable in the combined screening, not individually validated for the proposed pair. Source: internal workbook, J40:J110.

[6] Internal Pump Study. n.d.a. “Pump Simplification—Focus: East Africa.” Version 3. Unpublished presentation, supplied by the author. File: Pump Simplification - V3.pptx.

[7] Internal Pump Study. n.d.b. “EA SP Pump Simplification.” Unpublished engineering workbook, supplied by the author. Worksheets: Curves & Duty Points; 50 Hz Options Library. File: EA SP Pump Simplification(1).xlsx.

A dot on a flow–head plot is useful evidence of the hydraulic requirement, but visual enclosure by a curve does not establish full kit suitability. Several records can occupy similar positions. An original duty point may also describe a peak flow that differs from the minimum flow needed over an available pumping day. Daily yield, seasonal irradiance, allowable abstraction, motor loading, and operating limits determine whether the substitute actually supplies the required volume. Figure 2 redraws the SP points and the tabulated candidate curves on common numerical axes.

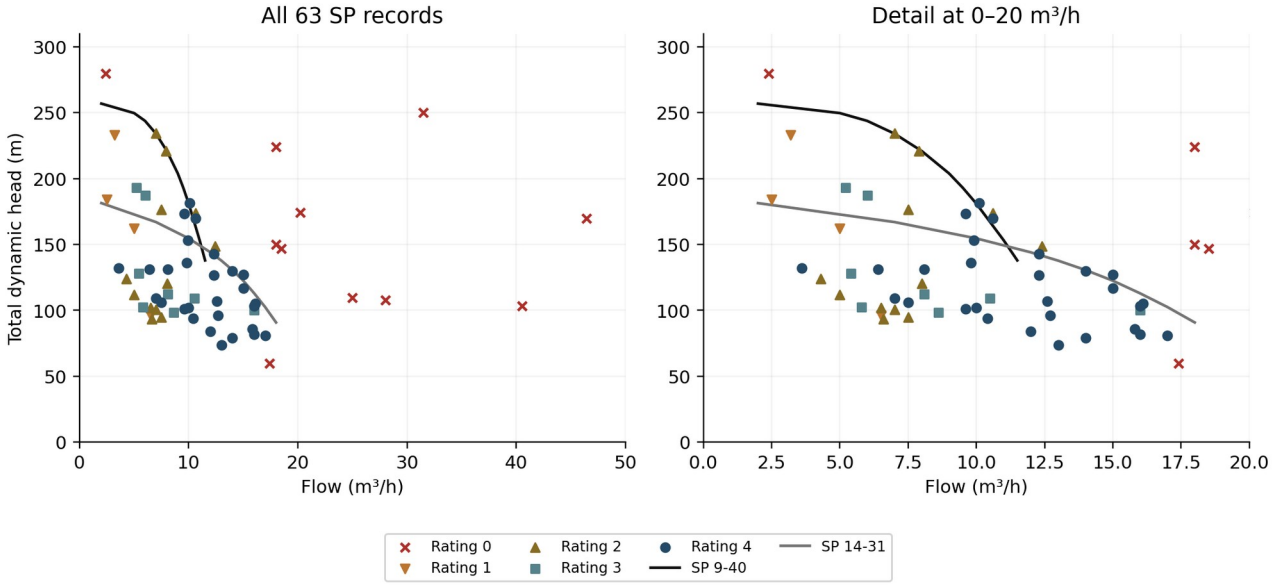


Figure 2. SP duty points and candidate 50 Hz curves, adapted from the study underlying presentation slide 12. All 63 records are plotted; overlapping points may conceal records. Right panel enlarges the common flow range. Source ratings are retained. Curves use tabulated workbook coordinates and are not full validated operating envelopes. SQFlex curves are omitted here because the plotted duty records are SP installations.

The workbook distinguishes production relative to the original design from production relative to stated water demand. These must remain separate. For example, the Chibelela row reports 103.8 cubic metres per day for the substitute with additional solar capacity, compared with 100.1 for the original design and stated demand of 171. The substitute slightly exceeds the original design output while supplying about 60.7 percent of the stated demand. This illustrates why final coverage should use a declared service requirement rather than a favorable replacement ratio alone.

A complete kit architecture

The proposed core portfolio comprises SP 9-40, SP 14-31, SQF 3-105, and SQF 7-55. The SQF pair represents the high-head, lower-flow and lower-head, higher-flow ends of the three 2.5 kW-class candidates in the workbook. SQF 5-70 remains a candidate for a fifth model if its intermediate duty range materially improves coverage, efficiency, or cost. This is a proposed selection for testing, not a completed optimization of the SQFlex portfolio.

For the SP family, the intended common motor is an appropriately specified 7.5 kW MS4000. The manufacturer-generated SP 9-40 sheet identifies that motor rating and gives rated currents of 18.4–18.8–19.6 A for its listed voltage configuration.[8] The exact motor product number, voltage, current, cable arrangement, and compatibility with both hydraulic assemblies must be fixed in the kit specification. Common motor naming alone does not establish interchangeability.

[8] Grundfos. 2018. “SP 9-40.” Grundfos Product Centre technical printout, version 2018.06.003, product 98699065. Manufacturer-generated document hosted by Lenntech. https://www.lenntech.com/uploads/grundfos/98699065/Grundfos_SP-9-40.pdf.

An 11 kW solar-compatible variable frequency drive is proposed as the common SP drive platform. Its selection must be confirmed against continuous output current, ambient-temperature and altitude derating, input voltage range, motor compatibility, and the intended photovoltaic array. The drive rating is distinct from the motor shaft-power rating and from the array nameplate capacity. These numbers do not need to be equal. They describe different parts of the energy-conversion chain.

The SQFlex family would use the compatible MSF3 motor platform and a common control-unit specification. Its integrated electronics make this a separate electrical architecture from the SP family. The proposal is one approved external drive platform for SP installations and one approved SQFlex controller platform, with common control functions where practical. It does not require routing SQFlex pumps through the SP drive. The workbook identifies the motor family, but the final component schedule must confirm exact variants and approved combinations.

The electrical kit should include a controlled bill of materials, enclosure arrangement, terminals, labels, and wiring diagram. It should define the isolation, overcurrent and surge-protection arrangements, earthing, dry-run protection, tank-level control, and any manufacturer-required output filtering. Standardization can reduce repeated design and assembly work, but protection ratings must follow the actual circuit configuration. Cable length, voltage drop, array current, and installation conditions remain parameters within approved limits.

Solar standardization should operate through repeatable modules. A program could select a qualified photovoltaic module specification, a limited set of string configurations, and a repeatable rack bay with standard fasteners and installation details. Projects would then use an approved number of bays and strings. Standard rack geometry does not eliminate checks for wind loading, foundations, corrosion exposure, shading, or land constraints. It reduces the number of details that must be redesigned while leaving site-dependent quantities explicit.

The same approach extends down the borehole and into commissioning. Approved pump connections, drop-pipe interfaces, cable joints, lifting provisions, and wellhead details can be grouped into a small set of compatible assemblies. Installation instructions can follow the physical kit. Commissioning records can use consistent fields for voltage, current, frequency, flow, water level, pressure, and controller settings. A technician who encounters a familiar system can draw on an established test sequence rather than reconstructing its design history.

Table 2 sets out the distinction between common equipment and site-dependent configuration. The kit should be understood as a bounded design with approved variants. Its boundaries are essential: a fixed kit that cannot accommodate a legitimate duty will force poor engineering decisions, while a kit with unrestricted variants will recreate the original equipment variety. Exceptions should record the failed eligibility criterion and the reason for selecting another assembly.

Subsystem	Common specification	Site-dependent configuration
SP assembly	SP 9-40 or SP 14-31; qualified common MS4000 motor	Duty, source yield, setting depth, cable length
SP drive and protections	Proposed 11 kW drive; approved electrical bill of materials	Verified current, derating, array and cable limits
SQFlex assembly	Proposed SQF 3-105 or SQF 7-55; compatible control platform	Daily delivery; optional SQF 5-70 evaluation
Solar generation	Qualified module and approved string/rack modules	Number of strings and rack bays within limits
Installation and maintenance	Standard interfaces, diagrams, checks, spare-parts schedule	Site civil works, hydraulic connections and local conditions

Table 2. Proposed standardization boundaries. Component ratings and combinations remain subject to manufacturer and site verification.

Efficiency at the pump and at the service level

Hydraulic efficiency remains important. The useful hydraulic power delivered to water is determined by flow, total dynamic head, water density, and gravitational acceleration. Electrical input also depends on pump, motor, and drive losses. A comparison between alternatives must hold the service requirement constant. Reporting lower electrical consumption while delivering less water or failing to reach the required storage elevation would not demonstrate an efficiency gain.

For illustration, lifting 100 cubic metres per day through 100 metres requires approximately 27.25 kWh per day of hydraulic energy, using water density of 1,000 kilograms per cubic metre and gravitational acceleration of 9.81 metres per second squared. At a combined electrical-to-hydraulic efficiency of 60 percent, electrical demand is 45.4 kWh per day. At 50 percent, it is 54.5 kWh per day, an increase of 20 percent. These are illustrative calculations, not measured results from the study. They demonstrate why a moderate efficiency penalty can matter.

Variable speed broadens the useful application range of a selected hydraulic assembly. It does not create unlimited flexibility. The Hydraulic Institute, Europump, and U.S. Department of Energy explain that static head materially changes the relationship between speed reduction, flow, and efficiency. In a high-lift water system, reducing speed can quickly reduce useful delivery as the available pump head approaches the static requirement. A simple cubic-power rule cannot establish the annual savings or daily production of these systems.[9]

Consequently, the proposed SP kit should be assessed across approved speed ranges with the actual system curve. A useful selection method would identify acceptable operating regions rather than shade the entire area below a maximum-speed curve as suitable. Minimum motor cooling, hydraulic operating limits, cable effects, and source yield should be incorporated into the eligibility test. Solar simulations should evaluate delivery across the day and through the limiting season, with storage considered alongside pumping.

[9] Hydraulic Institute, Europump, and U.S. Department of Energy. 2004. Variable Speed Pumping: A Guide to Successful Applications. Executive summary. https://www.energy.gov/sites/default/files/2014/05/f16/variable_speed_pumping.pdf.

The World Bank's Solar Pumping: The Basics treats solar pumping as an integrated system and emphasizes adaptation to local conditions.[10] That perspective supports evaluating the pump, power supply, and storage together. In the present proposal, standardization adds a portfolio dimension: equipment choices are also evaluated for their repeatability, supply arrangements, and maintainability across sites. The engineering requirement at each site remains the starting point.

Solar energy has no purchased fuel charge at the point of use, but an efficiency penalty still has costs. Additional photovoltaic modules may require more racking, foundations, cable, protection equipment, land, transport, and installation work. Components will eventually need maintenance or replacement. Conversely, additional energy demand does not necessarily require an equal percentage increase in array capacity because daily production depends on the changing available power and system operating point. Those effects require simulation or measured performance.

Electrical reliability is part of the pumping decision

UNICEF's 2016 assessment, authored by Emily Bamford and Djani Zadi, examined experience in Nigeria, Mauritania, Uganda, and Myanmar. Figure 9 attributes 43 percent of reported malfunction causes to wiring and electrical components and 25 percent to motor issues, including silting. Together these categories account for 68 percent of the plotted causes. These are shares of malfunction causes, not failure rates for all installations, and the motor category should not be relabeled as a verified pump-hydraulic failure category.[11]

The assessment also reports that only about one-third of minor repairs were completed within three days; limited local technical capacity and spare-parts access could prolong interruptions for weeks. This supports evaluating equipment, installation, and repair supply together.[12]

The joint Water Mission and UNICEF design and installation guide provides a technical foundation for qualifying the proposed kits, covering source assessment, pump selection, electrical design, installation, and commissioning.[13] Standardization would concentrate that engineering effort into repeatable, documented configurations. It would not remove the need to assess each source or correct poor well construction.

Outlay costs and economies of scale

The following cost categories describe mechanisms within the lifecycle: outlay, transactions, enforcement, and foregone opportunities. They cut across CapEx, CapManEx, and OpEx rather than forming additional accounting totals. For costing, each actual expenditure should be allocated once; opportunity effects should be reported separately with their assumptions.

Richard Westney provides a useful organizing framework: portfolio cost reduction arises through the interaction of standardization, economies of scale, and experience curves. His argument extends

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[10] World Bank. 2018. Solar Pumping: The Basics. Washington, DC: World Bank. https://documents.worldbank.org/curated/en/880931517231654485/pdf/123018-WP-P159391-PUBLIC.pdf.

[11] Bamford, Emily, and Djani Zadi. 2016. Scaling Up Solar Powered Water Supply Systems: A Review of Experiences. New York: UNICEF. See p. 18, figure 9. https://www.pseau.org/outils/ouvrages/unicef_scaling_up_solar_powered_water_supply_systems_a_review_of_experiences_2016.pdf.

[12] Bamford, Emily, and Djani Zadi. 2016. Scaling Up Solar Powered Water Supply Systems: A Review of Experiences. New York: UNICEF. See p. 18, figure 9. https://www.pseau.org/outils/ouvrages/unicef_scaling_up_solar_powered_water_supply_systems_a_review_of_experiences_2016.pdf.

[13] Water Mission and UNICEF. 2021. Solar Powered Water Systems: Design and Installation Guide. February 2021 English edition, 02-2021_SPG_E_002. https://globalwatercenter.org/wp-content/uploads/2024/04/Solar_Powered_Water_Systems_Guide_02-2021_English.pdf.

beyond repeated equipment to designs, work processes, specifications, and commercial arrangements. Common designs make aggregated purchasing possible; repeated execution gives teams opportunities to improve. He also identifies a management problem: a choice that benefits the portfolio may appear less attractive to an individual project judged only against its own immediate targets.[14]

Outlay costs should be assessed along the entire supply and service chain. A pump's advertised unit price does not capture volume purchasing, shipping, warehouse handling, installation labor, or the cost of waiting for missing equipment. A kit that appears more expensive when priced as an isolated purchase may become less expensive when recurring demand supports a different production and distribution arrangement. That possibility should be evaluated with actual quotations and order commitments.

For manufacturers, concentrated demand can support longer production runs, more predictable component requirements, and fewer configuration changes. Distributors may carry fewer slow-moving items, turn stock more frequently, and spread technical support and order-processing costs over more units. Consolidated shipments can reduce freight and handling per unit. Implementers may reduce repeated mobilization, incomplete deliveries, field storage, and labor spent waiting for equipment. These are mechanisms for potential savings at successive stages; they do not guarantee that every participant's cost or price will fall.

The relevant purchasing scale may span several organizations and utilities. An organization with a modest water portfolio may buy too few pumps to justify favorable stock commitments on its own. Several buyers using the same technically qualified components could provide a distributor with a recurring market. The purchasing group need not share every project design or use identical ownership arrangements. Agreement on equipment specifications, forecasts, and commercial responsibilities may be sufficient to aggregate compatible demand.

Applied here, the portfolio may extend across organizations. A shared technical platform could create a recurring market large enough to support stocked components and repeated installation practice. That is a coordination proposition: compatible demand, credible commitments, common technical controls, and records of performance must connect the buyers. Merely publishing a preferred pump list would leave most of the mechanism unfinished.

Volume purchasing works only if the apparent discount survives financing, inventory, obsolescence, warranty, and distribution costs. Competitive procurement can establish framework agreements with approved suppliers, volume price tiers, call-off orders, stock commitments, and delivery targets. Savings in production or distribution create room for lower prices; commercial terms determine how much is passed to purchasers. Supplier concentration also introduces exposure to shortages or defects, so qualified alternatives and an exception process remain important.

Last-mile delivery here means the final stage of delivering equipment to its destination, irrespective of whether the destination is urban, rural, or ultra-rural. It is a logistics function, not a label for the most remote community. Organizations that transport equipment from a distributor to installations already perform part of this function. Shared depots, scheduled routes, complete-kit dispatch, and coordinated deliveries could improve it. Remote communities are described as ultra-rural where appropriate; their actual transport and service costs should be measured.

[14] Richard Westney, "A Strategy For Driving Step Change Reductions in Capital Project Cost," Oil and Gas Facilities, March 17, 2015, Society of Petroleum Engineers, https://jpt.spe.org/strategy-driving-step-change-reductions-capital-project-cost. Practitioner framework; see the sections on standardization, economies of scale, experience curves, and portfolio versus project incentives.

The same advantages apply to capital maintenance. A qualified common motor could be stocked at a service depot or carried by a maintenance team serving compatible installations. With diagnostic capability, lifting equipment, approved replacement procedures, and authority to use the stock, the team could restore service without beginning a new procurement cycle. Utility-owned, distributor-held, or consigned stock are possible arrangements. Ownership, replenishment, payment, and accountability must be established in advance.

The internal Muatineni comparison illustrates why equipment consolidation still requires a complete cost comparison. In its retained-filter scenario, pumping-related outlay rises from approximately US$26,068 to US$29,363, or 12.6 percent. The pump becomes cheaper, but solar modules rise from 42 to 56 and rack assemblies from three to four.[15] This historical, project-level estimate does not include negotiated portfolio purchasing benefits and is not evidence that standardization either raises or lowers total lifecycle costs. Any proposal to remove an output filter requires separate technical verification.

A historical water-treatment comparison shows why capital and operating effects belong in the same assessment. An EPA study of package treatment plants estimated construction costs of US$488,236 against US$1,124,000 for conventional treatment at one million US gallons per day. Its annual treatment operation and maintenance estimates were US$40,409 and US$62,571, respectively—approximately 57 percent and 35 percent lower for the package alternative. These are historical modeled comparisons, not current prices or an isolated measurement of standardization. They nevertheless demonstrate that repeatable treatment assemblies have been evaluated for both initial and continuing costs in small-community water provision.[16]

Replacement costs across the asset life

Consider two hypothetical pumps providing the same required service. One costs P and lasts eight years; the other costs P/3 and lasts six months. Over an eight-year interval, with purchases at commissioning and each replacement date before year eight, the first requires one purchase. The second requires sixteen, costing 16P/3, or 5.33P. Thus, a two-thirds reduction in unit price can produce more than five times the undiscounted equipment expenditure.

For illustration, if P is US$3,000, the purchases total US$3,000 and US$16,000 respectively. Discounting the sixteen US$1,000 payments at an effective annual rate of 8 percent gives approximately US$12,178 in present purchase costs, compared with US$3,000 paid initially for the durable option. Both alternatives are assumed exhausted at the end of year eight. Labor, transport, retrieval, reinstallation, and service interruptions are excluded. The assumed lifespans are illustrative and are not claims about a particular brand or model.

This comparison explains how a lower CapEx allocation can create higher CapManEx and OpEx. It also demonstrates why comparing purchase prices without an analysis period is inadequate. Equipment quality is only part of the result: poor installation, unsuitable duty, ineffective protections, problematic source conditions, or incorrect drive settings may shorten the life of an otherwise suitable pump and motor. A standardized installation must therefore include the electrical system and the conditions under which the assembly is approved to operate.

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[15] Internal Pump Study. n.d.c. “EA Pump Simplification More Analysis.” Unpublished engineering workbook, supplied by the author. Worksheets: Analysis; Cost-Benefit Analysis. File: EA Pump Simplification More Analysis(1).xlsx.

[16] Richard G. Stevie and Robert M. Clark, Package Water Treatment Plants, Volume 2: A Cost Evaluation, EPA-600/2-80-008b (U.S. Environmental Protection Agency, July 1980), table 7, p. 44, and figures 22–25, https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=500013XO.TXT. Percentage differences calculated from the report’s historical cost estimates; the comparison is at the 1 MGD boundary of the applicable models.

The economic test is the discounted cost of supplying the same required service. Include equipment, installation, administration, maintenance, replacements, support, and any applicable residual value. Show provider revenue effects separately from expenditure and distinguish financial effects from customer and health consequences. Cost classifications should clarify the analysis rather than allow the same technician hour, outage, or lost sale to be counted more than once.

Established standards provide methods for making this comparison consistently. ISO 15686-5 addresses lifecycle costing of constructed assets and their parts, with an explicit analysis period and scope extending from acquisition through operation to disposal. ASTM E917 covers lifecycle costs of buildings and building systems; ASTM E964 addresses discounted benefit-to-cost and savings-to-investment ratios.[17] Their relevance is methodological: the proposed kit should be assessed against an alternative providing equivalent service, with the same horizon, discount assumptions, replacement treatment, and system boundary. The existence of an evaluation standard does not itself establish a percentage saving from standardization.

Transaction costs and repeat purchasing

Transaction costs arise in specifying a purchase, obtaining and evaluating quotations, negotiating terms, approving orders, coordinating suppliers, administering imports, and resolving contractual discrepancies. Physical storage and installation are direct resource costs; arranging and administering them creates additional transaction costs. Repeating the entire purchasing process for uncommon configurations can consume substantial staff time even when the equipment price is modest.

Complete, released specifications allow purchasing staff to order a known assembly against established terms. Routine orders can refer to an approved bill of materials, verified substitutions, and agreed inspection requirements. Engineering effort is then concentrated on qualification, site eligibility, and exceptions. This also makes a supplier's commitment clearer: delivering a nominally similar pump does not satisfy an order for a compatible and documented kit.

Predictable demand is valuable only when suppliers can trust the commitments behind it. Buyers need confidence in authenticity, delivery, and warranty support; suppliers need confidence in payment and realistic forecasts. Clear bid procedures and appropriate protection of proprietary quotations help maintain that relationship. Transparent competition can coexist with durable supply agreements. Recurring renegotiation and opportunistic substitution can undermine both. The conditions vary by market and should be documented rather than presumed from geography.

International-standard adoption also has a directly relevant African water example. An ISO-supported study of Sénégalaise des Eaux assessed management, abstraction, treatment, distribution, sales, engineering, and maintenance. It estimated annual benefits attributable to standards at about XOF 1.4 billion, or 1.9 percent of annual sales. The study also attributed a 1.54 percent reduction in energy costs to improved planning and operational control under its management system. These are case-study estimates involving management and technical standards, not a controlled test of pump commonality or a discounted whole-life result.[18]

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[17] ISO 15686-5:2017, Buildings and constructed assets—Service life planning—Part 5: Life-cycle costing, public scope, https://www.iso.org/standard/61148.html; ASTM E917-17(2023), Standard Practice for Measuring Life-Cycle Costs of Buildings and Building Systems, public scope, https://store.astm.org/e0917-17r23.html; ASTM E964-15(2026), Standard Practice for Measuring Benefit-to-Cost and Savings-to-Investment Ratios for Buildings and Building Systems, public scope, https://store.astm.org/e0964-15r26.html. These are evaluation methods, not estimates of savings caused by adopting standards.

[18] International Organization for Standardization, "Water Senegal, Senegal," Economic Benefits of Standards, vol. 2 (2012), chap. 10, especially the business-function impact tables and conclusion, https://www.iso.org/iso/2012_economic_benefits_of_standards_2_senegal_water_senegal_en.pdf. Study conducted July–December 2011 using 2010 financial indicators. ISO's case-study factsheet reports rounded annual benefits of XOF 1.4 billion, equivalent to 1.9% of sales: https://www.iso.org/iso/ebs_case_studies_factsheets.pdf.

The Senegal example supports a narrower and more useful conclusion than a universal savings percentage: common procedures, defined responsibilities, monitored indicators, and technical requirements can have measurable economic value within water service itself. A small pump portfolio should sit inside that management structure. Equipment commonality, conformity to international standards, and organizational process standardization are related interventions, but their effects should be identified separately when evaluating results.

Scope must be defined through the service objective before equipment purchasing becomes the dominant decision. Budgets and schedules are real constraints, but delivering within both does not establish that the appropriate service was built. Where funding is insufficient, changes in service level, phasing, or coverage should be explicit and assessed with the operator and community. Quietly reducing essential equipment quality or protections transfers costs and risk into the operating period.

There is also a risk of inventory-driven design. Suppliers stock what has sold, organizations buy what is available, and designers adapt projects to the resulting stock. This feedback can perpetuate an unsuitable selection. Consolidation should begin with verified duties, source conditions, service requirements, and lifecycle performance; purchasing commitments should then support the selected portfolio. Ubiquity alone does not establish suitability.

Opportunity costs of delay and repeated failure

A specialized component with a long lead time can become the constraint on completing a project. The internal presentation reports pump procurement periods of three to four months, sometimes followed by further delays.[19] Where this waiting lies on the critical path, readily available kits could allow earlier commissioning and earlier deployment of the same team on its next project. The benefit depends on whether another activity would still constrain completion.

Waiting also creates direct costs: idle labor, accommodation, supervision, storage, and remobilization. Staff may remain away from families longer, increasing welfare and supervision burdens. The corresponding opportunity cost is the work those people and that capital could otherwise accomplish. More unfinished projects create more simultaneous commitments, coordination, and changes of attention. A portfolio can therefore lose throughput even while every team appears occupied.

Late completion can jeopardize grant milestones and delay revenue, but the consequences extend beyond financial schedules. Community contributions, training, and mobilization are often organized around an expected service date. Long delays may weaken participation and confidence in promised service. They can also affect working relationships with public authorities and future service-area assignments or approvals. These are plausible consequences to investigate in the relevant jurisdiction, not assured financial benefits of standardization.

During operation, an outage can reduce current sales and cause customers to resume using previous sources. Some may not return when service resumes; others may permanently reduce purchases. The economic analysis should distinguish immediate lost sales from persistent customer attrition and reduced use. Lost revenue is relevant to cash planning; lost contribution after avoidable costs is the appropriate starting point for estimating the financial benefit of restored sales. Claims about the scale or permanence of attrition require customer records.

Reliable and predictable supply also protects the value of community engagement and use of the service. A technically functioning asset does not recover those benefits automatically after a long

[19] Internal Pump Study. n.d.a. “Pump Simplification—Focus: East Africa.” Version 3. Unpublished presentation, supplied by the author. File: Pump Simplification - V3.pptx.

interruption. Customer confidence, collection patterns, tariffs, alternative sources, and actual demand all affect recovery. Service restoration should therefore be followed by evidence of resumed use, not simply confirmation that the pump runs.

Repeated maintenance can consume the capacity needed to improve the service. In an informal ten-seed allocation exercise conducted by the author, one operator responsible for several systems placed eight seeds against pump replacement, pump cleaning, and well flushing associated with iron oxide problems. Only two seeds represented all other duties. This was an elicited estimate from one operator, not a timed work study. It illustrates how one recurring technical problem can dominate a service organization's workload.

The operator's labor is an operating expenditure. Leak detection, investigation of unauthorized connections, chlorine replenishment, preventive maintenance, and improvement work displaced by that labor are foregone opportunities. Standardizing equipment would not itself solve iron precipitation or poor borehole development. It could simplify diagnosis and repair while freeing attention for source-specific investigation and a durable corrective intervention. Root-cause work remains essential.

Funds repeatedly consumed by pump and electrical replacements are unavailable for network improvements, planned renewal, or expansion. Where policy and financing arrangements permit, improved performance may also leave more resources for subsidizing rural and ultra-rural service. Those resources are not automatically available as cash: organizations must distinguish reduced spending, released staff capacity, and revenue recovered, then decide deliberately how each will support better service.

Repetition and continuous improvement

Repeated execution can release capacity as well as reduce purchasing costs. In a 2024 geothermal study, El-Sadi and colleagues examined Fervo Energy's first eight horizontal enhanced-geothermal-system wells, including wells at Project Red and Cape Station. They reported more than a 60 percent reduction in drilling days normalized by total measured depth. Their sequential performance and learning-curve charts document the application of technical and operational learning across wells.[20] This is a geothermal construction result, not a water-pumping savings forecast. Its relevance is the ability to retain and apply learning where recurring work shares sufficiently similar conditions.

A corresponding petroleum example is Coletta, Arias, and Mendenhall's Eagle Ford drilling campaign, whose SPE/IADC paper reports more than a 52 percent reduction in drilling time and 45 percent in cost over two and a half years. The improvements involved several changes in technology, execution, and management rather than repetition alone.[21] A Total Argentina presentation similarly illustrates a declining well-cost curve alongside standardization and a change in drilling fluids.[22]

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[20] Kareem El-Sadi, Brittany Gierke, Elliot Howard, and Christian Gradl, "Review of Drilling Performance in a Horizontal EGS Development," Proceedings, 49th Workshop on Geothermal Reservoir Engineering, Stanford University, February 12–14, 2024, SGP-TR-227, pp. 1–2, figures 1–2, https://pangea.stanford.edu/ERE/db/GeoConf/papers/SGW/2024/Elsadi.pdf. The charts show sequential well-delivery performance and learning curves; the reported reduction concerns drilling days normalized by total measured depth.

[21] Claudio J. Coletta, Camilo Arias, and Scott Mendenhall, "Drilling Improvements in Pursuit of the Perfect Well in the Eagle Ford—More Than 52% Reduction in Drilling Time and 45% in Cost in Two and a Half Years," SPE/IADC-178897-MS (2016), https://doi.org/10.2118/178897-MS, as summarized by Adam Wilson, "Drilling Improvements Work Toward the Perfect Well in the Eagle Ford," Journal of Petroleum Technology 68, no. 9 (2016): 104–105, https://doi.org/10.2118/0916-0104-JPT. The publisher's summary was consulted; the full conference paper was not available for review. The conference paper was not peer reviewed.

[22] Jean-Yves Lansot, "Total Argentina Gas Shale Wells—Implementation of Clean Based Fluids," AADE Fluids Management Group presentation, February 21, 2019, slides 8–9, https://www.aade.org/download_file/force/3228/510. The well-cost learning

These examples establish the plausibility of substantial accumulated improvement in commodity infrastructure; they do not establish a transferable percentage or prove that component consolidation caused the entire reduction.

For water programs, the corresponding learning record would connect each installation to engineering hours, procurement time, field labor, commissioning defects, repair duration, and actual service delivery. Teams need enough continuity to apply what they learn, and the authority to revise the approved configuration when evidence warrants it. Standardization should preserve successful improvements in the next released design. Repeating an unsuitable design or a recurring failure is repetition without learning.

Enforcement costs and focused technical proficiency

Enforcement costs, as used here, are the resources required to verify and sustain conformity with approved requirements. They include checking the authenticity and compatibility of supplied equipment, inspecting installation, witnessing commissioning, reviewing maintenance, and controlling changes. A supervisor can verify a familiar assembly against a released drawing and test procedure more readily than reconstruct the requirements of a different system at every visit.

Municipal practice provides a close precedent. Dea and Gans's ASCE paper on the Washington Suburban Sanitary Commission describes a design manual, standard specifications, standard detail drawings, field reports of design deficiencies, and retained design files. The stated purposes included shorter and less costly design and construction, reduced inventory costs, and greater staff flexibility across facilities; the authors reported that experience supported those objectives.[23] The important connection is between standard details and operational feedback. Designers, contractors, operators, and supervisors use common requirements while contributing different expertise.

This applies during both initial construction and capital maintenance. Replacement should preserve the approved configuration or follow a documented engineering review of the proposed change. The process can preauthorize equivalent components and routine replacements while reserving new combinations for the responsible designer. A field technician should not need to invent a pump–motor pairing or redesign electrical protections to restore service. Replacing like for like is also insufficient when recurring failures indicate that the original selection or installation was unsuitable.

A qualified kit can include preconfigured drive parameters, wiring diagrams, protection settings, installation photographs, inspection points, and commissioning limits. Site-specific cable lengths, source conditions, and other variable inputs remain explicit. Incorrect installation or programming can damage even high-quality equipment, so the kit must preserve the connection between the hardware and its approved operating instructions. Configuration changes should update the asset record and maintenance guidance.

Verification can itself be organized more efficiently. The National Research Council's Safe Water From Every Tap observed that repeated pilot testing could erode package-plant savings; manufacturers reported testing additions exceeding 30 percent of equipment costs. It recommended independent certification to reduce duplicative testing while retaining appropriate site evaluation.[24]

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curve annotates a 63% reduction alongside casing-architecture standardization and a drilling-fluid change. This industry presentation is an additional illustration, not an independently controlled estimate of standardization's contribution.

[23] Stanley J. Dea and Roger L. Gans, "Design Standardization Program of WSSC," Journal of Management in Engineering 2, no. 2 (1986): 111–123, https://doi.org/10.1061/(ASCE)9742-597X(1986)2:2(111). The accessible publisher abstract describes the program and reports success against its objectives; no quantified savings estimate is claimed here.

[24] National Research Council, Safe Water From Every Tap: Improving Water Service to Small Communities (Washington, DC: National Academy Press, 1997), Summary, https://www.nationalacademies.org/read/5291/chapter/2. The reported testing-cost increase was supplied by manufacturers, not a controlled average across all package plants.

For pumping kits, the analogous proposal is to qualify recurring assemblies once under a defined process, then verify that each installation falls within the approved conditions. Shared qualification cannot replace borehole assessment, source-water evaluation, or commissioning.

Research supports a nuanced approach to repetition. Staats and Gino, using two and a half years of transaction data from a Japanese bank, found that specialization within a day was associated with improved productivity, while variety in experience across days also improved productivity. The implication proposed here is to combine repeated practice on approved pumping configurations with planned development across other water-service responsibilities. The study does not identify an optimal number of pump models or quantify savings for water technicians.[25]

The sporting analogy is a limited repertoire of well-rehearsed plays, with clear responsibilities and known responses to common situations. It illustrates execution discipline rather than proving that four or eight plays is universally optimal. Collins's hedgehog concept offers a related illustration of sustained organizational focus.[26] Neither analogy substitutes for evidence about installation defects, repair times, or learning in the actual workforce.

A technician may need competence in several essential functions without mastering every pump, drive, motor, and electrical arrangement in the market. Deliberate repetition within a few applications can reduce unnecessary variation in training and troubleshooting. Specialist engineers and electricians should remain available for work beyond the technician's approved scope. Standardization makes that division of labor more practical; it should not lower professional expectations or treat brief training as equivalent to specialist qualification.

Staff turnover makes documented configurations, supervised practice, and competency assessment particularly important. Training investment should be tested through demonstrated tasks and retained performance. An organization seeking growth in dependable service needs expertise and time for continuous improvement. The aim is to develop a capable workforce supported by repeatable systems, with investment judged against service quality and long-term performance.

Remote oversight and comparable performance

Remote oversight begins with a known installation record: the pump and motor, drive model and parameters, array capacity, setting depth, hydraulic arrangement, commissioning performance, and available water-level information. A small approved equipment portfolio reduces the number of configurations that analysts must understand. Monitoring then tests whether a known installation behaves as expected.

Production trends, together with available electrical and source data, can help flag underproduction, abnormal starts and stops, or changes in energy use. Adequate time resolution is needed to detect cycling; daily totals can conceal frequent interruptions. Irradiance, tank demand, operating speed, head, and source behavior affect interpretation. The purpose is to prioritize investigation and direct the next measurement, not to infer a unique fault from production alone.

With suitable instrumentation, engineers can compare observed behavior with expected operation and investigate electrical faults, borehole deterioration, changing drawdown, or abstraction exceeding approved limits. Static water level requires an appropriate nonpumping measurement; it should not be inferred directly from a daily production total. Alerts may shorten detection delays and reduce reliance on customers or operators first reporting a problem.

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[25] Staats, Bradley R., and Francesca Gino. 2012. "Specialization and Variety in Repetitive Tasks: Evidence from a Japanese Bank." Management Science 58 (6): 1141–1159. https://doi.org/10.1287/mnsc.1110.1482.

[26] Collins, Jim. n.d. "The Hedgehog Concept." Accessed November 2, 2026. https://www.jimcollins.com/concepts/the-hedgehog-concept.html.

Comparable equipment and consistent records make comparisons across systems more meaningful, provided head, demand, irradiance, and source constraints are accounted for. Statistical or machine-learning tools could support anomaly detection as data accumulate, but their performance must be checked against field findings. Monitoring has value when someone is assigned to review an alert, investigate, authorize action, and verify the result. Sensors without a response process simply record the outage.

Inventory and the availability of complete kits

Component commonality can allow one spare to satisfy several possible needs. Baker, Magazine, and Nuttle analyze safety-stock decisions with common components and a service-level constraint. Their specialized model provides a theoretical basis for evaluating pooled requirements; it does not imply a universal percentage reduction in stock. For water programs, the value depends on the extent of genuine interchangeability, the distribution of failures, replenishment times, and the locations where equipment is needed.[27]

A common SP motor could be held as a spare for either standard hydraulic assembly, provided the approved interfaces and ratings match. This may permit replacing a failed motor while retaining a serviceable hydraulic assembly. The saving depends on the actual failure mode and the ability to retrieve, diagnose, repair, and reinstall the equipment. A motor in stock cannot resolve a failed borehole, damaged drop pipe, unavailable lifting equipment, or a fault that has not been correctly identified.

Complete-kit availability is a more useful readiness measure than pump availability alone. An SP pump and motor may be ready while the drive, cable splice, surge protector, or compatible connector remains unavailable. A program should therefore count how many complete, deployable kits it holds and identify the component limiting that number. Procurement schedules should account for the longest replenishment requirement among the necessary components. Standardizing that surrounding equipment is central to the proposed service benefit.

The supplied stocking proposal uses budget limits, country stock caps, and preferred pump allocations to explore inventory decisions.[28] Its four-SP-model list addresses a different stocking alternative from the two-SP-plus-two-SQFlex architecture advanced here. Its weighted quantity objective should not be interpreted as proof of maximum service coverage. A revised model could select pump families and country stock levels subject to verified technical eligibility, expected demand during lead time, and a target service level.

A practical first implementation can use transparent reorder rules before introducing an optimization model. Record each withdrawal, replenishment date, emergency transfer, and stockout. Separate planned project demand from repair demand. Establish supplier commitments for the standard components and identify a qualified substitute for critical items where feasible. Commonality concentrates demand and may improve purchasing leverage, but it can also concentrate exposure to a supplier interruption or a defect affecting an entire component family.

Validation and application beyond the initial portfolio

The first validation task is to establish one clean evaluation register. Each record should identify the scheme, pump position, country, installation or planning date, required daily volume, total dynamic

[27] Baker, Kenneth R., Michael J. Magazine, and Henry L. W. Nuttle. 1986. “The Effect of Commonality on Safety Stock in a Simple Inventory Model.” Management Science 32 (8): 982–988. https://doi.org/10.1287/mnsc.32.8.982.

[28] Internal Pump Study. n.d.d. “Pump Stocking MILP Model Proposal.” Unpublished working document, supplied by the author. File: Pump Stock MILP Proposal - Ben-tern.docx.

head, source constraints, and existing power arrangement. Repeated schemes, upgrades, multiple pumps, and alternative model names should be distinguished. The denominator should count a declared unit, such as pumping installations, rather than interchangeably using projects, pumps, or communities.

Next, evaluate each record against the proposed four-model portfolio using consistent acceptance criteria. For SQFlex, compare SQF 3-105 and SQF 7-55 and quantify the incremental contribution of SQF 5-70. For SP, retain the original rating as historical information and calculate new pass or fail results against the required service and approved kit limits. A marginal design should remain visible rather than silently joining the accepted category. Report the cost of exceptions alongside their number.

Temporal and geographic differences deserve separate reporting. The presentation shows a shift toward SP pumps and larger community-system motors in recent years, while some large systems serve refugee settlements. Adding older small-system records can raise an overall coverage percentage without showing how well the portfolio fits new work. Report results for the same date window across both families and for relevant application groups. Any exclusions must be declared before claiming coverage for the remaining population.

A prospective comparison should follow eligible standardized installations and comparable conventional installations through procurement, commissioning, and operation. Useful outcomes include installed cost, engineering hours, order-to-site time, incomplete deliveries, daily water production, electrical energy per cubic metre, stockout days, repair duration, and days meeting the service requirement. Differences in head, demand, source yield, country logistics, and system age should be considered before attributing results to standardization.

For broader application, other organizations could contribute anonymized equipment and duty-point records using the same fields. This would test whether the candidate kit covers a recurring regional need or mainly reflects one organization’s project mix. The approach is transferable even if the specific pump models change. A common evaluation method can support competitive procurement and equivalent products while preserving the benefits of repeatable interfaces, electrical assemblies, and installation procedures.

Customer outcomes and aligned incentives

The performance measure should connect expenditure to actual service. Report lifecycle cost per customer served at a declared service level over a stated analysis period, alongside reliability, quality, affordability, and use. Define whether a customer is a person, household, connection, or institution. Connection counts and the population within a service area are not interchangeable with verified users.

For comparisons over time, annualized lifecycle cost per customer-year can be useful if customer counts reflect the period actually served. Compare systems within relevant groups, including settlement density, remoteness, income, source conditions, and required service level. Report subsidies separately so that a low tariff is not mistaken for a low cost of service. A portfolio should not improve its reported unit cost merely by excluding expensive rural and ultra-rural customers.

Count-based equipment coverage should be accompanied by demand-weighted coverage and the population associated with eligible schemes. Uncommon large installations may account for a substantial share of water production. An additional pump model can be justified by its incremental service coverage, lower energy requirement, or reliability benefit, even if it adds few installations. Those gains should be compared with its inventory, training, documentation, and support burden.

Procurement, construction, engineering, community development, and operations need performance measures that recognize their joint effect on customers. Purchase price, budget compliance, and commissioning dates remain useful, but they should sit alongside sustained service and renewal costs. Donor agreements and organizational targets can support this by budgeting for lifecycle requirements, documenting handover responsibilities, and requiring operational feedback to inform subsequent designs.

An initial standardized-kit pilot should track order-to-site time, complete deliveries, engineering and procurement hours, field labor, installation defects, daily delivery, energy per cubic metre, repair time, customer retention, and actual expenditures. Comparable conventional installations should be evaluated over the same period, with differences in duty and context recorded. This would test whether consolidation improves execution and service rather than merely reducing the number of equipment labels.

Conclusion

The East African portfolio provides a specific starting point for pumping system standardization: 63 SP records contain 43 model labels, and the broader screening reaches 90 percent preliminary coverage under stated assumptions. Two SP hydraulic assemblies, a common qualified motor and drive, and two complementary SQFlex assemblies offer a testable basis for a much smaller set of complete pumping configurations.

Municipal standardization, historical package-treatment comparisons, ISO's Senegal water-utility case, and geothermal and petroleum learning curves place this proposal within a substantial history of practice. Westney's portfolio framework explains how common designs, aggregated demand, and accumulated experience can reinforce one another. The contribution here is a specific pumping-system architecture and a method for testing it against water-service outcomes, rather than a claim to have originated these principles.

The evidence also sets boundaries. Annual economic benefits, historical capital comparisons, drilling-time reductions, and lifecycle present costs are different measures. They cannot be added together or imported as a forecast for African water systems. The proposed portfolio must demonstrate its own savings, reliability, and service coverage through technically qualified installations and transparent operating records.

CapEx, CapManEx, and OpEx are interdependent parts of the cost of sustained service. Community engagement, project management, and multidisciplinary design likewise contribute to the same customer outcome. Equipment consolidation is valuable when it improves that outcome over the full lifecycle, including the capacity to maintain, renew, and expand service. Four pumps is a concrete proposition for testing how much dependable water service a simpler, better-supported system can deliver.