Life Is On | Schneider Electric

How electrical distribution equipment retrofit services contribute to a circular economy

by Giovanni Zaccaro

Executive summary

A circular economy is today's alternative to the traditional "take, make, and dispose of" industrial model. It redefines products and services, minimizes waste, and saves money. Practices such as "retrofit, refurbish, and recycle" apply to electrical distribution devices (e.g., switchboards, circuit breakers, and accessories), prolonging lifecycles and reducing total cost of ownership.

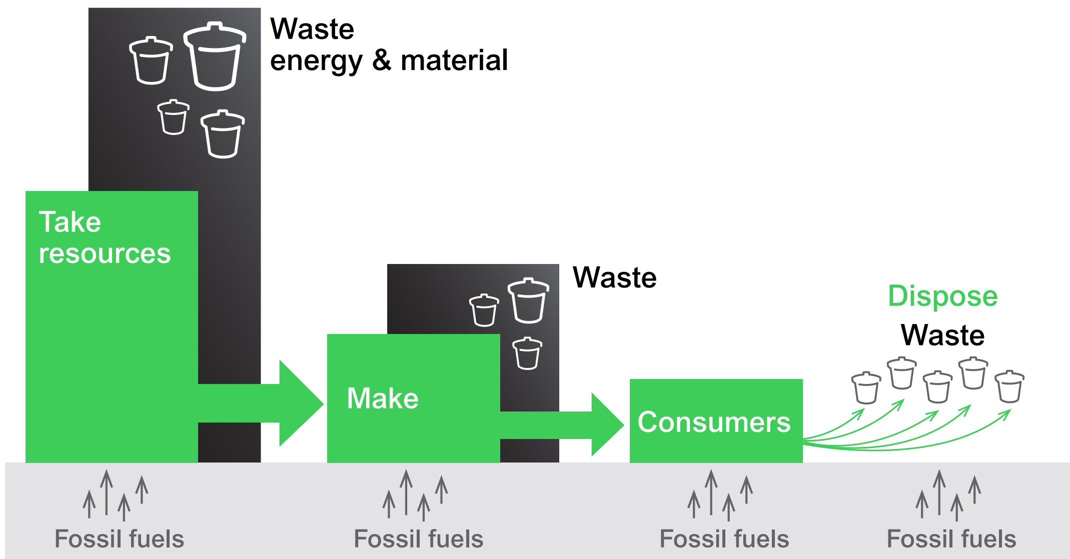
This paper explains the circular economy model and illustrates the subsequent environmental and economic benefits of retrofitting electrical distribution equipment.

Introduction

Across the globe, a fundamental shift is taking place from a long-established linear global economy to a more circular model. The linear economy[1] is based on a "take, make, consume, and throw away" approach to resources (see **Figure 1**).[2] Its main disadvantages include a growing shortage of materials, increased pollution and landfill disposal, and increased material demand. As environmental priorities shift to more planet-friendly "green" approaches, there is a widespread growing demand for a more responsible approach to using and consuming products.

Figure 1

Linear economy method of consumption



The circular economy is a newer economic format inspired by ecosystem principles and restorative design. A circular economy increases resource resilience, eliminates waste, and creates shared value through enhanced material and immaterial flows circulation.[3]

This "cradle-to-cradle" concept is achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing, and recycling (see **Figure 2**).[4]

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[1] https://ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview

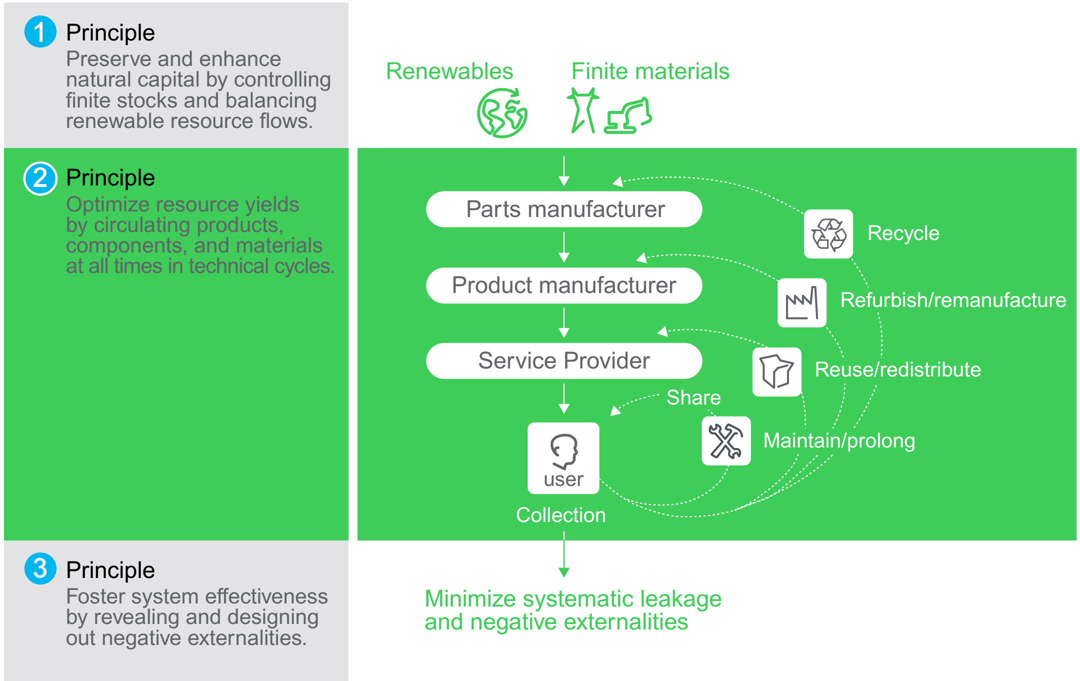
[2] Multilingual Environmental Thesaurus: http://www.eionet.europa.eu/gemet/en/concept/15216

[3] http://www.circular.academy/circular-economy-some-definitions/

[4] https://www.ellenmacarthurfoundation.org/circular-economy/interactive-diagram

Figure 2

Circular economy approach of consumption



One of the many areas where circular economy roots are beginning to flourish is in the domain of low-voltage (LV) and medium-voltage (MV) electrical distribution switchgear. A company like Schneider Electric, which for years has been committed to sustainability best practices, has invested considerable capital in assuring that its core products, such as power distribution equipment, maintain a low-carbon footprint and a high degree of recyclability. This paper explains how retrofit, reuse, refurbishment, renewal, and recycling work within the domain of electrical distribution switchgear.

Retrofitting switchgear

Two component categories make up a typical LV and MV electrical switchgear system: **passive and active**.

The passive components include steel frames, cover plates, barriers, and horizontal and vertical bus structures.

The active components are more critical and include power circuit breakers, contactors, protection relays, and/or fuse devices. These components are responsible for protection from overcurrent.[5] The circuit breakers, contactors, and protection relays are the three active components that have the most impact on maintenance and obsolescence issues (see **Figure 3**).

[5] Guidelines for Modernizing Existing Electrical Switchgear in LV and MV Networks, Cired 2017, Glasgow, UK.

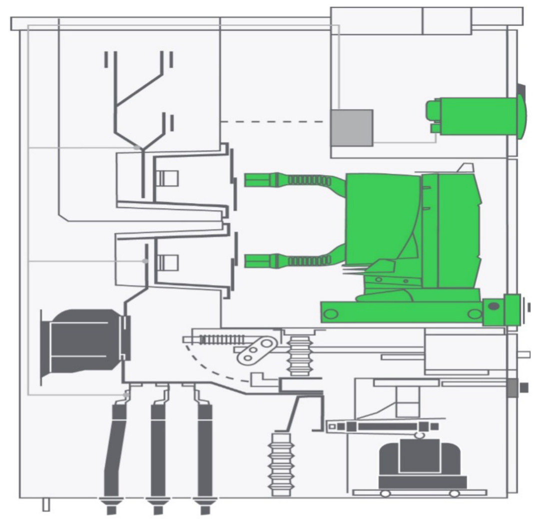


Figure 3

Switchgear active components are highlighted in green, while passive components are highlighted in gray.

The components in **Figure 3** undergo different stress levels depending on operations and the influence of the surrounding environment (e.g., heat, humidity, chemicals, and dust). Also, due to the lifecycle specifications outlined by the original equipment manufacturer (OEM), they experience variable obsolescence rates.

When a switchgear unit is deemed ready for an upgrade, a retrofit approach replaces specific switchgear components to renew existing functions, add new functions, like digital connectivity, or generally prolongs the whole switchgear's life. This is typically performed on outdated active components, such as circuit breakers in primary distribution, contactors, and protection relays.

Circuit breakers and contactors require more care as they ensure equipment reliability and safety. In protection relays, these can be easily replaced by modifying the switchgear's front door and wiring. When retrofitting (see **Figure 4**), the rest of the switchgear (the housing, which is the largest physical part of the switchgear, for example) is kept "as is" and its life prolonged. The obsolete equipment can be refurbished, repaired, or reused in other equipment, and quality is best assured when the OEM performs the service.

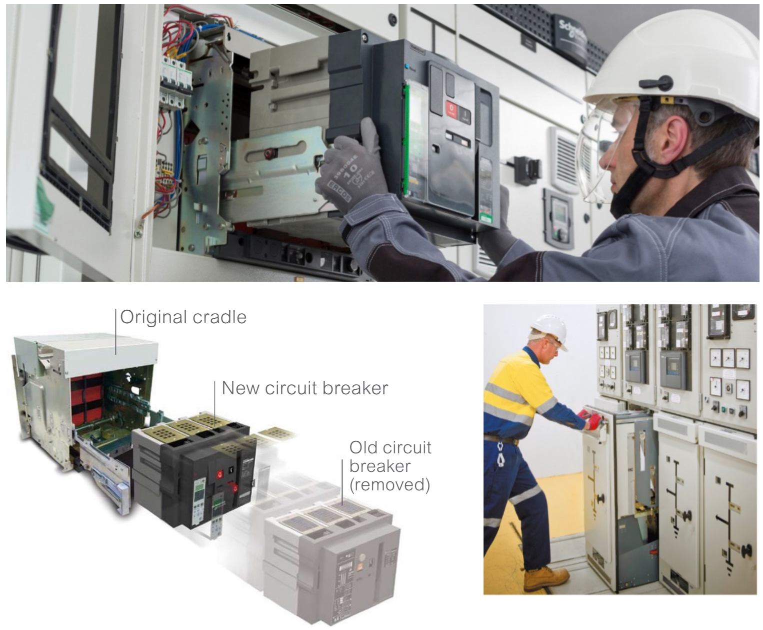


Figure 4

Illustration of an aging, obsolete circuit breaker replaced by a modern circuit breaker while maintaining the original cradle.

Recycling SF_6 gas

Obsolete switchgear equipment can also be recycled to provide the material with a new life. This recycling must be performed in strict compliance with standards to protect the environment. For example, MV equipment may contain sulfur hexafluoride (SF_6) gas or polychlorinated biphenyl (PCB) oil, which qualified personnel must dispose of in authorized workshops. SF_6, at the time of disposal, is recognized by numerous government organizations as hazardous waste. Since the 1990s, it has been known that 1kG of SF_6 vented into the atmosphere corresponds to roughly 23 tonnes of CO_2.

As a result, SF_6 gas is regulated at local, state, federal, and international levels. Fortunately, owners of power equipment technologies that contain SF_6 don't need to concern themselves with the risk and complexity of disposal and recycling if they involve knowledgeable, legitimate partners when retiring obsolete electrical equipment.

Guidance surrounding the disposal process – provided by the International Electrical Commission's IEC 62271-4 standard – details how SF_6 is first collected from switchgear and other equipment facing retirement, then filtered and cleaned at specialty gas handling facilities, recovering and recycling 99% or more of the SF_6. OEMs then use the purified SF_6 in manufacturing new switchgear products, closing the loop that supports a circular economy.

Switchgear modernization indicators

Facility and plant managers often debate when the time is right to invest in electrical installation modernization. With each passing year, the likelihood of costly unplanned downtime increases as the business evolves and more demand is placed on their electrical systems. In addition, as the global utility power supply becomes more unstable, internal electrical systems are subjected to more wear and tear.

Five key indicators help to signal *when* the time is right to modernize:

1. Spare parts are difficult and expensive to obtain
2. Maintenance costs are rising
3. Components are visibly deteriorating
4. Business conditions accelerate the urgency of upgrade
5. High criticality of the processes affected should the electrical systems fail

Let's examine each of these individual drivers in more detail.

1. Spare parts availability

Consider two types of spare parts when weighing switchgear modernization decisions: spare parts for **commercialized products and obsolete products**.

Spare parts for commercialized products include the manufacturer's electrical distribution equipment as an extension of their commercialized offering. These spare parts can be accessed online or via printed equipment catalogs.

Spare parts for obsolete products are for products at the end of their sales lifecycle. They are available to support an existing installed base of products that are no longer commercialized. These parts typically remain available for ten years for LV and 12 years for MV equipment.

When spare parts for obsolete products are no longer readily available (see **Figure 5**), the continuity of service and support is at risk. If a device breaks down, parts may not be available to fix it. At this stage, launching a modernization initiative is imperative.

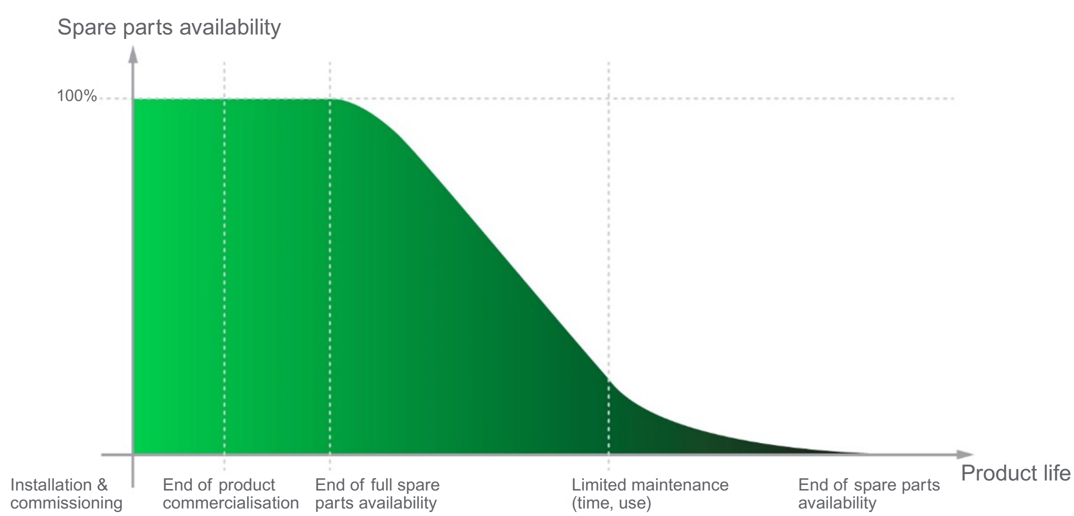


Figure 5

Spare parts' availability is affected by the phase out scheduling of equipment manufacturers.

Specific maintenance agreements can be negotiated under certain circumstances, such as managing an older product's large existing installed base. These are usually costly as spare parts are rare, if available at all, and the associated installation expertise for repair is difficult to secure. Spare parts for both commercialized and discontinued electrical equipment can be supplied via OEMs.

2. Rising maintenance costs

Manufacturing companies are constantly under pressure to manage their costs. Maintenance is a considerable expense item on a plant's P&L statement. Maintenance costs trend upwards when skilled labor is in short supply, when component prices rise, and when the frequency of repair increases. If modernization is delayed for too long, maintenance costs increase exponentially (see **Figure 6**). Modernization becomes a cost control solution that also provides the additional benefit of higher operational reliability.

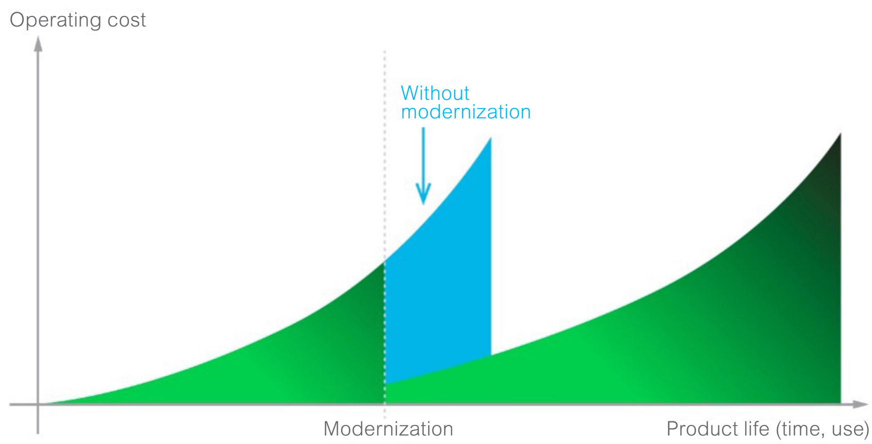


Figure 6

Maintenance costs increase as products get older. A timely upgrade can reset the bar on maintenance costs.

3. Degree of equipment wear and tear

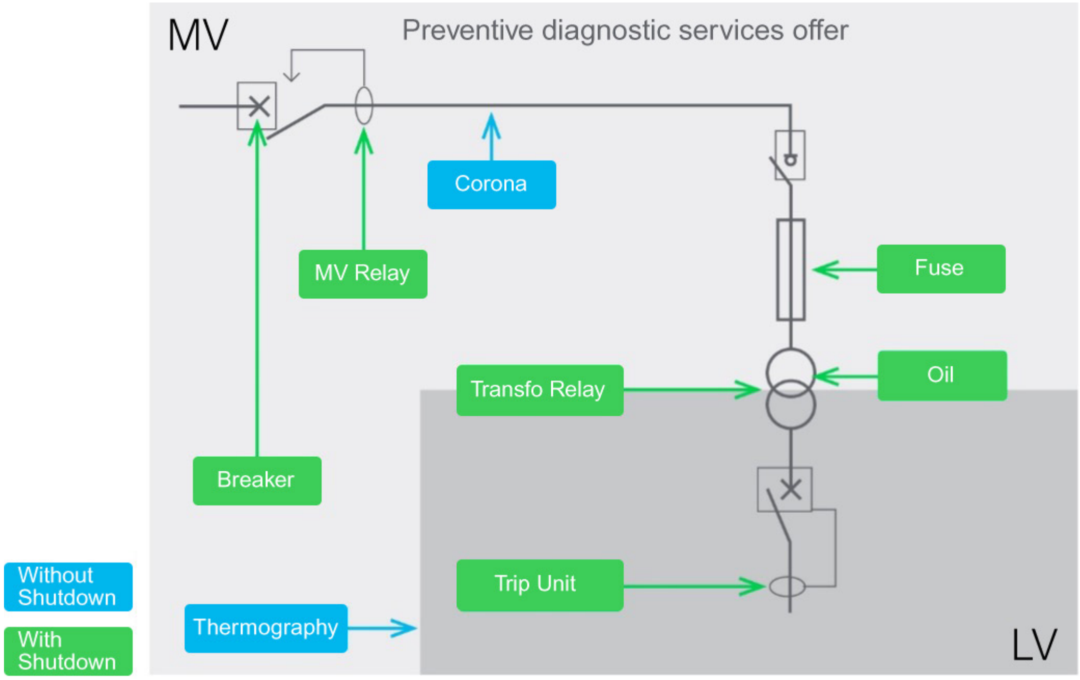
Aging materials reduce equipment reliability. Both dielectric breakdowns of insulating components and deterioration of aging mechanical parts can disrupt equipment uptime.

The steel/copper or resin housings do not usually show much wear over time. Risks are usually related to moving parts damage due to dust/chemical deposits when basic maintenance operations are not regularly performed.

Diagnostic tools can check the wear and tear of electrical equipment (see **Figure 7**) and compare current performance to how the equipment had traditionally performed.

Figure 7

Types of equipment upon which diagnostics can be performed



4. Business / marketplace conditions

Often, the changing nature of both Internal and external factors can influence modernization priorities. For example, power requirements within an industrial facility may evolve to support newly expanded manufacturing lines. Technology trends such as digitization may introduce new ways of supervision and monitoring that result in considerable cost savings.

Outside forces, such as regulatory bodies, may introduce new standards that influence the workplace's mechanical and human safety aspects. Or growing trends, such as an increase in cyberattacks, may threaten the security of connected systems and require upgrades that impact electrical systems.

5. Critical processes

When new processes are deemed critical (like the rapid production of vaccines during the pandemic), the electrical systems that support those key manufacturing processes need to be rock solid and completely reliable. Such a situation would drive a quick upgrade to aging electrical distribution assets.

Environmental and financial benefits

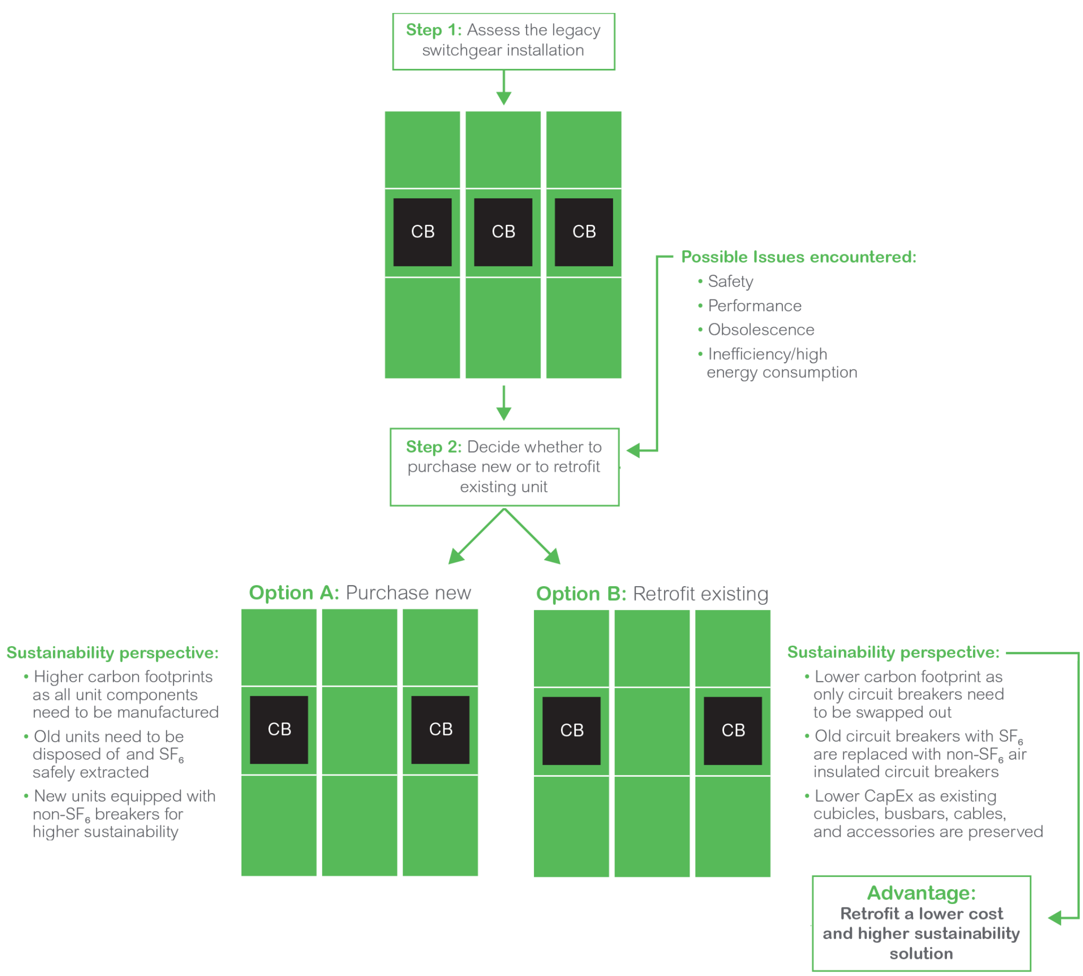
Since retrofit solutions replace only a portion of the existing electrical equipment, fewer waste materials need to be processed than a complete replacement. For example, consider a typical MV electrical distribution installation, with 12 switchgear consisting of 8 feeders, 2 incomers, a line-up bus section, a bus riser, and 11 circuit breakers. The existing, original circuit breakers are aging and use SF_6 insulation technology. To upgrade them with more modern vacuum technology circuit breakers (SF_6-free = with no SF_6), there are two options to consider:

1. Complete replacement
2. Retrofit the circuit breakers only and keep the switchgear housing and accessories

Since retrofit solutions replace only a portion of the existing electrical equipment, fewer waste materials need to be processed than a complete replacement. For example, in electrical distribution, retrofitting a circuit breaker unit inside a switchgear avoids manufacturing new cubicles, busbars, cables, and accessories. Calculating the environmental footprint (e.g., saved CO_2 emissions, saved primary resources consumption, and saved freshwater) helps illustrate what can be avoided if a retrofit is selected over "buy new," (see **Figure 8**).

Figure 8

Environmental savings of a retrofit upgrade approach



A product environmental profile[6] (PEP) provides an environmental assessment of our products and allows us to arrive at the figures we have published in **Figure 9**. For example, a PEP tells us how many kgs of primary resources are needed to manufacture a switchgear unit. The equipment profile reveals the constituent materials of the product, all the manufacturing certificates, and the distribution resources (packaging and weight) required to ship the equipment, as well as emission equivalents of those products and movements.

The PEP data can then be used to calculate the environmental savings of the retrofit solution versus a complete replacement. In essence, the PEP is an assessment that addresses all lifecycle phases of a product, including manufacturing, distribution, installation, use, and end of life, see **Figure 9**.

Figure 9

Example of PEP assessment

Source: Schneider Electric

Compulsory indicators		OKKEN 115/70-2 MCC Low Voltage Switchboard - 87020					
Impact indicators	**Unit**	Total	Manufacturing	Distribution	Installation	Use	End of Life
Contribution to mineral resources depletion	kg Sb eq	6,21E-01	6,21E-01	0*	0*	2,24E-04	0*
Contribution to the soil and water acidification	kg SO_2 eq	4,23E+01	1,76E+01	4,03E+00	0*	2,03E+01	3,58E-01
Contribution to water eutrophication	kg PO_4^{3-} eq	9,45E+00	3,00E+00	9,33E-01	6,36E-02	5,36E+00	8,80E-02
Contribution to global warming	kg CO_2 eq	3,13E+04	6,09E+03	8,52E+02	4,71E+01	2,42E+04	1,34E+02
Contribution to ozone layer depletion	kg CFC11 eq	2,97E-03	2,14E-03	1,72E-06	0*	8,25E-04	7,55E-06
Contribution to photochemical oxidation	kg C_2H_4 eq	6,08E+00	1,68E+00	2,90E-01	8,65E-03	4,06E+00	3,84E-02
Resources use	**Unit**	Total	Manufacturing	Distribution	Installation	Use	End of Life
Net use of freshwater	m3	1,09E+02	8,98E+01	7,62E-02	2,08E-02	1,89E+01	1,47E-01
Total Primary Energy	MJ	4,72E+05	1,76E+05	1,14E+04	0*	2,83E+05	1,74E+03

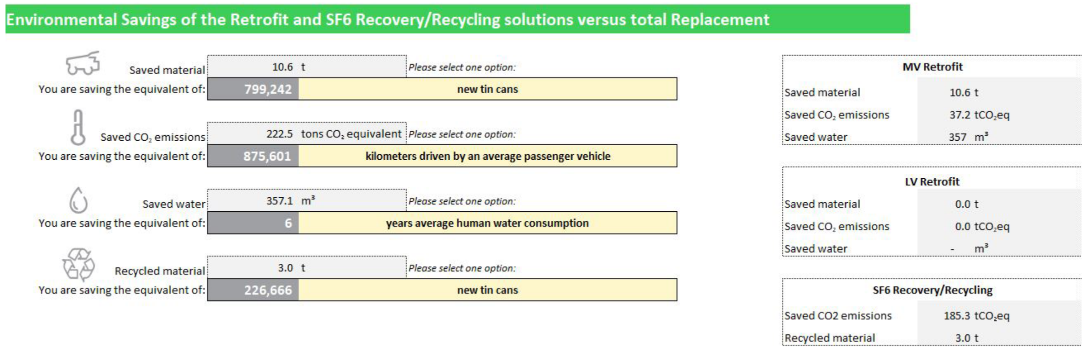
Software generates the sustainability indicators (e.g., raw material depletion, energy depletion, water depletion, global warming, ozone depletion, air toxicity, photochemical ozone creation, air acidification, water toxicity, water eutrophication, and hazardous waste) used in PEP documents.

The PEP calculations show that a retrofit option for a typical 12-cubicles MV installation (see above description) saves 799,242 MJ of energy, avoids emitting 37.2 tonnes of CO_2 to the atmosphere, and reduces water consumption by 35.1 m³ during the product's manufacturing phase when compared to a complete replacement option. **Figure 10** illustrates how these numbers translate into avoided resource consumption benefits.

[6] PEP for MCset range, PEP for LF range, PEP for Evolis range

Figure 10

Illustration of environmental benefits of switchgear retrofit approach over “rip and replace.”



Further environmental benefits can be achieved if the 11 previously described SF_6 technology circuit breakers are recycled. We assume that the obsolete circuit breakers would not have been recycled appropriately, and the SF_6 gas vented to the atmosphere.

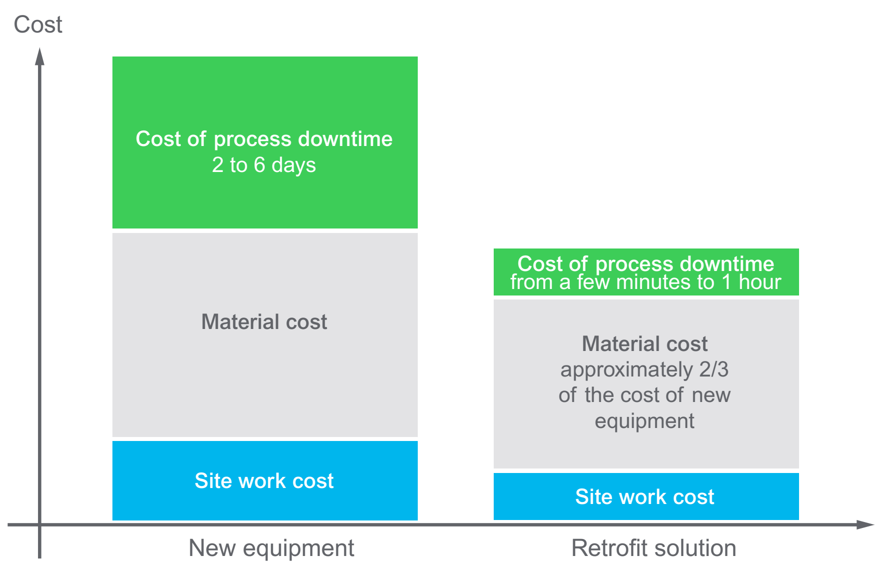
In addition to increased environmental benefits, retrofitting switchgear installations also presents economic advantages (e.g., what’s good for the planet is also good for your wallet). Retrofit operations can cost up to 65% less than new installations. Not only are there reduced equipment costs, but cabling changes and/or additional construction work can be avoided.

Online trade-off tools exist to not only calculate the environmental savings of a retrofit project and/or of equipment recycling, but also the cost differences in equipment, project management, recycling, commissioning, training, and downtime (e.g., the time it takes to install the new equipment vs. retrofit work).

Figure 11 summarizes the cost differences between a retrofit vs. a purchase new approach.

Figure 11

Financial comparison of new vs. retrofit approach



Switchgear energy efficiency (old vs. new)

Two MV air-insulated switchgear (AIS) units from different manufacturing periods were chosen to compare energy efficiencies in a laboratory test.

The voltage drop was measured before and after an IEC temperature rise test (where the power dissipated is directly proportional to the resistance and is indicated by the voltage drop values).

The measurements revealed no appreciable difference between the two switchgear units, confirming that the older units are just as energy-efficient as the newer ones. This clears any doubt of having environmental impact advantages in the "use" phase of the purchase new approach versus the retrofit approach.

Retrofit is also applicable to digitization upgrades

The interconnected nature of today's business transactions is driving a higher cost of downtime. Among Fortune 1000 companies, the average total cost of unplanned application downtime per year is $1.25 billion to $2.5 billion. The average cost of an infrastructure failure is $100,000 per hour, with critical application failure costing $500,000 to $1 million per hour.[7] Power supply anomalies contribute significantly to these numbers.

Switchgear has now become part of the integrated, corporate-wide approach to asset performance management. Open technology architectures, such as Schneider Electric's EcoStruxure,™ drive business value by leveraging cloud computing, edge power distribution. Online systems can now determine the up-to-the-minute health of switchgear assets and even predict the future behavior of those same assets thanks to sensors embedded in the switchgear and analytics programs that deploy artificial intelligence.

For instance, within the realm of electrical equipment, rising heat inside electrical cabinets is often a sign of a loose connection or eroding insulation. If left unchecked, the situation could lead to a short circuit or even arc flash incident, which, in turn, leads to protracted downtime.

Recognizing that a heat anomaly exists allows maintenance personnel to perform a fix ahead of time, with minimal disruption to operations, before an incident of costly unanticipated downtime occurs. These conditions can even be monitored remotely, which frees up maintenance staff to perform other tasks that require attention. The ability to both reduce labor costs and anticipate what kinds of issues are developing before unscheduled downtime occurs are two essential values of predictive maintenance.

Minimal work is involved in installing the proper internal sensors that enable digital operations during the switchgear retrofit process. The sensors allow the connection of switchgear assets to the cloud, where performance data can be easily analyzed, and behavioral trends can be identified. Once the switchgear units are digitized and performance measured, strategies for improving uptime performance and enhancing sustainability can be developed.

[7] Shimel, Alan, DevOps.com, "The real cost of downtime," Sept. 2015

Conclusion

Compared to installing new equipment, the retrofitting of switchgear can result in indisputable environmental savings and economic savings of 43% to 65%. The practice of retrofitting electrical distribution switchboards (circuit breakers, contactors, and protection relays) contributes directly to the concept of building a circular economy.

When compared to new products, retrofitting solutions reduce environmental impact in several ways:

- Switchgear housings and accessories, such as plugs, lights, LV switches, and extra LV cabinets are reused
- There is minimal construction work involved in a retrofit scenario
- Existing cables and wires can be preserved (unless they show signs of wear)
- Obsolete active components can be refurbished or recycled
- Equipment can be upgraded with sensors and connected to a cloud platform
- Data analysis can then provide insights that drive actions to improve performance and efficiency and decrease energy costs and CO_2 emissions.

For the equipment owner, retrofit solutions are economical and faster to install. This results in reduced production downtime and less risk of human error during installation. Leading equipment manufacturers, like Schneider Electric, are committed to resource circularity and to minimize product environmental impact. When manufacturers and consumers require fewer resources to accomplish their business goals, health, safety, and the environment are better protected.

About the author

Giovanni Zaccaro is currently Sustainability Program Manager for Schneider Electric's Secure Power BU. Amongst the many responsibilities held within the company, he has worked several years in the Medium Voltage department, particularly on SF_6 technology products and services. He has been a member of several electrical systems associations, such as Gimelec, CIGRE, and T&D Europe, and has published various papers on the circular economy and SF_6 topics. Giovanni holds a Master's Degree in Mechanical Engineering from the Politecnico di Milano (Italy). His thesis has been sponsored by (formerly) Daimler-Benz AG and the Fachhochschule für Technik Esslingen (Germany). He has had several long-term educational and work experiences around the world, mainly in the USA, France, and Germany.

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