How Retrofit Services for Electrical Distribution Contribute to Circular Economy

by Giovanni ZACCARO

Executive summary

Circular economy is today's alternative to the "take, make and dispose" industrial model. It redefines products and services, minimizes waste and saves money. Thanks to retrofit solutions, this "re" concept (reuse, refurbish, recycle, renew, etc.) is applicable to electrical distribution equipment. Switchboards and accessories can be reused and obsolete components can be refurbished, repaired, or recycled, to minimize waste. As such, the lifecycle of operational equipment is prolonged and less money is spent. This paper explains the circular economy model, shows how governments are promoting it, and explains and calculates the subsequent environmental and economic benefits achieved by retrofitting electrical distribution equipment.

Introduction

What are linear and circular economies?

Linear economy[1] is the traditional economic model based on a "take, make, consume, throw away" approach to resources[2]. Its main disadvantages include a growing shortage of materials, increased pollution and landfill disposal, and increased material demand. But environmental priorities have changed, and there is widespread growing demand for more responsible products.

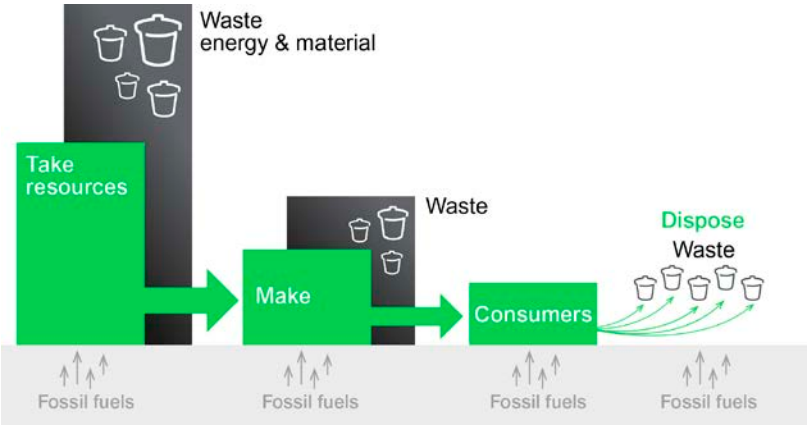


Figure 1

Linear economy [1]

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

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

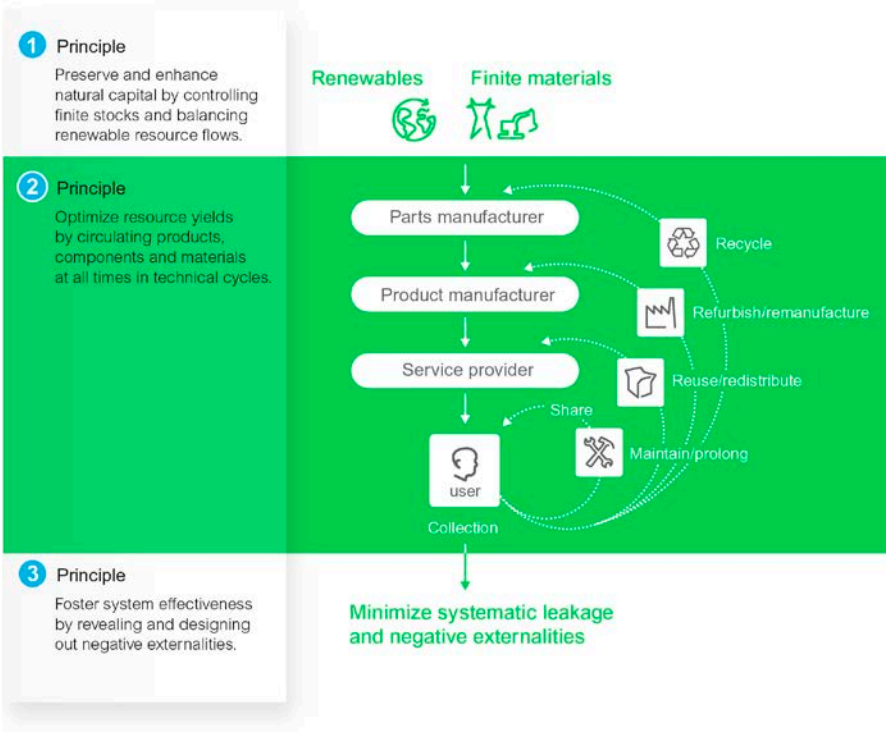


Figure 2

Circular economy

[1] Source: https://www.ellenmacarthurfoundation.org/news/circular-economy

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

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

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

The circular economy package in the EU

The Environment Action Program

Over recent years, the European Union has launched Environment Action Program (EAP) as part of its environmental policy. The current program, the seventh, named "Living well, within the limits of our planet," was adopted in November 2013 and covers the period up to 2020[5].

Circular economy as a priority

The program lists nine priority objectives, in order to protect the environment's natural capital, stimulate resource-efficient, low-carbon growth and innovation, and safeguard people's health and wellbeing with reduced carbon emissions.

A special focus is on turning waste into a resource, with more prevention, re-use and recycling, and by phasing out wasteful and damaging practices like landfilling[6]. Specific indicators for resource efficiency aim to guide consumers in their purchasing experience.

The action plan

A mandate has been sent by the European Commission[7] to European standardization organizations (CEN/CENELEC/ETSI) to work on this domain, requesting the development of standards to define and measure the main aspects of the Circular Economy. The objective is to develop 12 standards for March 2019. These standards will be horizontal, meaning that they will not be directly applicable to products, but will define the framework to develop product standards by the corresponding product committees.

Hence, a new Joint Technical Committee (JTC10) has been establish between CEN and CENELEC. The JTC10 created the following 6 project teams (or working groups) in order to work on the definition of new standards, each related to a specific subject:

- PT1: Terminology
- PT2: Durability
- PT3: Upgradability, ability to repair, facilitate re-use, use or re-used components
- PT4: Ability to remanufacture
- PT5: Recyclability, recoverability, use of recycled materials
- PT6: Documentation and marking of products

[5] Source: Decision No 1386/2013/EU of the European Parliament and the Council of the 20/11/2013 (http://eurlex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013D1386&from=EN)

[6] Source: http://ec.europa.eu/environment/pubs/pdf/factsheets/7eap/en.pdf, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the committee of the Regions, Brussels 2/12/2015, COM (2015) 614 (final).

[7] Source: Commission implementing decision of 17/12/2015 (https://ec.europa.eu/food/sites/food/files/safety/docs/cff_animal_vet-progs_wd-decision_2444_2015.pdf)

The circularity of retrofit

How can we retrofit electrical switchgear?

Two categories of components make up a typical low and medium voltage 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, or fuse devices. These components are responsible for protection from overcurrent[8]. The following two active components and one passive component have the most impact on maintenance and obsolescence issues. Figure 3 illustrates these components.

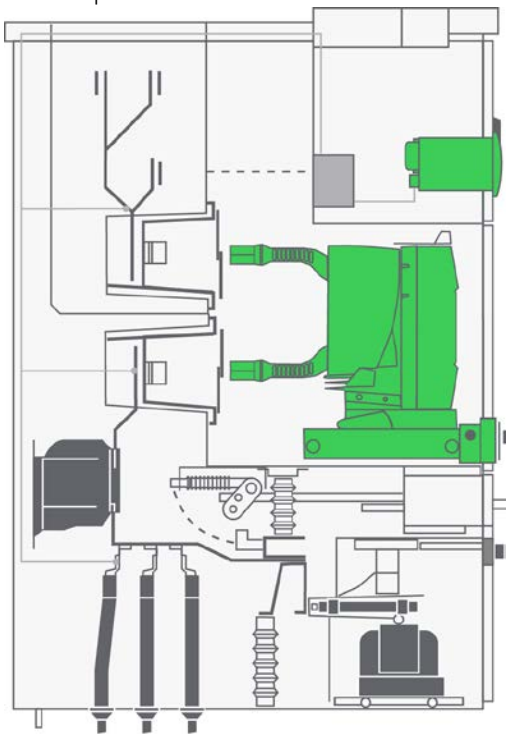


Figure 3

Illustration of a typical switchgear:

- *The steel/copper/resin housing. The housing or enclosure is a passive component (in gray)*
- *The circuit breaker, either removable or fixed, and the protection relay. These are active components (in green)*

These components experience different levels of stress depending on operations and also due to their sensitivity to surrounding environment (e.g., heat, humidity, chemicals, and dust). They also often have different estimated obsolescence expectancies, which are generated as a result of the life cycle specifications outlined by the original equipment manufacturer (OEM).

The main reasons why we need to modernize switchgear are listed on page 6.

Retrofit in electrical distribution consists of replacing switchgear components to renew, upgrade or add new functionalities, like connectivity. This is typically performed on outdated active components, such as circuit breakers in primary distribution, contactors and protection relays, and as such, enable the whole switchgear's life to be prolonged.

Thanks to retrofit services, equipment manufacturers are fully following the circular economy model. Let's take a look at the details.

Circuit breakers and contactors, which are the core active element of switchgear, require more care as they are critical in ensuring equipment reliability and safety.

In the case of protection relays, these can be easily replaced by modifying the switchgear's front door and wiring.

The rest of the switchgear (the housing for example) is kept "as is" and its life prolonged. This consists in the largest part (in terms of mass and volume) of the switchgear.

[8] Source: GUIDELINES FOR MODERNIZING EXISTING ELECTRICAL SWITCHGEAR IN LV AND MV NETWORKS, CIRED 2017, Glasgow, UK.

The obsolete equipment can be refurbished or repaired, particularly when it's the OEM who is performing the service, thanks to their expertise, the technician's skills, workshop facilities, tools and logistics, which are already in place.

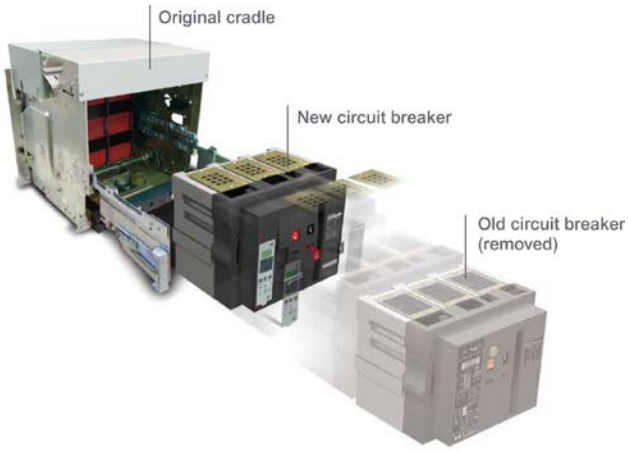


Figure 4

An aging obsolete circuit breaker is replaced by a modern circuit breaker, while maintaining its original cradle.

Alternatively, the obsolete equipment can be recycled and the material given a new life. This must be done according to state-of-the-art end-of-life processes[9] to comply with strict standards, in order to avoid losing the environmental advantages of the whole operation.

There are also stringent regulations to be aware of and to respect. As an example, MV equipment may contain SF_6 gas or PCB oil, which need to be disposed by qualified personnel in authorized workshops. The process guided by the International Electrical Commission's standard IEC 62271-4, 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 exact type of loop that supports a circular economy.

[9] Source: State of the art process of end-of-life treatment for SF6 Medium Voltage equipment, ED2E 2016 conference, Grenoble, France.
SF6 End-of-life Recycling for Medium and High Voltage (MV & HV) Equipment White paper: http://www2.schneider-electric.com/documents/support/white-papers/renewable-energy/SF6-end-of-life-medium-high-voltage-equipment.pdf

Why do we modernize and upgrade switchgear?

As the years (and decades) go by, utilities, facility managers, and plant managers question whether it is time to modernize their electrical installation. They are confronted with the omnipresent problem of balancing costs versus the urgency to provide the reliability their customers require. Listed below are some key issues that these stakeholders should consider when evaluating their installed base of power distribution equipment:

- Spare parts availability
- Maintenance costs
- Degree of equipment wear
- Urgency of upgrade
- Criticality of the processes affected

Spare Parts availability

When making equipment upgrade decisions, the spare parts question should be analyzed by considering different distinct categories of spare parts. Listed below are examples of these categories:

Spare parts for commercialized products

These parts include electrical distribution equipment that is made available by the manufacturer as an extension of their commercialized offering. These spare parts can be accessed on-line or via printed equipment catalogues.

Spare parts for obsolete products

The products these spare parts are associated with are at the end of their sales lifecycle. However, they are made available to support an existing installed base of products that are no longer commercialized, and typically remain available for a period of 10 years for low voltage and 12 years for medium voltage equipment.

When such spare parts are no longer readily available, the continuity of service and support is at risk. If a device breaks down, no parts may be available to fix it. At this stage, launching a modernization initiative is advisable.

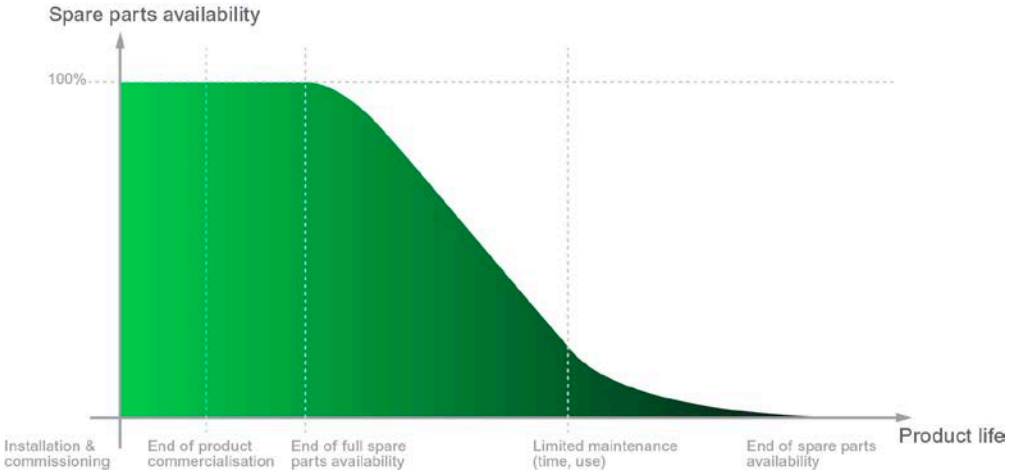


Figure 5

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

Limited maintenance agreements

Under certain circumstances, such as managing a huge existing installed base of an older product, specific maintenance agreements will be built. 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.

Maintenance costs

In addition to the life cycle of the products, the decision to upgrade and modernize is also linked with the risk of product failure and the increased cost of maintenance over time. The promotion of maintenance, reparability and reuse of products are great opportunities to create new business, new jobs, and skills.

To guarantee the quality of these services as well as the reliability and safety of products, field services and spare parts markets must be carefully regulated. Product warranties are part of the Extended Producer Responsibility which drives manufacturers to develop and extend the life-time of their products, either directly or through certified partners. Figure 6 illustrates the curve for how maintenance costs can be reduced as a result of a timely upgrade.

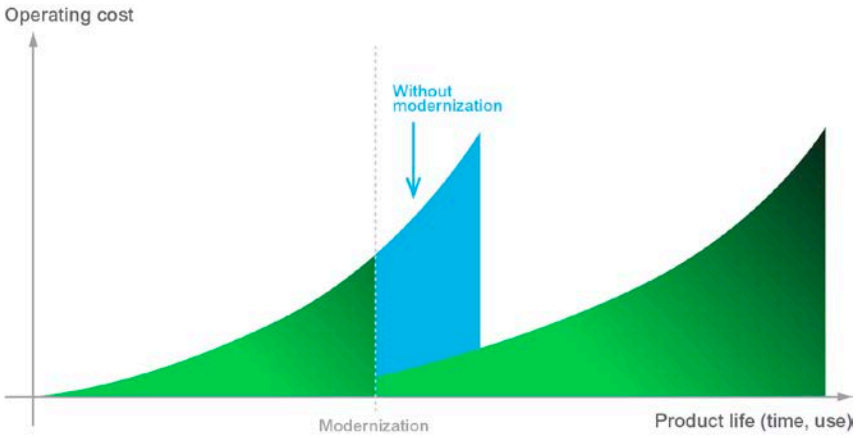


Figure 6

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

Degree of equipment wear and tear

Aging materials reduce equipment reliability. Both dielectric breakdown 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 as a result of dust/chemical deposits when basic maintenance operations are not regularly performed.

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

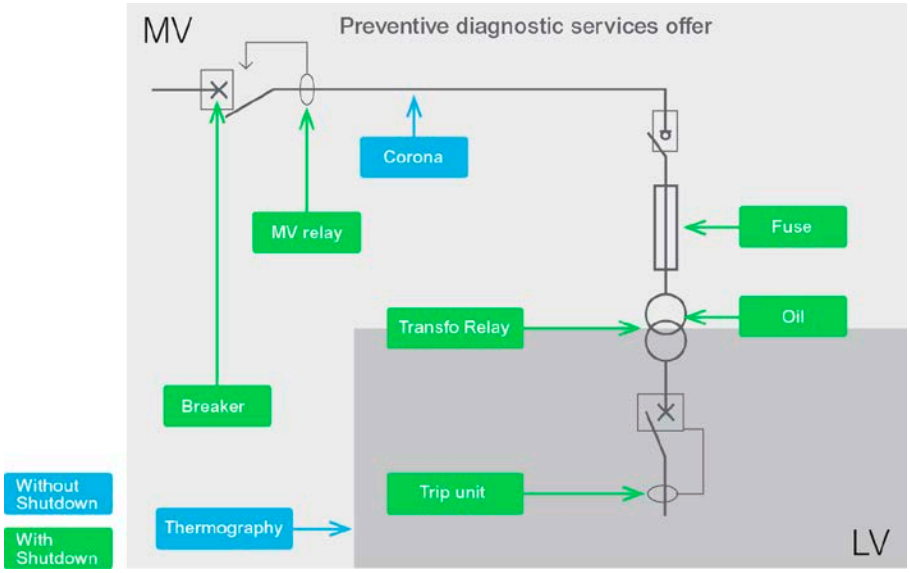


Figure 7

Types of equipment upon which diagnostics can be performed.

Reasons to upgrade

Electrical installation upgrades are influenced by both internal and external factors.

Internal factors:

- Modification/evolution of power requirements within an industrial facility.
- Improvements of supervision and monitoring abilities of existing installations. In these cases, connectivity upgrades open the door to considerable operational cost savings.

External factors:

- Compliance with new regulations enforcing a ban on hazardous substances (asbestos, tin, chemicals, etc.).
- Compliance with new standards influencing both mechanical and human safety.
- Increased protection against potential cyber-attacks on connected equipment.

Criticality of associated processes

When a decision is made to modernize an electrical installation, the first step is to prioritize the most important parts of the installed base for modernization, by taking into account available budget and the tools and expertise available.

When manufacturers perform these assessments, four key aspects are considered: a maintenance plan, a modernization plan, a monitoring plan, and a management plan.

Environmental benefits of retrofitting existing installations

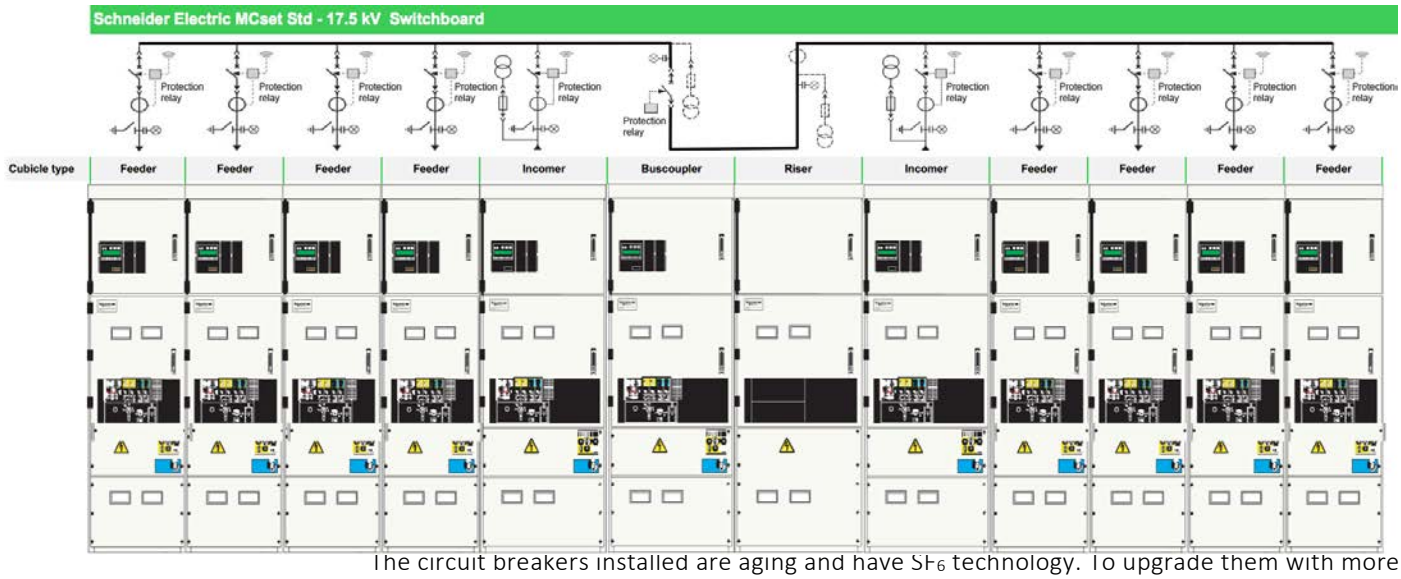
Calculating environmental benefits

Now that we have proven that retrofit services are part of the circular economy approach, let us calculate the environmental benefits.

As an example, we will take a typical primary distribution installation, with 12 switchgears (8 feeders, 2 incomers, a bus coupler, a riser and 11 circuit breakers), see figure 8.

Figure 8

Example of a typical primary distribution installation.



The circuit breakers installed are aging and have SF_6 technology. To upgrade them with more modern vacuum technology circuit breakers, there are two options:

1. Replace the complete switchboard

OR

2. Retrofit the circuit breakers only and keeping the switchgear housing and accessories

Figure 9

Switchboard replacement versus retrofit.

The Product Environmental Profile

To calculate the environmental impact of both options, it is necessary to use documents such as the product environmental profile (PEP) of the equipment[10].

The PEP is a lifecycle assessment, which analyses the complete environmental impact of a product, from cradle to grave. The PEP gives information on the constituent materials of the product, all manufacturing certificates, the distribution materials (packaging and weight), the impact during use (e.g. emissions).

Software is used to calculate and evaluate 11 indicators (for all phases: manufacturing, distribution and utilization phases), such as global warming, energy depletion, raw material depletion.

Table 1

Example of the product environmental impact of a switchboard.

Primary cubicle						
Indicator	Definition	Unit	Sum	M	D	U
RMD	Raw Material Depletion	Y-1	$1.0025\ 10^{-11}$	$9.8184\ 10^{-12}$	$6.7934\ 10^{-15}$	$1.9968\ 10^{-13}$
ED	Energy Depletion	MJ	$2.4276\ 10^{+5}$	$5.9465\ 10^{+4}$	$4.8613\ 10^{+3}$	$1.7843\ 10^{+5}$
WD	Water Depletion	dm^3	$6.2938\ 10^{+4}$	$3.4825\ 10^{+4}$	$5.2139\ 10^{+2}$	$2.7592\ 10^{+4}$
GW	Global Warming	$g{\approx}CO_2$	$1.3263\ 10^{+7}$	$3.7784\ 10^{+5}$	$3.668\ 10^{+5}$	$9.1174\ 10^{+6}$
OD	Ozone Depletion	g≈CFC-11	1.697	$6.6042\ 10^{-1}$	$2.517\ 10^{-1}$	$7.845\ 10^{-1}$
AT	Air Toxicity	m3	$2.8299\ 10^{+9}$	$9.9889\ 10^{+5}$	$7.4254\ 10^{+7}$	$1.7568\ 10^{+9}$
POC	Photochemical Ozone Creation	$g{\approx}C_2H_4$	$4.5827\ 10^{+3}$	$1.1093\ 10^{+3}$	$3.0931\ 10^{+2}$	$3.1642\ 10^{+3}$
AA	Air Acidification	$g{\approx}H^+$	$2.3115\ 10^{+3}$	$8.1703\ 10^{+2}$	51.563	$1.4429\ 10^{+3}$
WT	Water Toxicity	dm_3	$3.2085\ 10^{+5}$	$9.456\ 10^{+5}$	$4.6193\ 10^{+4}$	$2.2165\ 10^{+6}$
WE	Water Eutrophication	$g{\approx}PO^4$	$1.9977\ 10^{+2}$	$1.6737\ 10^{+2}$	6.356	26.039
HWP	Hazardous Waste Production	kg	$1.5704\ 10^{+2}$	11.512	$2.1982\ 10^{-1}$	$1.4531\ 10^{+2}$

[10] Source:
PEP for MCset range: https://www.schneider-electric.com/en/download/document/ENVPEP110103EN/,
PEP for LF range: https://www.schneider-electric.com/en/download/document/ENVPEP090937EN_V0/,
PEP for Evolis range: https://www.schneider-electric.com/en/download/document/ENVPEP051205EN/

Results

In figure 10, it is clear that the retrofit option (option 2) has less environmental impact than option 1. PEP calculations show that the retrofit option saves 773,904 MJ of energy, and avoids emitting 40,076 kg of CO_2 to the atmosphere, and reduces water consumption by 389 m3 during the product's manufacturing.

These theoretical results, given by calculations made on computer, do not include the environmental impact of installing other accessories or protection relays. So the real difference in environmental impact can be even higher, in favor of the retrofit solution. Further environmental and economic benefits can be obtained by upgrading the switchgear with sensors connected to cloud-based platforms. The data (facility information, sustainability metrics and supply data) can be analyzed. Projects for improved performance and sustainability are then developed.

Figure 10

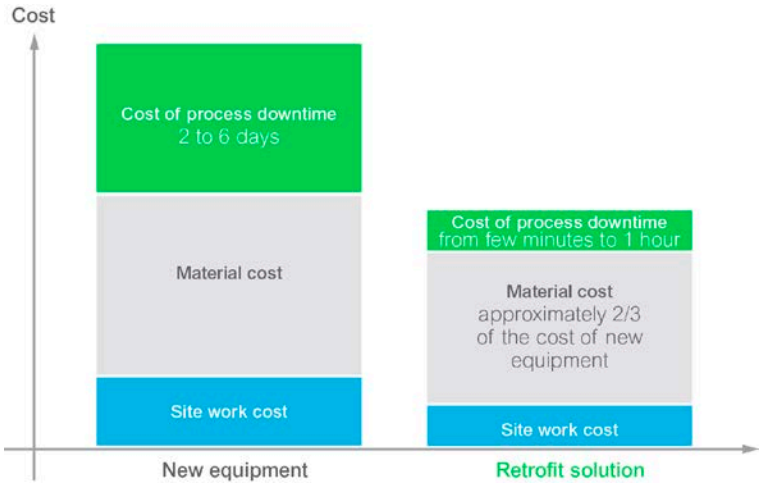
Environmental impacts avoided thanks to retrofit solutions.

Economic benefits of retrofit

If the environmental impact is reduced when retrofitting an installation rather than replacing existing equipment, it is probable that there are also economic advantages (what's good for the planet is also good for your wallet). The first most likely to impact reduced capital expenditure (CAPEX). As we can see in figure 11, retrofit operations can cost up to 65% less than new installations. Not only are there reduced equipment costs, but cabling changes and/or civil works can be avoided.

Figure 11

Economical comparison between new equipment and retrofit solution.



To quantify the cost savings of retrofit solutions versus new installations, a calculation tool has been developed. The tool takes into account the following criteria, such as:

- Equipment price
- Project management costs
- Civil works
- Cable/wiring costs (both MV and LV)
- Recycling costs
- Commissioning costs
- Training costs
- Costs due to loss of production (downtime days x turnover per day).

Conclusion

The results clearly favor retrofit solutions, with savings ranging from 43% to 65%. Retrofitting electrical distribution switchboards (circuit breakers, contactors and protection relays) can be applied to the concept of circular economy. Retrofit solutions reduce their environmental impact in comparison to simply installing new products:

- Switchgear housings and accessories, such as plugs, lights, LV switches, and extra LV cabinets are reused
- There is minimal civil work
- Cables and wires can be kept
- Obsolete active components can be refurbished or recycled
- Equipment can be upgraded with sensors and connected to a platform. Deep analysis of related data provides insights to drive actions to improve performance and efficiency and decrease energy costs.

For the equipment's owner, retrofit solutions are not only economical, but also faster to install, meaning less production downtime and fewer risks during installation. Top equipment manufacturers ensure resource circularity thanks to their commitment to minimize the environmental impact of their products and by helping their customers do more with fewer resources, while helping protect their health, safety, and the environment.

About the author

Giovanni Zaccaro is the EOL Program Manager, responsible for SF6 technology services in Schneider Electric's Global Field Services department. He is a member of several electrical systems associations, such as Gimelec, CIGRE and T&D Europe, and has published various papers on the SF6 topic. 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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