CIRCL-E: FROM DECOMMISSIONING TO REGENERATION

CIRCULAR STRATEGIES FOR ENERGY POWER PLANTS

ARUP

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Contents

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Executive summary

The concept of Circular Economy and its founding principles have emerged over the past few years as the best option to design and realize a sustainable economic system. Moreover, the fast technological transformation and the growing awareness on environmental challenges have helped to accelerate its adoption. Institutions at any level - regional, national and local - have the Circular Economy as a key topic in their agenda. At the same time companies in many industry sectors are assessing potential benefits provided by a circular approach to their business. Two key goals define the Circular Economy:

- Reducing the externalities at any stage of the life cycle of an asset;
- Retaining value for an asset at its highest level.
  This should apply at any scale, from the site and its infrastructures to buildings, components and materials. At the short-term the Circular Economy applied to the decommissioning of existing Energy Power plants could provide social, economic and environmental benefits to the local communities and surrounding areas.

Additionally, when applied to the design of new power plants - including renewable energy - Circular Economy could provide a set of tools and best practices that will both improve the design and operations of the asset as well as influence the future decommissioning operations by making them more efficient and effective.

A number of principles can be used to implement circular strategies into decommissioning of Energy Power plants both in the case of existing and future assets:

- Focus on renewable inputs at the design stage, both material and energy;
- Improve operations by extending the life of the assets, through modular design and extended maintenance;
- Share resources, by increasing availability of assets in secondary markets therefore capitalizing on the residual value;
- Optimize the end of life strategies and value extraction from end of life through upcycling, reuse and recycling.

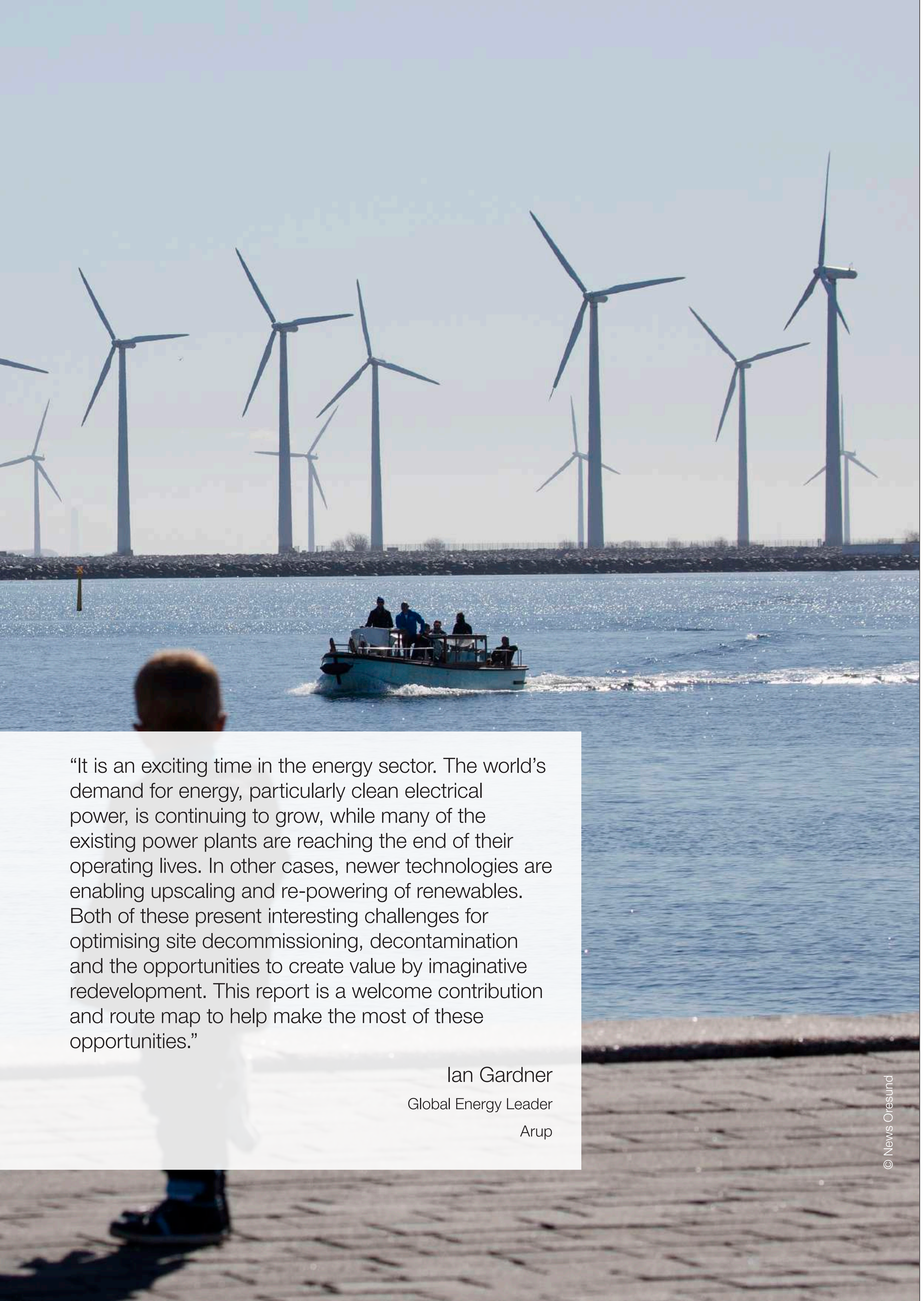
€630bn/y

The overall saving potential thanks to better use of resources in the industry sector in EU[1]

Up to 3.9%

The increase of EU GDP thanks to significant materials cost savings obtained through a Circular Economy approach[1]

1) European Commission. Communication EC COM (2014) 398 "Towards a Circular Economy: A zero waste programme for Europe", 2014



“It is an exciting time in the energy sector. The world’s demand for energy, particularly clean electrical power, is continuing to grow, while many of the existing power plants are reaching the end of their operating lives. In other cases, newer technologies are enabling upscaling and re-powering of renewables. Both of these present interesting challenges for optimising site decommissioning, decontamination and the opportunities to create value by imaginative redevelopment. This report is a welcome contribution and route map to help make the most of these opportunities.”

Ian Gardner

Global Energy Leader

Arup

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01 Introduction

Over the past few years the energy sector has been facing a dramatic transformation for a number of reasons including:

- A decrease in demand growth, mainly due to improvements in energy efficiency, due to the introduction of innovative energy solutions and technologies;
- An increase in competitiveness of renewable energy resources due to the latest technological advancements;
- An improved environmental awareness, leading to higher environmental requirements and standards as well as a strong focus on decarbonization, thus putting more pressure on energy companies than ever.

Due to these aspects, only the most recent and performing thermal power plants succeeded in staying in business, while the less performing and competitive ones had to be decommissioned. Differently from what it was expected just a few years ago, the new competitive situation was such that repowering of thermal plants was often not economically viable anymore.

At the same time, the first generation of renewable plants is currently reaching the end of life. In this case - as opposed to thermal power plants - repowering represents a very competitive solution, as existing sites are the most favorable and it provides the best performance avoiding impacting new sites.

In this context, the principles of Circular Economy offer an opportunity to shape a way forward, both for tackling the issue of decommissioning of thermal power plants and to lead the repowering operations of the renewable ones. More generally, at planning stage, the design of any new asset shall be approached considering these founding principles.

The identification of principles and indicators to assess the different initiatives is essential to apply circularity at the many levels of intervention.

$4.5tn

The estimated efficiencies for performing Circular Economy business models globally by 2030[2]

+25%

The global demand for energy increase by 2040[3]

2) Lacy, Peter; Rutqvist, Jakob, Accenture. Waste to Wealth – The Circular Economy Advantage, New York/London: Palgrave Macmillan, 2015

3) ExxonMobil. 2017 Outlook for Energy: A View to 2040, 2017

€15k/MW

The average cost of the decommissioning of the above-ground facilities for the gas turbines open cycle power plants[4]

€90k/MW

The average cost of the decommissioning of the above-ground facilities for the coal power plants[4]

4) Source: Enel, 2018

1.1 Scope and Vision

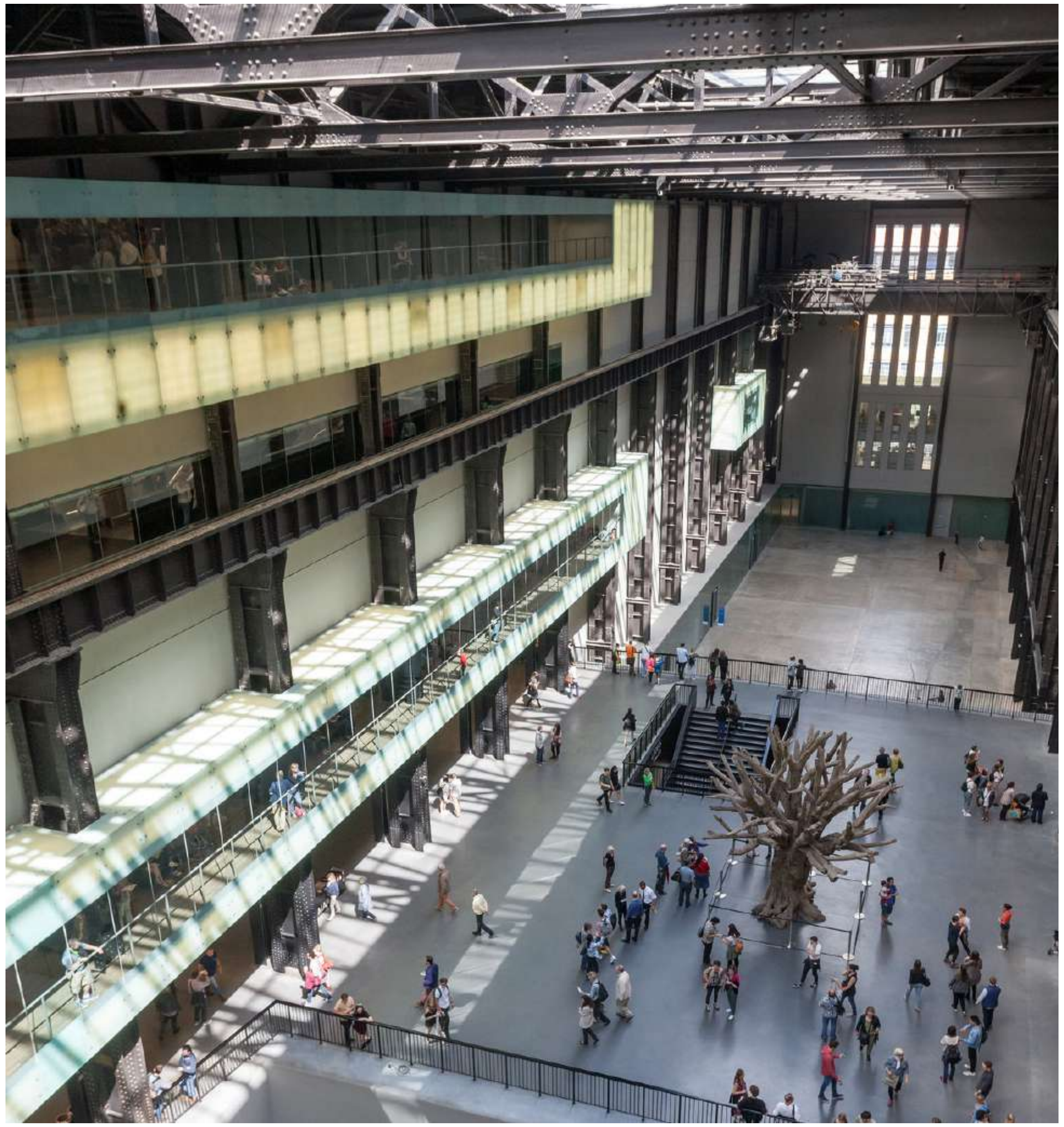
Decommissioning of power plants represents a major financial and environmental issue for energy companies and has a socio-economic impact on local communities. At a global scale, several thermoelectric power plants have already reached - or are on the verge of reaching - their End of Life (EoL), and thus face the urge of being decommissioned and - eventually - dismantled. Additionally, a large portion of renewable power plants is now approaching the planned decommissioning stage.

At present, energy companies have started implementing a future-decommissioning thinking at the design stage; however, the matter remains complex and needs a holistic and structured approach.

This research develops a methodology based on a Circular Economy approach applicable to both existing and new built plants that would guide the decommissioning of mainland power plants towards their regeneration. Therefore the research defines a set of indicators that can be used at different stages of the decommissioning process. They would be a tool to strategically create call for tenders, as well as they can be used at planning stage to set the objectives of intervention. Finally they can be used to measure the success of the regeneration process measuring the benefits produced in environmental, social and economical terms.

At the mid-term, the principles set within this document will influence current decommissioning operations as well as allowing implementation of best practices for the planning and execution of the next generation of power plants. The overall aim is to demonstrate that a new paradigm is possible by assessing:

- How new approaches may trigger a virtuous process whereby value is created through total site repurposing and not only through re-use and re-purpose of materials. This implies considering the power plant to be decommissioned as an asset, as opposed to a liability;
- How the re-use and re-purpose of materials and systems from existing buildings, equipment and structures could trigger a potential higher economic return for the asset owner.



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Up to 50y

The average lifetime of energy power plants currently entering decommissioning[5]

840M tons

The amount of metals, fossil fuels, minerals and biomass that could be annually saved by reducing worldwide resource use by only 1%[6]

1.2 The Methodology

The ideal approach to decommissioning - in a circular vision - should start from the initial phases, meaning that a new asset shall be regenerative by design. This implies that circular strategies to decommissioning shall be applied from the planning stage of both new and future energy power plants, being based either on fossil fuels or renewable energy sources.

The main purpose of our work is to identify the best practices to tackle the issue of existing power plants - meaning assets not specifically designed according to Circular Economy principles. This implies defining the least impactful strategies and best practices focusing on the EoL of such assets.

The diagram on the following page showcases the key phases of the decommissioning process of existing assets, being these the demolition and renovation stages. This two stages will be analyzed in depth through different scenarios in Chapter 4.

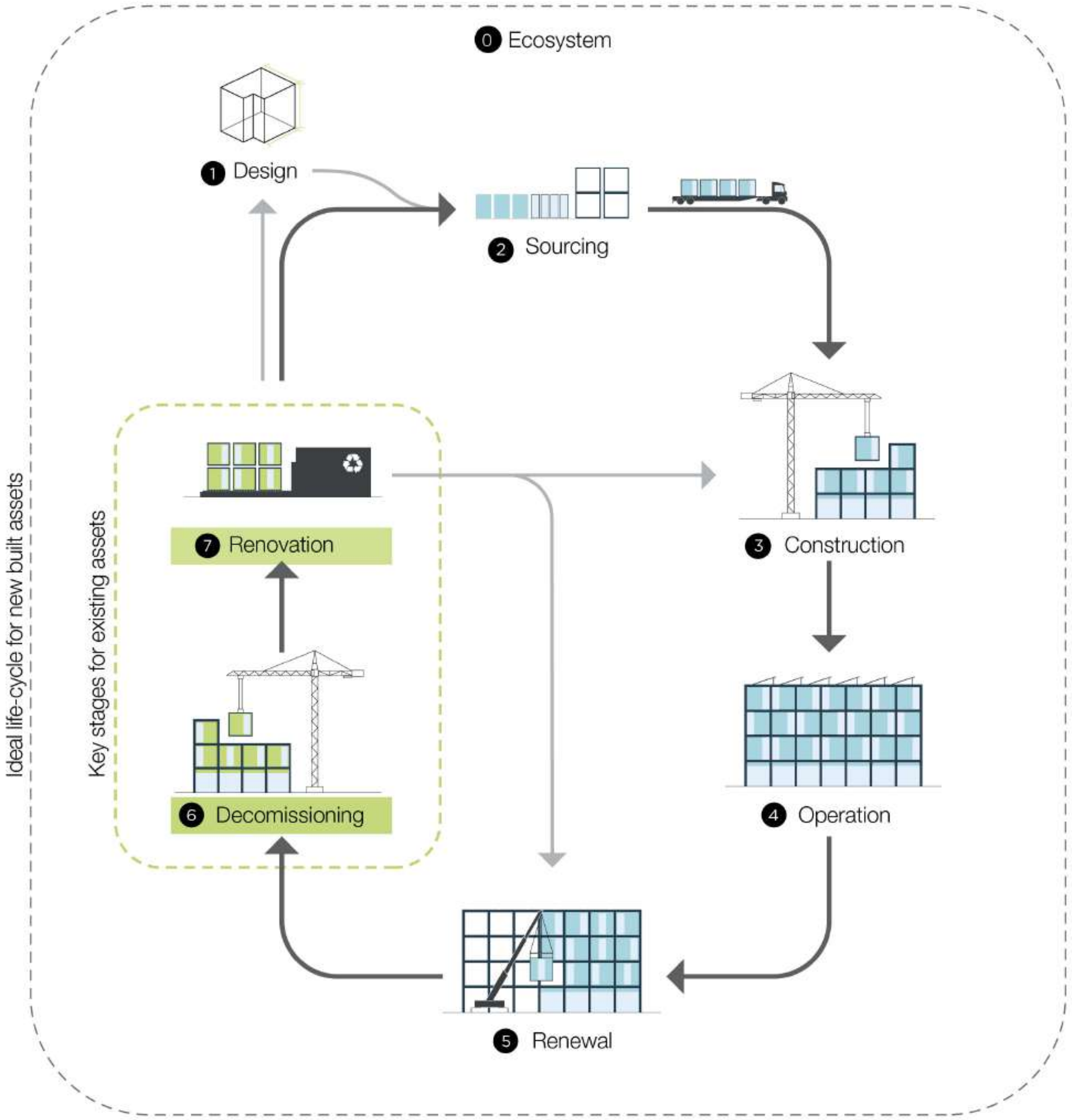
In parallel to that, a set of principles would be needed in parallel to guide the planning phases for new assets - at strategic level - thus influencing all the following stages of the life cycle. These would serve for energy companies to assess the best possible approach considering the full life cycle and not to just approach decommissioning as a separated, unplanned stage.

To support the circular approach a set of Key Performance Indicators (KPIs) has been defined alongside their expected impacts on social, environmental, technical and financial aspects.

This set of KPIs can be used for evaluating the most beneficial regeneration strategies for the reference site, allowing a comparative evaluation both from a qualitative and a quantitative point of view.

However to allow a proper assessment of the most appropriate regeneration strategies the KPIs will not be enough. They shall be used in combination with a number of guiding principles coming from e.g. stakeholders interest and perspectives, constraints and opportunities deriving from regulations at local, regional and national level as well as the palability of investment and the sustainability of the business model behind the regeneration plan.

5) RSK. Decommissioning of power plants, M0395_2
6) The Boston Consulting Group. The Urgency - and the Opportunity - of Smart Resource Management. https://www.bcg.com/publications/2017/sustainability-operations-urgency-opportunity-smart-resource-management.aspx (accessed June 26, 2018), 2016



Circular Life cycle for an Energy Power Plant: the key stages are identified according to a traditional decommissioning approach, closing the loop in the renovation phase. The stages highlighted in green refer to key stages in case of existing assets, these will be discussed in depth in following chapters.

6tons

The amount of materials wasted per person in Europe every year[7]

27y

The average time required in US to currently redevelop a coal power plant[8]

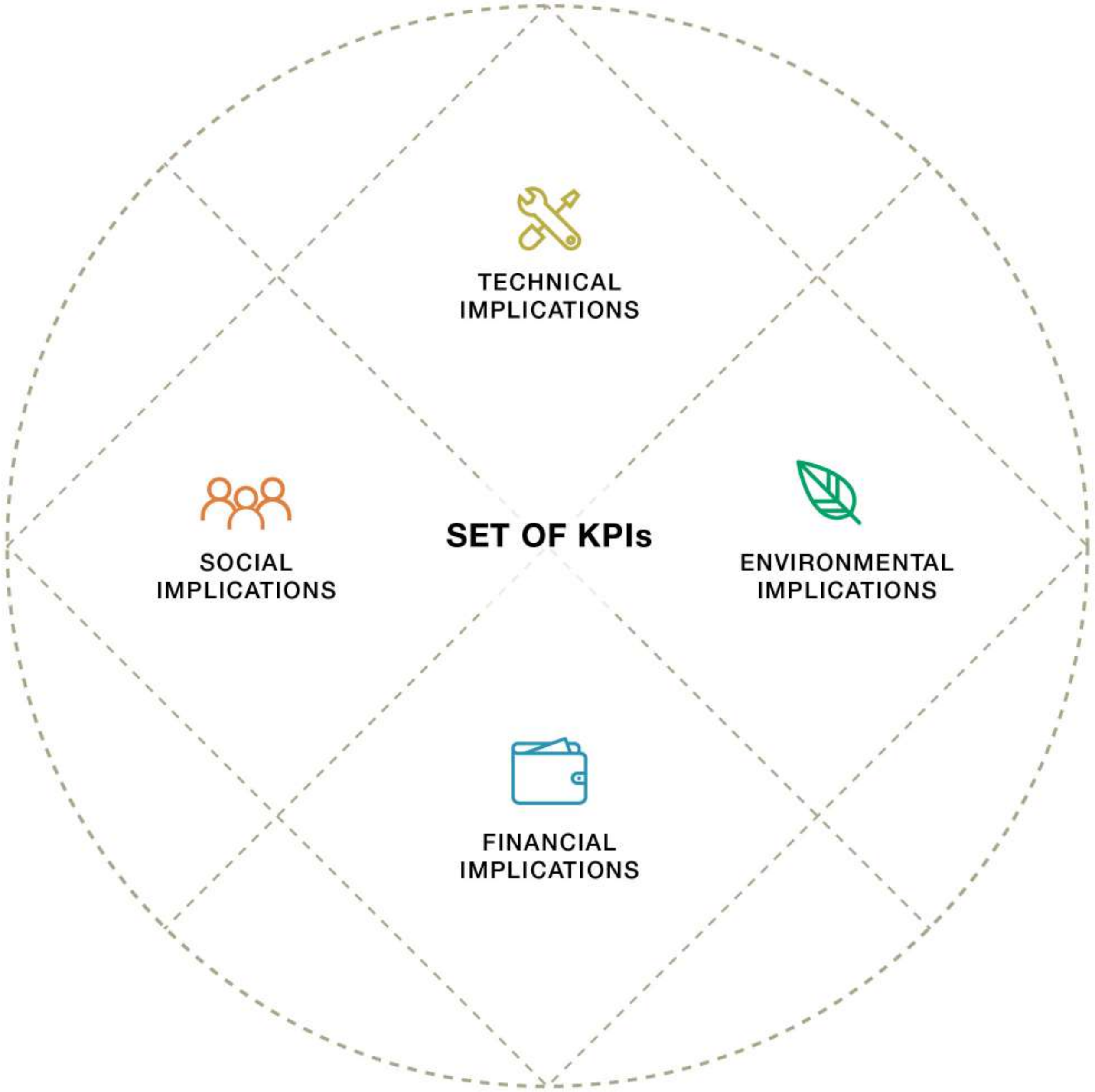
The best practices of intervention have been identified for the four main pillars of a circular approach, these being:

- **Technical implications:** these pertain both potential implications associated to waste management and address alternative scenarios with respect to traditional waste disposal options. They include the use of digital platforms to create more transparent and capillar chains of secondary assets distribution;
- **Social implications:** these are associated to the regeneration of power plants. They address how decommissioning could become a resource for the local communities by generating cascade benefits in terms of livability of cities, opportunities of new jobs and employment in the area;
- **Financial implications:** these evaluate the financial benefits associated to the balance sheet of energy companies when applying Circular Economy principles as opposed to traditional decommissioning processes;
- **Environmental implications:** these refer to assessing the impact of decommissioning operations with respect to the environmental emissions, as well as consumption of primary resources.

To test the use of both the KPIs and the relevance of best practices, three scenarios have been identified according to the most realistic options of decommissioning. Alongside these scenarios both decision making strategies and more operative approaches have been evaluated.

At the end of the research, a case study has been introduced to showcase potential tangible outputs for a transformation.

7) European Commission. Waste. http://ec.europa.eu/environment/waste/ (accessed June 26, 2018)
8) Delta Institute. Transforming coal plants into productive community assets, 2014



The research investigates technical, environmental, social and financial implications, through a set of KPIs.

-80%

GHG reduction in 2050 compared to 1990 in Europe[9]

Up to 98%

Cost-effective decarbonisation of the power sector from 2005 to 2050[9]

54%

Germany and Poland alone are jointly responsible for 51% of the EU's installed coal capacity and 54% of emissions from coal in 2017[10]

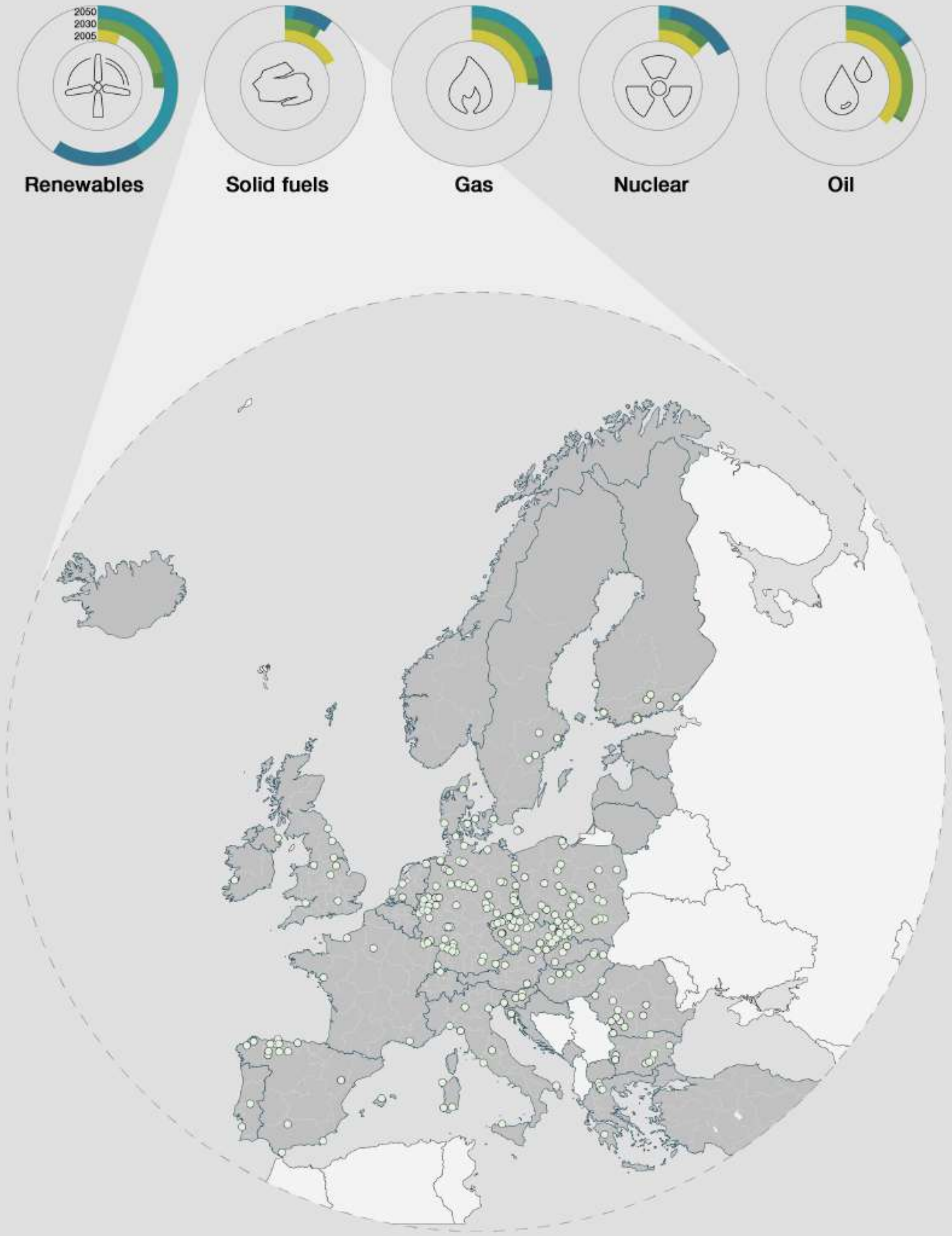
Focus 1 | The European Context

Hundreds of power plants have been dismissed in recent years, and more will do over the next decade. For this reason, planning for the decommissioning process of these facilities will be essential to minimize potentially negative impacts.

However, those factors played minor roles if compared to the long-standing drop in electricity demand and prices. In addition, the last Paris Agreement (Paris COP21) clearly states that the global community is committed to a low-carbon future. Within this framework, the energy sector is critical to the achievement of this goal.

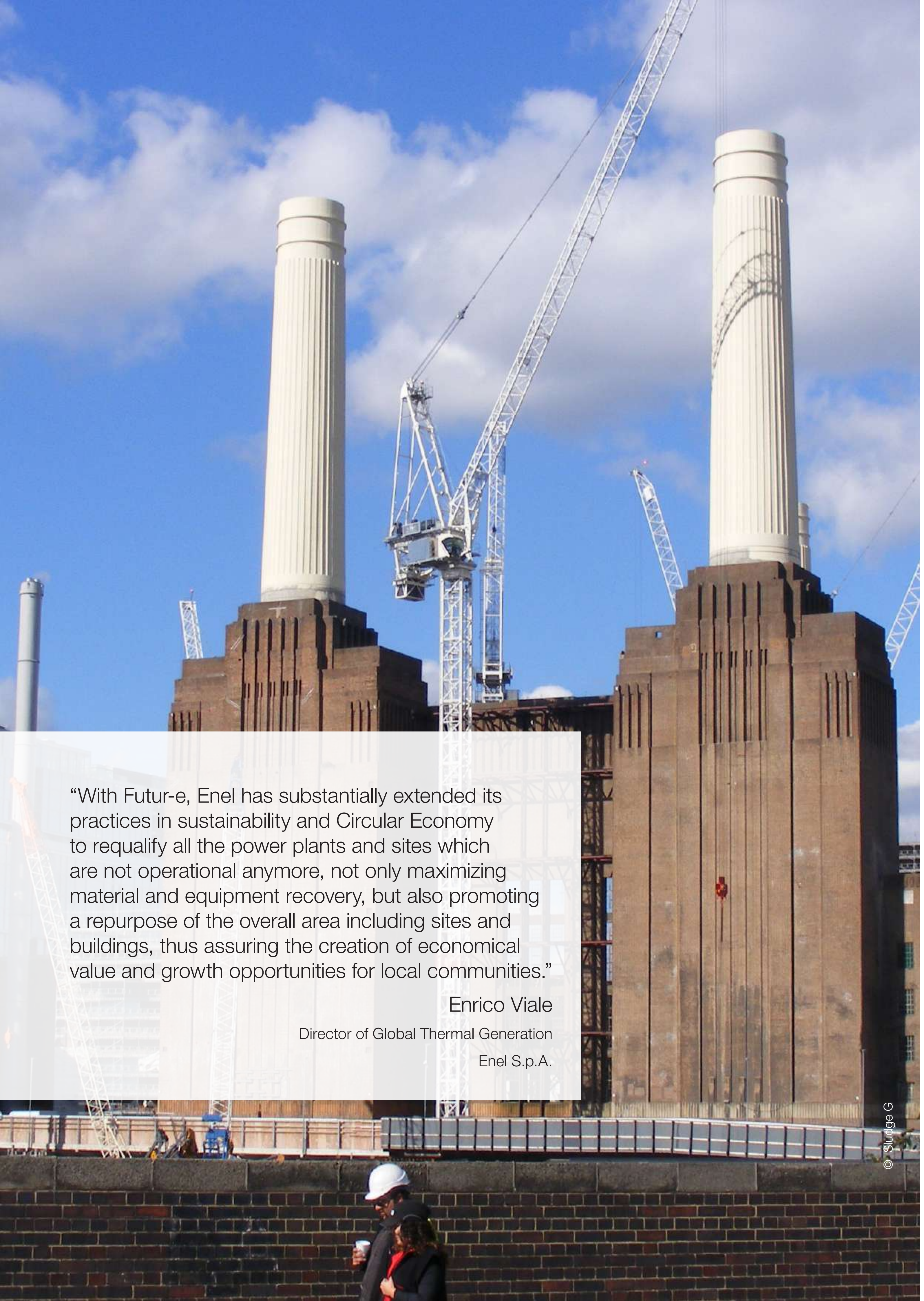
To date, power generation remains the largest GHG-emitting sector in Europe, being responsible for roughly one third of all energy-related GHG emissions and more than half of the verified emissions under the EU Emissions Trading Scheme. For the EU to achieve the goals of the Paris Agreement, it will need to rapidly decarbonize the power sector.

As of 2016 the EU has over 300 power plants with 738 separate generating units. Transition to renewable energy and progressive phasing out of thermal production is the path forward to achieving emissions reduction.



Distribution of Coal plants in Europe.

9) EEA. Transforming the EU power sector: avoiding a carbon lock-in, Report N° 22, 2016
10) Climate analytics. Coal phase out in the European Union. http://climateanalytics.org/briefings/eu-coal-phase-out.html (accessed June 26, 2018)



© Sludge G

“With Futur-e, Enel has substantially extended its practices in sustainability and Circular Economy to requalify all the power plants and sites which are not operational anymore, not only maximizing material and equipment recovery, but also promoting a repurpose of the overall area including sites and buildings, thus assuring the creation of economical value and growth opportunities for local communities.”

Enrico Viale

Director of Global Thermal Generation

Enel S.p.A.

02 A New Approach to Decommissioning

To date the approach to decommissioning has mainly followed a linear model. Therefore, the assets to be decommissioned are mainly considered as an aggregate of waste materials and the main target for energy companies is to minimize the costs associated with decommissioning activities.

In general, in the traditional approach there is no consideration of the immaterial value associated with the asset in terms of the relationships created with the local stakeholders during the years of operation. This could instead be strategically exploited to define an alternative development for the site and to maintain growth and employment for the community.

The traditional approach entails one of the following two scenarios:

- Shut down the plant and maintain it idle, thus fulfilling the minimum environmental and maintenance interventions as required by law. This might imply keeping the asset in this condition endlessly;
- Dismantle the plant, treat all materials and components as waste and decommission the site without a specific focus on environmental or social impacts, nor on preserving the asset value.

These two approaches, although different in the generated impacts, showcase the same linear view. In both cases, existing assets are considered as waste and stakeholders are not involved in the decision making process - except for the extent foreseen by law - and little information is generally disclosed to the outside.

While these approaches appear to be cost effective and less controversial at first sight, they instead represent a huge loss of value at various levels and they both increase the potential liability of the energy companies. On the contrary, the existing assets embed a large potential value that can be exploited through the application of Circular Economy-based approaches.

33%

The economic impact of waste management over the decommissioning process[11]

11) Larsson, Arne et al. “Waste Management Strategy for Dismantling Waste to Reduce Costs for Power Plant Decommissioning-13543.” WM Symposia, 1628 E. Southern Avenue, Suite 9-332, Tempe, AZ 85282 (United States), 2013

2M

The number of jobs created thanks to the improvement of annual resource productivity in EU[12]

$100bn/y

The value kept by adopting Circular Economy principles in the construction sector[13]

A consistent circular approach through the value chain would consider existing assets as a value, and it would be more transparent and inclusive with respect to the relationships with the stakeholders. This might imply integrating requirements and proposals from local stakeholders to steer the process of intervention.

2.1 A Linear Decomissioning Process

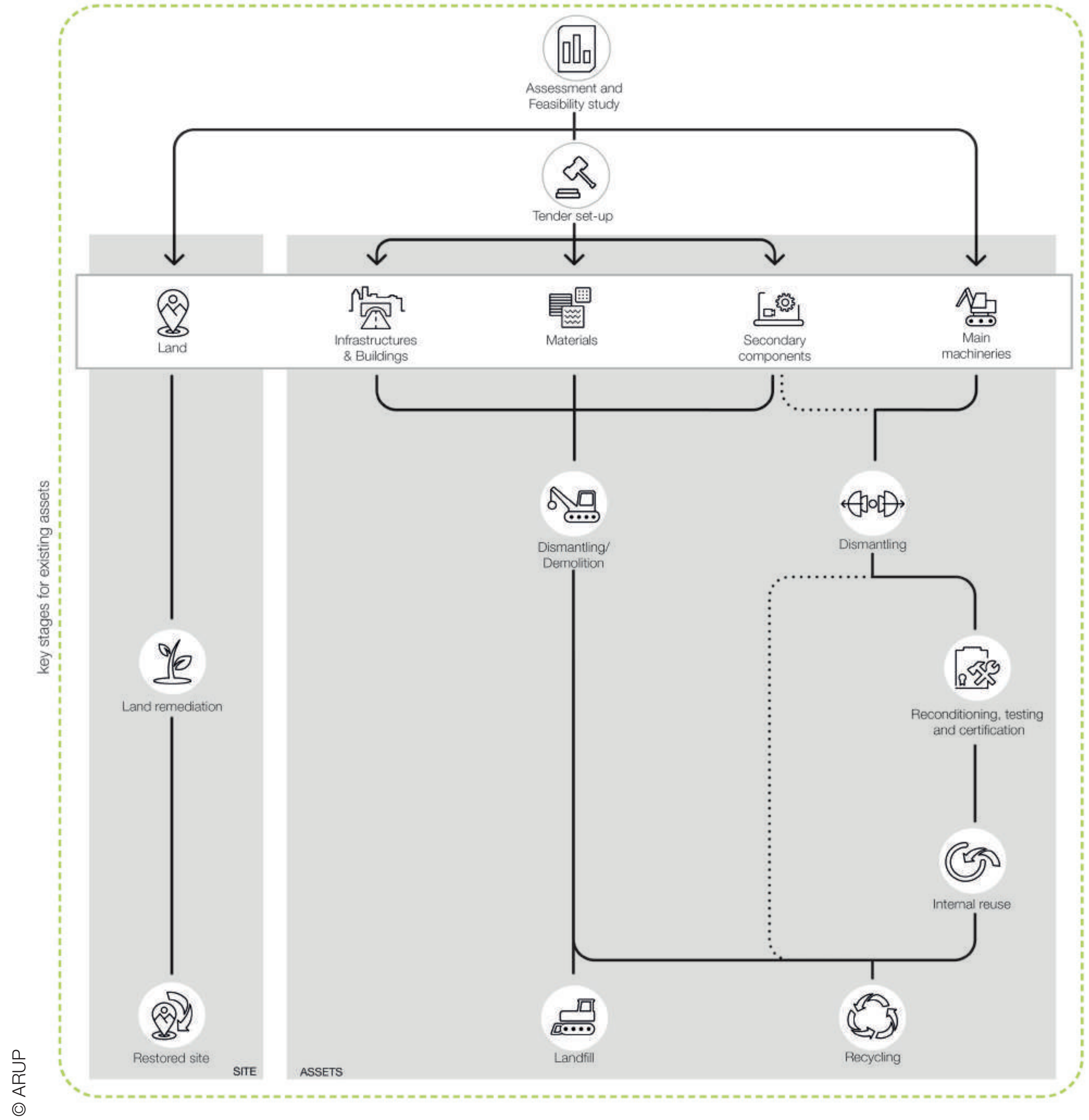
Decommissioning represents a key phase in the life cycle of a power plant. This is due to its relevance in terms of cost impacts on the balance sheet of energy companies as well as to the environmental and socio-economic implications it might have on the site and surroundings.

Decommissioning of an energy site implies identifying a set of strategies to minimize social and economic impacts on the local communities, for example in terms of loss of employment and negative impact on many satellite activities.

Nowadays, in most cases the decommissioning process of a power plant is undertaken following a linear approach that typically consists in the following stages:

- *Assessment and feasibility study:* at this stage the energy company carries-out a macro assessment of the plant from the technical point of view and some preliminary studies to define the future stages of decommissioning. These include the identification of possible internal opportunities to reuse main machineries through downgrading or recovered spare parts;
- *Tender set-up:* at this stage, the main tender requirements for the demolition activities are identified. Tender phase aims at selecting a company in charge of demolition and disposal activities;
- *Dismantling and demolition:* at this stage components selected for the internal re-use are dismantled and then transported to the new location, while the remaining components and materials are demolished and then disposed through landfill or recycled as secondary raw materials;
- *Land remediation:* if required, land remediation surveys and studies are carried out. Depending on the future use of the site, specific remediation activities are undertaken.

12) European commission. Commission staff working document, Analysis of an EU target for Resource Productivity, 2014
13) World Economic Forum, 2016



The different stages that constitute the linear decommissioning process.

Up to 24%

The reduction of material inputs thanks to resource efficiency in the value chain in EU by 2030[14]

Up to 80%

Recycling by weight in Offshore Wind Decommissioning in Scotland[15]

2.2 The Value of a Circular Process

Applying strategies based on a circular approach to decommissioning might result in a strong increase of value for the asset compared to a linear approach:

- Infrastructures still in condition to operate on the site can be maintained, thus saving costs associated to build and put in operations new ones;
- Use of existing structures and connections - e.g. high voltage power connection or water intakes - reduces the time needed to obtain the necessary authorizations from relevant authorities, as well as the costs to build new ones;
- Buildings, structures and spaces can be re-utilized with new functions, thus reducing the need for new investments as well as demolition costs;
- Materials can be retained and reused in a different context, instead of being disposed as waste, thus avoiding use of virgin resources;
- Main areas dedicated to industrial activities would be kept, thus avoiding the involvement of pristine areas;
- Local ecosystems and competences, would be kept active to exploit the long-term efforts made to grow them through years of operations;

The site itself may represent an asset with a high value not only for the existing infrastructures, but also thanks to non-tangible features. These may include a strategic location - typically characterized by the proximity of large cities or touristic and cultural landmarks – the access to coastal water or to existing infrastructures as well as the existing network of social and economic relationships established during the period of plant operation. This greatly increases the number of possible end uses or conversion strategies.

In terms of social impact on local communities, a circular approach to decommissioning aims at maximizing the positive impact in terms of job creation and minimize the negative impact in terms of job losses. This is also reinforced by the possibility to apply strategies for re-use and re-purpose of materials and parts.

14) European Commission. Communication EC COM (2014) 398 "Towards a Circular Economy: A zero waste programme for Europe", 2014
15) Bryant, Scott, Zero Waste Scotland. The benefits of a Circular Economy approach during decommissioning, 2016

When considering a circular approach, it is important to consider the overall risk reduction it provides through the decommissioning process. In fact, an approach based on cooperation with local stakeholders is more likely to reduce criticisms when it comes to the implementation phase.

2.3 A Set of Circular Scenarios

The successful implementation of the circular strategies represents a rather complex matter with a number of factors concurring to the actual success. First and most importantly the energy company shall be committed to that to get an effective decision making process. This also implies that the business model behind a circular approach to decommissioning shall be solid enough to represent a valid alternative for both the energy company and new potential investors, if compared to a linear process.

Secondly, but equally important, it is the relationship with the various stakeholders that are part of the transformation process. These include local institutions and authorities - such as Municipalities - as well as private investors, banks and developers that shall see the actual opportunity to support a circular process.

To understand the potential implications of a decommissioning process based on the Circular Economy, we defined the following comparative scenarios:

- **Total Decommissioning:** this scenario entails returning the restored land to the grantor. During the dismantling process, materials and components are sold to external markets to be re-used;
- **Regeneration:** this scenario entails the partial decommissioning of the plant and the site regeneration with a new function. In this case infrastructures and buildings are partially re-used in order to accommodate a new development project, while components and materials, if not re-used in the new project, are sold to secondary external markets;
- **Re-Power:** this scenario entails the repowering of the plant. Thus the existing site accommodates a new energy plant promoting the re-use of infrastructures, main machineries and components.

Up to 8.5GW

The yearly increase for the repowering market from 2017 to 2027[16]

16) Wind Europe. Repowering and lifetime extension: making the most of Europe's wind energy resource, 2017

Focus 2 | The Project Futur-e

23

Power plants inolved[17]

13GW

Total power to be decommissioned through Future-E[17]

Enel has chosen to take the lead in the transition towards a more sustainable model for the power industry with Futur-e, a program to redevelop the sites of 23 thermal power stations that are no longer competitive on the domestic energy market, with approximately 13 GW of total installed power. The goal is to envision new uses for the sites of these power stations, beyond the limits of the energy sector, and fitting the criteria of innovation as well as social, environmental and economic sustainability.

The project has been carried out through a number of different approaches, such as international calls for ideas and projects, workshops, real estate procedures, round-table discussions: all initiatives have in common the desire to identify, on a case-by-case basis, solutions that local communities can believe in.

To do so Enel has designed a competition process from scratch aimed at finding projects and investors, involving local institutions and technical partners. Interested investors can participate by presenting their proposals to purchase and redevelop sites. The proposed projects are evaluated by a jury composed of representatives of Enel, local institutions and the academic sphere. Only projects that meet a set of key parameters, specifically environmental, economic and social sustainability, innovation and the application of principles of Circular Economy, are allowed to move on to final negotiations for the acquisition of the site.

The process is led through meetings, conferences and round tables with institutions, experts and private individuals, each of whom can contribute to the success of this initiative. Working towards a shared goal is the key to transforming the potential problem represented by the rapid and radical change in the energy industry into an opportunity for large communities.

In contrast with the linear approach for decommissioning, Futur-e is designed to be circular on its own, leading an entire industrial site that has reached its EoL towards a new, more sustainable use.

This approach is in line with Enel's new vision for Open Power, which sees the company focusing on working together with local communities to design a bright future for these sites.

17) Enel. Futur-e Project. https://corporate.enel.it/en/Futur-e/project (accessed June 26, 2018)

Location of the 23 power plants of the Futur-e Project.

“Businesses, governments, investors are becoming increasingly aware of the relevance of tracking the progress in transitioning towards the Circular Economy, by adopting dedicated metrics and indicators to support investment decision-making and by assessing the impact of circular initiatives. Consistency of data and persistence in measurability are core drivers to boost the circular paradigm, at both business and societal level”

Massimiano Tellini

Head - Circular Economy Innovation Center

Intesa Sanpaolo S.p.A.

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03 Measuring the transformation

Measuring the quality and the potential impact of the different scenarios for a transformation project is pivotal for a successful process to be successfully implemented. To do so the adoption of Key Performance Indicators (KPIs) represents a necessary step to provide a potential quantitative feedback to drive the decommissioning and potential future transformation of the site and to understand its impact.

Four main pillars have been introduced in Paragraph 1.2 to guide the decommissioning process, these being:

- The technical indicators for the intervention, meaning the actual opportunity to use, transform and put in operations the assets available on the site. These could be at the scale of the available infrastructures, buildings, components or materials;
- The social indicators of the intervention, meaning the expected impact on the local communities as a consequence of the transformation. These include the integration in the process of the different stakeholders;
- The financial indicators that imply the economical viability of the intervention both from the investors and from the developers side and the expected positive impact and return on the local economy;
- The environmental impact that implies the level of pollution and emissions associated to the decommissioning process as well as the opportunity to limit the exploitation of energy and precious resources such as water.

All these aspects are crucial to drive an effective transformation and their combined impact would support a circular intervention.

500M tons

The reduction of greenhouse gas emissions between 2015 and 2035 due to the EU measures[18]

+2,2%

The growth of global energy demand in 2017[19]

18) European Commission. Circular Economy, Closing the loop an ambitious EU Circular Economy package. http://ec.europa.eu/environment/circular-economy/index_en.htm (accessed June 26, 2018)
19) BP. BP Statistical review of world energy, 67th edition, 2018

Up to 36%

The potential reduction of steel environmental footprint thanks to its reuse into buildings[20]

3.1 Technical Indicators

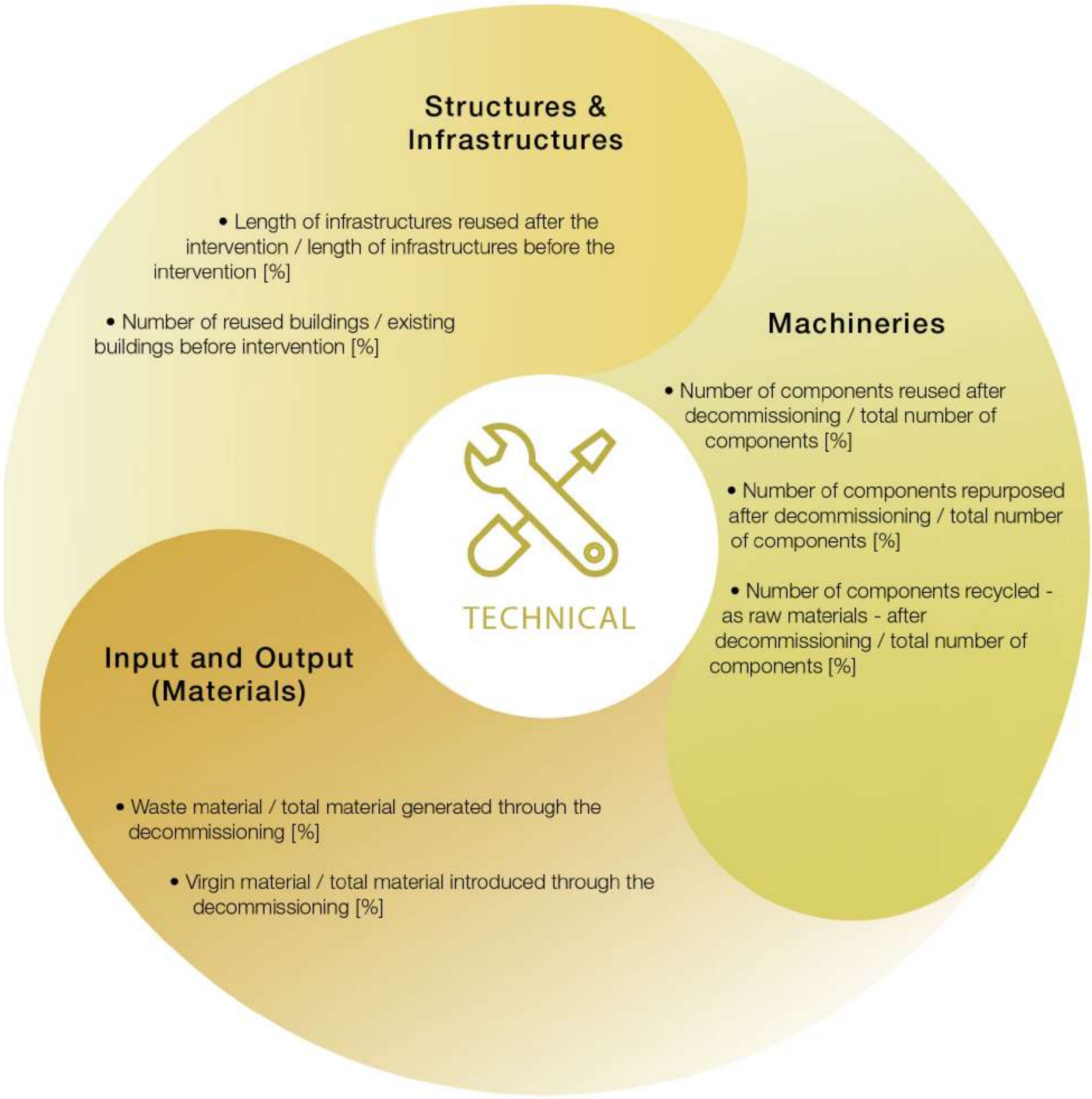
One of the main aspects of the Circular Economy relates to the assessment of material flows to evaluate the impacts on natural resources and the production of waste.

Three main indicators can be considered when undertaking decommissioning activities:

- *Structures & Infrastructures:* these KPIs aim at measuring the rate of reuse of infrastructures services (like roads, railways, etc.) and buildings;
- *Machineries:* these KPIs consider the number and type of main machineries and building operation components, by keeping their functionality. In a linear decommissioning process these components are typically considered as waste materials. This is also due to some issues possibly deriving from the complexity of tracking these components within a plant. A circular approach implies identifying opportunities of re-use also through secondary marketing;
- *Input and Output (Materials):* these KPIs pertain assessing the reciprocal quantity of virgin and waste materials involved through the decommissioning process.

The diagram in the next page explains in details the different KPIs considered for the three main indicators reported above.

20) Worldsteel Association. Reuse. https://www.worldsteel.org/steel-by-topic/circular-economy/case-studies/reuse-case-studies.html (accessed June 26, 2018)



The technical KPIs are related to structures and infrastructures, machineries, input and output materials.

3.2 Social Indicators

580k

Number of jobs that will be created in Europe thanks to the 2018 Circular Economy Package[21]

170k

Number of direct jobs that could be created in Europe by 2035 through the measures on waste management[22]

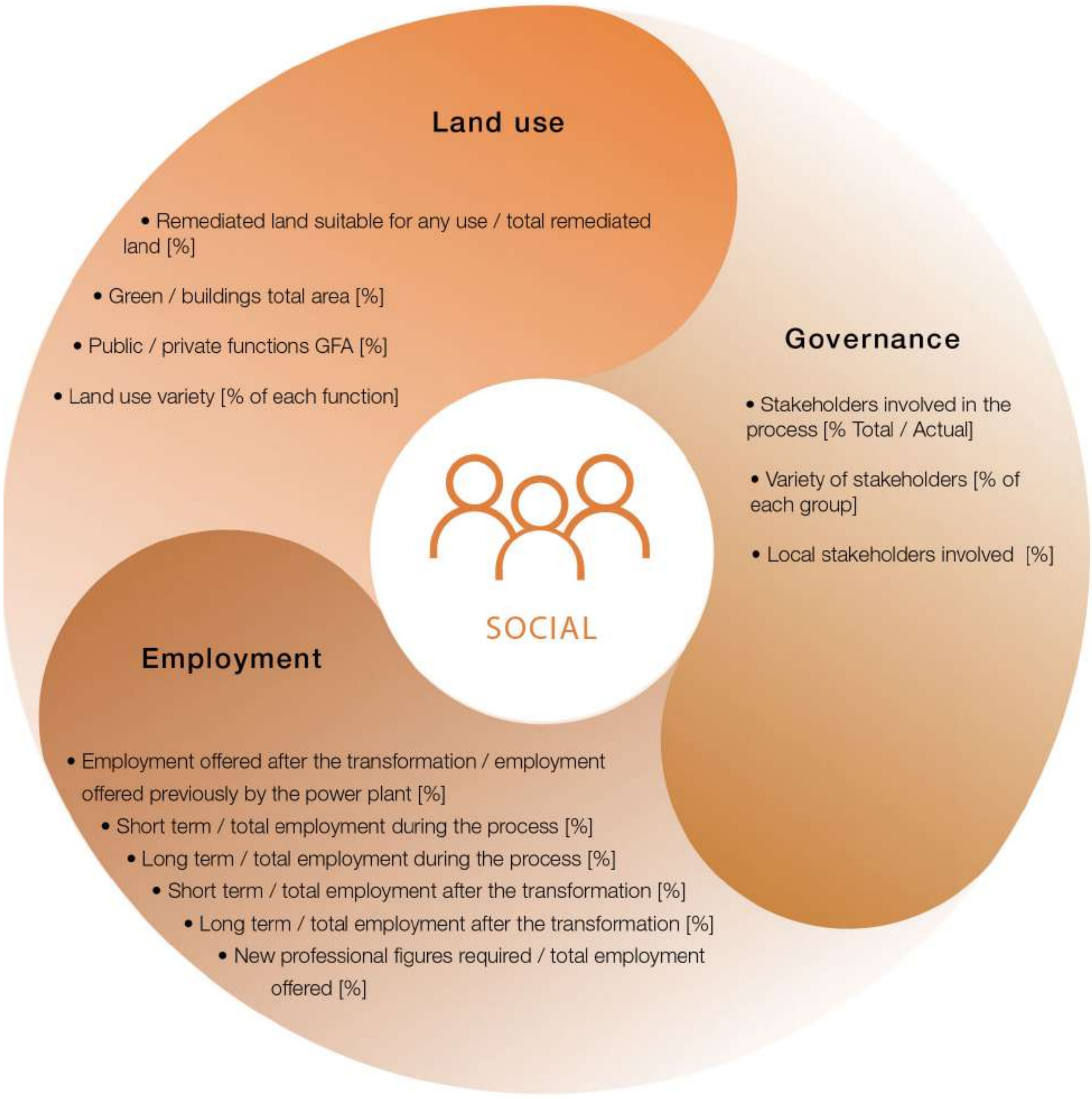
The second set of KPIs focuses on the social implications associated to the transformation and regeneration strategies for a site entering the decommissioning stage. Arguably, under the perspective of circularity, the social aspects of transformation and regeneration of a power plant shall be seen in close connection with both the environmental and economic aspects due to the positive influence on people network, local communities and society as a whole.

Three main performance indicators can be considered when undertaking decommissioning activities:

- *Land use:* it includes the type of human activities taking place as well as the suitability of an area for a given activity/function (residential, commercial/business, industrial, government facilities/services, parks and recreation areas, agriculture, roads, etc.);
- *Governance:* this set of KPIs include the variety of engaged and involved stakeholders in the process. Planning and management requires an effective coordination and collaboration. By analysing the process of information exchange through all the phases, it is possible to understand the transparency of management and the engagement of all stakeholders - e.g. the use of sharing platforms, open data, open budget tools;
- *Employment:* these KPIs focus on the analysis of the new employment offered on site during and after the process, not only with quantitative data, but also in terms of range of professional positions, definition of new skills and duration of the employment (long lasting vs short term).

The diagram in the next page explains in details the different KPIs considered for the three main indicators reported above.

21) Ehero, Circle Economy. Circular Jobs, Understanding Employment in the Circular Economy in the Netherlands, n.d.
22) European Commission. Circular Economy, Closing the loop an ambitious EU Circular Economy package. http://ec.europa.eu/environment/circular-economy/index_en.htm (accessed June 26, 2018)



The social KPIs are related to land use, government and employment.

€600bn

Savings for EU businesses, equivalent to 8% of their annual turnover thanks to the 2018 Circular Economy Package[23]

3.3 Financial Indicators

As it can be easily guessed, financial aspects represent a key factor in defining the feasibility of any investment, independently from its nature. The set of financial KPIs has been set to evaluate not only the profitability for the investors but even the broader effect on the area affected by the decommissioning and regeneration process.

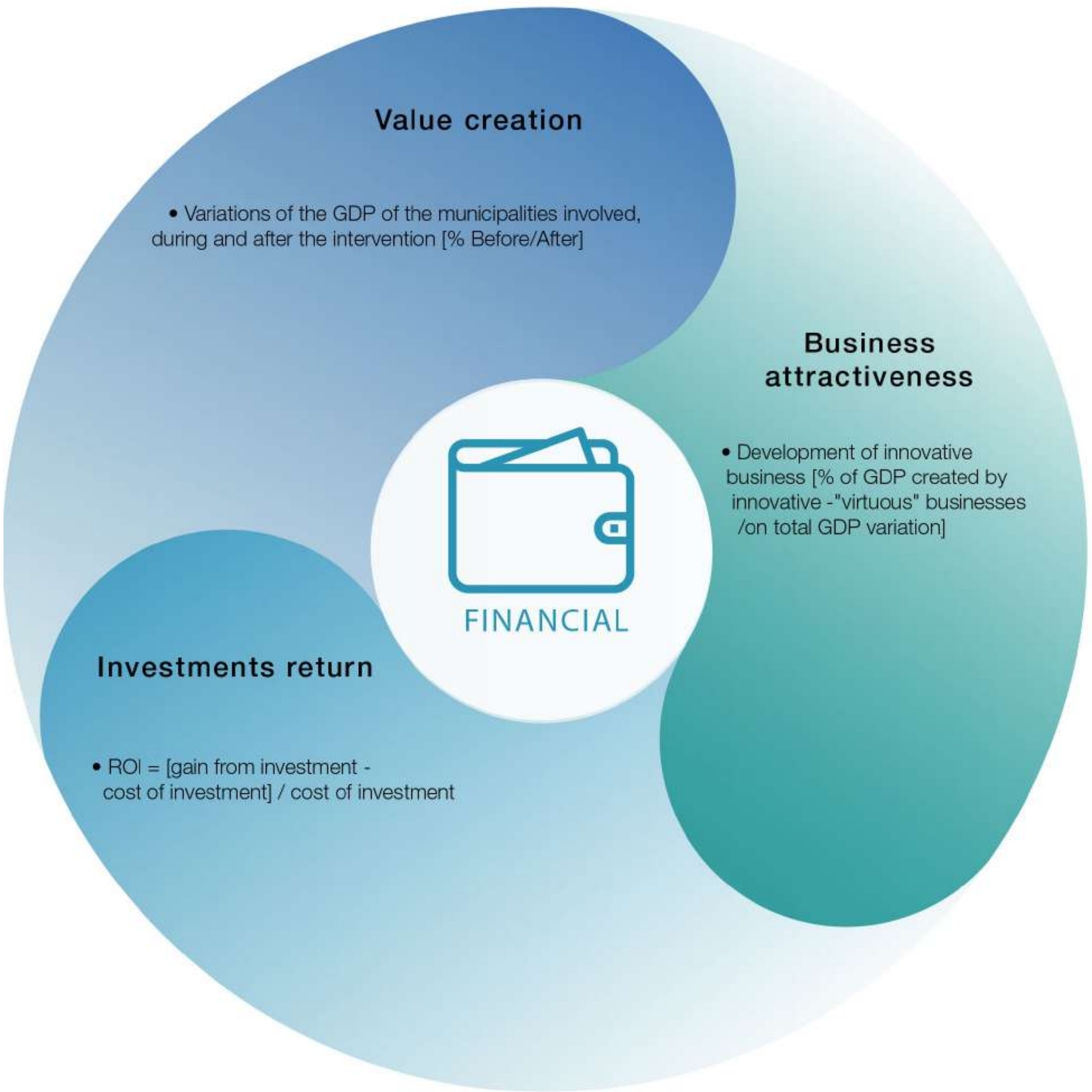
Financial aspects are essential to start evaluating the impact of intervention. It is a prerequisite that needs to be satisfied to set the investment strategy.

Three main performance indicators can be considered when undertaking decommissioning activities:

- *Return of Investment (ROI):* this KPI represents a classic approach to evaluate the investment with the aim of representing the overall value created by the initiative for investors and lenders;
- *Value creation:* it is assessed by measuring the variation of GDP (or similar indexes) recorded by local municipalities. It aims at measuring the value created for the community after and during the process (e.g. turnover or added value created during the dismantling phases and/or by the new established initiatives after the regeneration/repower process);
- *Business attractiveness:* it focuses on the value created by "virtuous" initiatives. It aims at identifying the quantity and quality of value created including field and typology of the initiatives. These shall be considered virtuous in addition to profitable.

The diagram in the next page explains in details the different KPIs considered for the three main indicators reported above.

23) European Commission. Circular Economy, Closing the loop an ambitious EU Circular Economy package. http://ec.europa.eu/environment/circular-economy/index_en.htm (accessed June 26, 2018)



The financial KPIs are related to value creation, business attractiveness and Return On Investment (ROI).

450M tons

The reduction of EU carbon emissions by 2030 thanks to the 2018 Circular Economy Package[24]

3.4 Environmental Indicators

From an environmental point of view water, energy and emissions are the main factors having impact in a decommissioning activity, regardless of the scenario considered.

The KPIs identified to measure such impacts are expressed as a ratio between the resource/virgin material and the total resource/material used.

Some other aspects have not been considered here such as the reclamation of land or the noise emissions on the side.

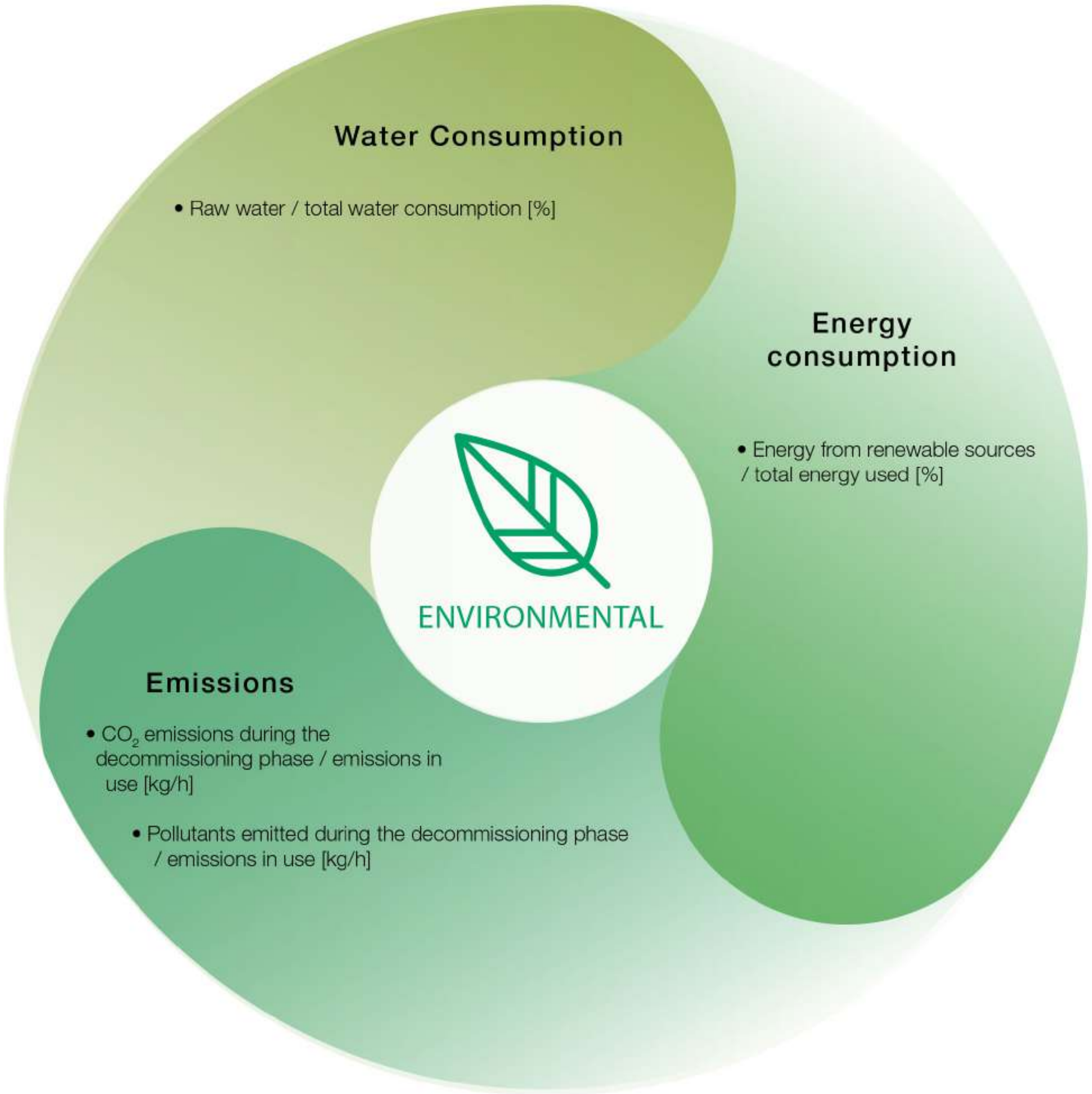
However these are not directly related to the exploitation of natural resources and they are generally monitored in force of the existing regulations.

Three main performance indicators can be considered when undertaking decommissioning activities:

- *Water consumption:* it is expressed as the ratio between raw resource and total water consumption;
- *Energy consumption:* this KPI focuses on the ratio between energy from renewable resources and total energy used;
- *Emissions:* these KPIs refer to both CO_2 and pollution emissions during the phases of use and decommissioning for the asset.

The diagram in the next page explains in details the different KPIs considered for the three main indicators reported above.

24) European Commission. Circular Economy, Closing the loop an ambitious EU Circular Economy package. http://ec.europa.eu/environment/circular-economy/index_en.htm (accessed June 26, 2018)



The environmental KPIs are related to emissions, water and energy consumption.

2050

The year in which Enel will reach carbon neutrality[25]

50tons

The amount of metals and other recycled materials saved in the Sustainable Construction Site of Apiacàs in Brazil, thanks to the implementation of recovery systems and maximized recycling practices[25]

Focus 3 | A Sustainable Construction Site

The Sustainable Construction Site is an operating model that provides a decision-making guide to recognize and measure impacts and to improve sustainable performances of each project with an efficient use of resources. It is a model - developed by Enel - designed with a bottom-up approach which takes advantage of best practices from worksites and closely involving personnel. The model is based on the typical Sustainability dimensions - Environmental, Social and Governance (ESG) - and on the main aspects where impact is foreseen. Main aspects include:

- People, territory and safety: minimize or empower the impact that the construction site has on workers, society and local communities;
- Emissions, climate: reduce the dangerous emissions, including greenhouse gas emissions and other dangerous pollutants, during all stages of a project's life cycle and to be resilient to climate change;
- Energy: minimize electric energy consumption and maximize the ratio of energy produced by renewable sources during construction;
- Materials: reduce the total amount of material used and increase the Circular Economy approach, pursuant to the conservation of global natural resources;
- Water: reduce the total water consumption and increase the use of reused and recycled water;
- Waste: minimize waste production and maximize waste reuse/recycling;
- Biodiversity: minimize negative impacts on natural species and their habitats on, and near, the site.

All in line with the Global Reporting Initiative (GRI) standards, for the measurement phase, the impact on the Sustainable Development Goals (SDGs) is evidenced.

The Sustainable Construction Site model is being implemented on all new and ongoing Enel´s construction sites, including the decommissioning of Energy Power Plants so to mitigate the associated impacts. Sustainable solutions applied include promotion of local entrepreneurship, re-use of materials, LED lighting, plant-based waste water treatment systems and rainwater harvesting.

25) Enel. The sustainable worksite model is the future. https://www.enelgreenpower.com/stories/a/2017/09/the-worksite-of-the-future-is-sustainable (accessed June 26, 2018), 2017

Thunder Ranch, Oklahoma - USA.

© Paul Carstairs Arup

04 A Circular Decommissioning

Decommissioning involves various types of power plants including coal, oil and gas fired thermoelectrical units, gas fired combined cycles and open cycle gas turbines. They differ for a number of aspects including the number of units installed in each site, the units' rating and the installation date.

Site destination after decommissioning varies accordingly to the adopted scenario and it is reasonable to assume that only a small part of the existing installations could be functional to the new potential use and business. Correspondingly, the dismantling activities of the parts of the plants not functional to the new business will be carried out originating a large amounts of components/equipment and end of life materials. A large part of them is either operating or can be reconditioned and recovered to their original function.

From this point of view, the decommissioning in the energy power sector represents a significant opportunity for addressing alternative scenarios for waste management and for applying Circular Economy principles and practices not only at a strategic scenario level but also at a more operative one.

To support this approach it is key to verify the opportunities of re-use, re-purposing and re-manufacturing for materials and components also in different industries other than the energy sector. This would trigger a potential economic return for the asset owner and for the supply chain as a whole.

The current evidence shows a significant unexplored potential to develop cross-industry markets and to realise cascade benefits from a socio-economic stand point. The use of Materials Passports, Materials Banks and digital platforms would be functional to support secondary marketing and novel end of life strategies.

54%

The amount of EU coal-fired power plants that are currently cashflow negative. This number could increase to 97 percent by 2030 due to rising carbon prices and stricter air quality rules[26]

28%

The amount of wind turbines that will be older than 15 years in 2020. These will soon reach their designed service life[27]

26) Reuters. Nearly all European coal-fired power plants will be loss-making by 2030 -research.
27) Ziegler, Lisa et al. "Lifetime extension of onshore wind turbines: A review covering Germany, Spain, Denmark, and the UK." Renewable and Sustainable Energy Reviews 82 (2018): 1261-1271, 2018

+94%

The power generation growth coming from emerging economies worldwide[28]

Up to 50%

The price reduction of refurbished/remanufactured wind turbines with respect to the new ones[29]

4.1 Total Decommissioning

This scenario entails the complete decommissioning of the asset with the purpose of returning the restored land to the Grantor. Given the final destination of the site, the focus in this scenario is given to materials, components and equipment recovery. Available components and machineries from the existing plant are made available to be re-used either inside the energy company or in secondary markets. A number of main differences apply with respect to a linear approach as explained by the diagram at the following page.

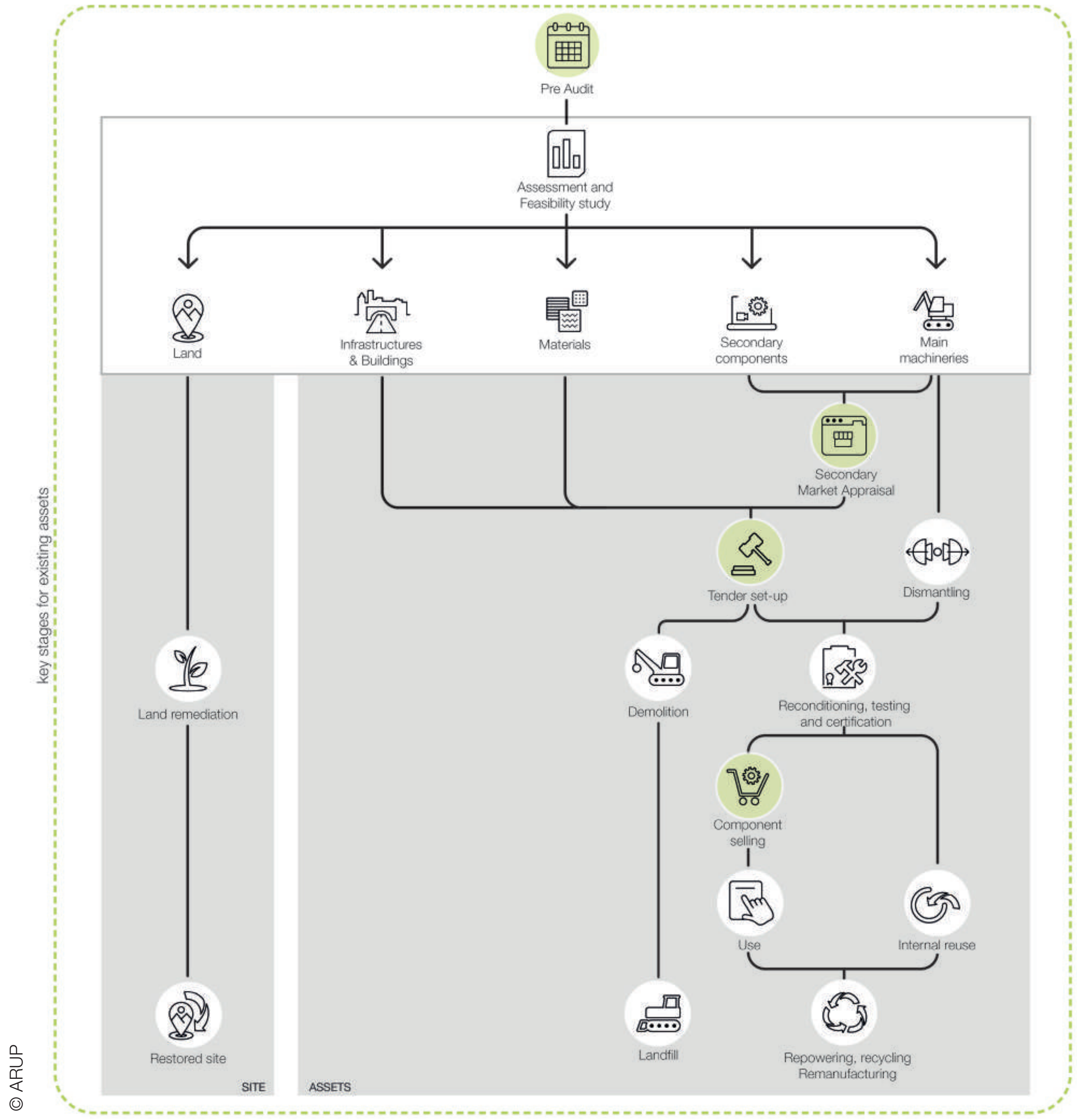
Pre Audit:

- With the purpose of increasing assets re-use, the first step is represented by the creation of an inventory of materials available in the power plant, at least for main components. The inventory provides technical information as well as age, size and conditions for each item;
- Notwithstanding the importance of this activity, due to the designing practice in place at the time of their construction, the majority of the power plants to be disposed do not have the necessary information easily available for components other than the main ones. Therefore, potential difficulties may arise in collecting data. This suggests to postpone the inventory activity after that a market survey is undertaken with the aim to identify which parts, and under what conditions, could be actually accepted by secondary markets. Data collection will be limited to these components or performed to a very limited extent, depending on the market requirements.

Assessment and feasibility study:

- Components assessment is performed for the entire plant to evaluate the potential internal and external re-use of main machineries and components (downgrading, spare parts, external selling). Internal re-use for the energy company is normally a priority being associated to the highest recovery of value.

28) BP. BP Statistical review of world energy, 67th edition, 2018
29) Ricardo Energy & Environment, Local energy Scotland. Briefing Paper: Refurbished/Remanufactured Wind Turbines, 2016



The different stages that summarize the scenario of total decommissioning. Green stages are peculiar for the scenario.

-7,7%

The fall in natural-gas power generation in the U.S. in 2017[30]

+1,6%

The increase of carbon emissions from energy consumption in 2017[30]

30) BP. BP Statistical review of world energy, 67th edition, 2018

Secondary Market Appraisal/Tender set-up:

- After the preliminary assessment, an appraisal of potential secondary market opportunities is carried out. The aim of this stage is to identify companies interested in acquiring materials and components throughout the disposal to be sold and re-used. Some specialized operators could support the sale to Third Parties. With this respect, the use of on-line selling platforms and bidding portals is relevant to allow the meeting of the offer with the demand from larger markets and industry sectors. The support of operators specialized in second hand industrial equipment is important to select those components that are really attractive for the market;
- Then a tender for dismantling and demolition activities is carried out. Tender requirements could include Circular Economy principles such as minimum material percentage to be re-used and type/ variety of materials to be recovered. The greater is the materials recovery, the more competitive the offer will be. Alternatively, the sale of recovered parts can be done independently limiting the tender only to the removal/demolition activities;
- Depending on the adopted approach, the tender can be open to:
  - A single buyer/consortium (a demolition company operating together with a recycling portal), who performs both the removal/ dismantling activities as well as the components selection and sale on the secondary market;
  - Only demolition companies that will be instructed to dismantle and demolish the different parts of the plant according to the selection carried out previously.
- In any case, anticipated visits at plant site are essential to enable involved stakeholders to directly select components and machinery to be reused.

Removal, Dismantling and Transportation

- Compared to the traditional dismantling process, a specific phase of removal of those assets which will be sold or re-used prior to the demolition process will be performed. It has to be considered that costs for this type of removal are on average two to three times higher than costs related to the traditional demolition process: this is an essential information to address the selection of reusable equipment and components compared to their value on secondary markets;
- Dismantled assets to be sold for re-use are delivered to buyers or stored ready for further processing. Those components which cannot be re-used in a secondary market follow the traditional demolition and recycling process.

Component selling:

- Components are normally made available on the secondary market according to an “as is” approach. Eventual reconditioning, testing and certification activities, if necessary/required, are performed by the buyer or by the broker. No warranties are provided from the energy company;
- In the case that comparable new products are available, it is unlikely that potential buyers would prefer used/reconditioned components/materials unless there is a significant cost or lead time benefit over new products;
- Potential issues may arise from the necessity to develop a new supply chain to absorb the volume of different components that could be re-used/sold;
- Restraints on components re-usage are currently in place, see Paragraph 5.1 for further information on the regulatory framework.

+13,4%

The growth of net generation from utility-scale clean energy sources, excluding hydro according to the Energy Information Administration (EIA)[31]

Up to 3

Potential increase in spending for disassembly compared to demolition[32]

31) Foehringer Merchant, Emma. Natural Gas and Coal Generation Fell in 2017, While Renewable Energy Grew. https://www.greentechmedia.com/articles/read/natural-gas-and-coal-generation-fell-in-2017-whilerenewable-energy-grew#gs.ZZg02T0 (accessed June 26, 2018)
32) Source: Enel, 2018

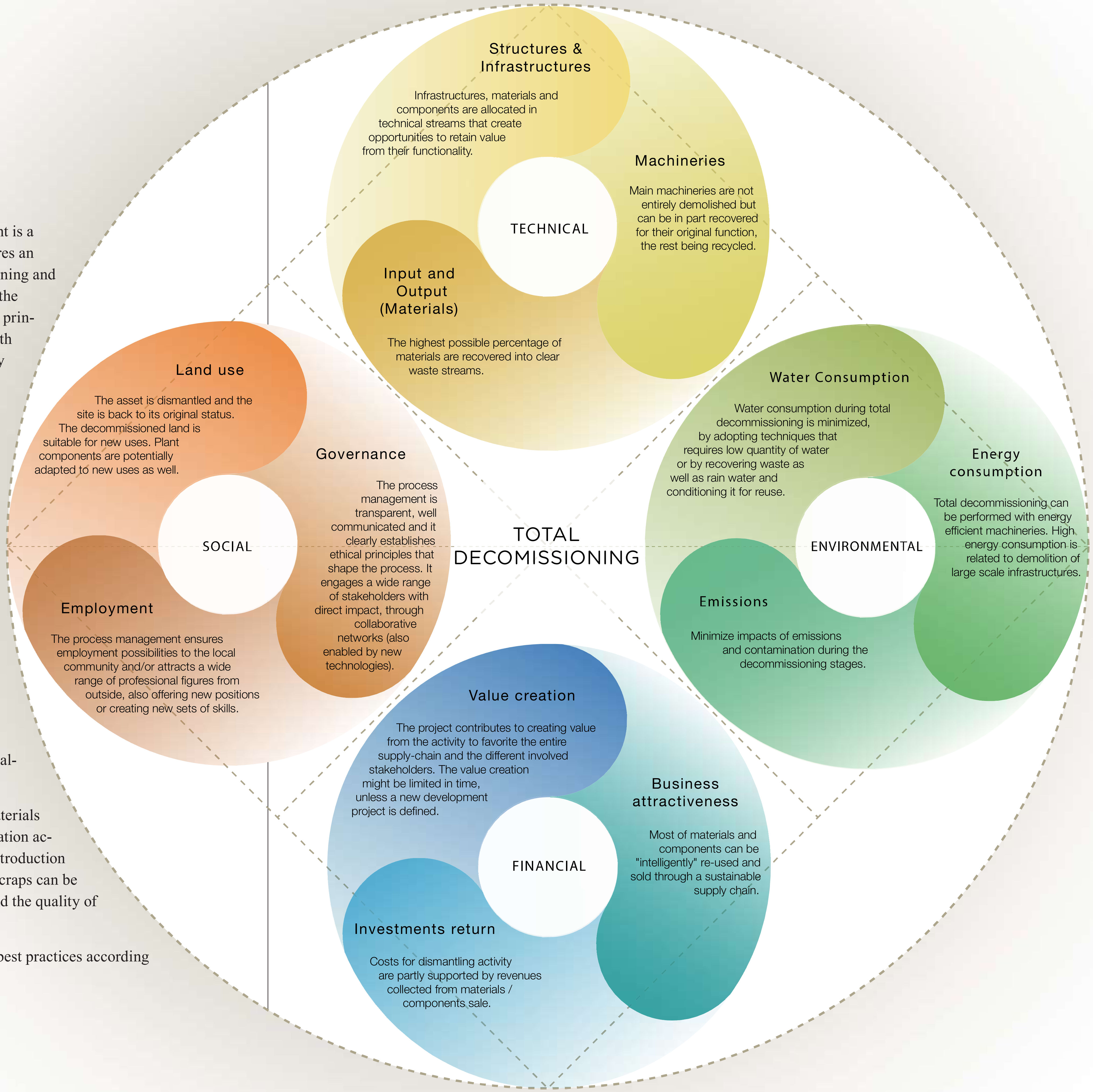
Best Practices

The total decommissioning of a power plant is a complex and expensive activity, that requires an important effort by the asset owner in planning and financing its execution. On the other hand the extensive application of Circular Economy principles can give an important backup for both cost reduction and improving sustainability of the utility.

Circular Economy can be applied, according to todays best practice, at several levels. At the higher level the reuse of machineries and components for their proper function is pursued, dismounting them instead of demolishing. The main machineries, usually designed for the specific use in power generation, rarely see their final destination outside of the energy sector. Instead, for smaller components, both electrical and mechanical - designed according to more common industry standards - the reuse in markets and industries different from the original one can be proposed. Here, the goal is to maximize their value by finding the more convenient application with an economic balance higher than the break even point.

At the lower level, it is pursued the raw materials recovery, that only requires a proper separation according to base material and subsequent introduction in the recycling market. Finally, concrete scraps can be used directly on site, after fine crushing and the quality of materials is provided.

The diagram on the right summarizes the best practices according to the four pillars of the analysis.



Up to $80mn

The redevelopment costs of aging power plants for mid-size developments in the US[33]

Up to $180mn

The redevelopment costs of aging power plants for large-size developments in the US[33]

4.2 Regeneration

This second scenario entails a project of site regeneration. In this case, the plant is partially decommissioned and then replaced by a new project, which typically does not relate to the energy sector.

Power plant components are then re-used in secondary markets, while existing infrastructures, buildings and materials are included, where possible, in the new project.

In this scenario, the business model has some similarities with the scenario of total decommissioning with respect to the opportunities at the end of life for the materials and components. At the same time, different activities are needed to undertake the development of the regeneration project, including assessing and possibly exploiting the value of existing infrastructures and building as a whole, as well as focusing on the added value provided by site specific immaterial features (e.g. proximity to large cities, cultural or geographical landmarks, coastal waters, etc.).

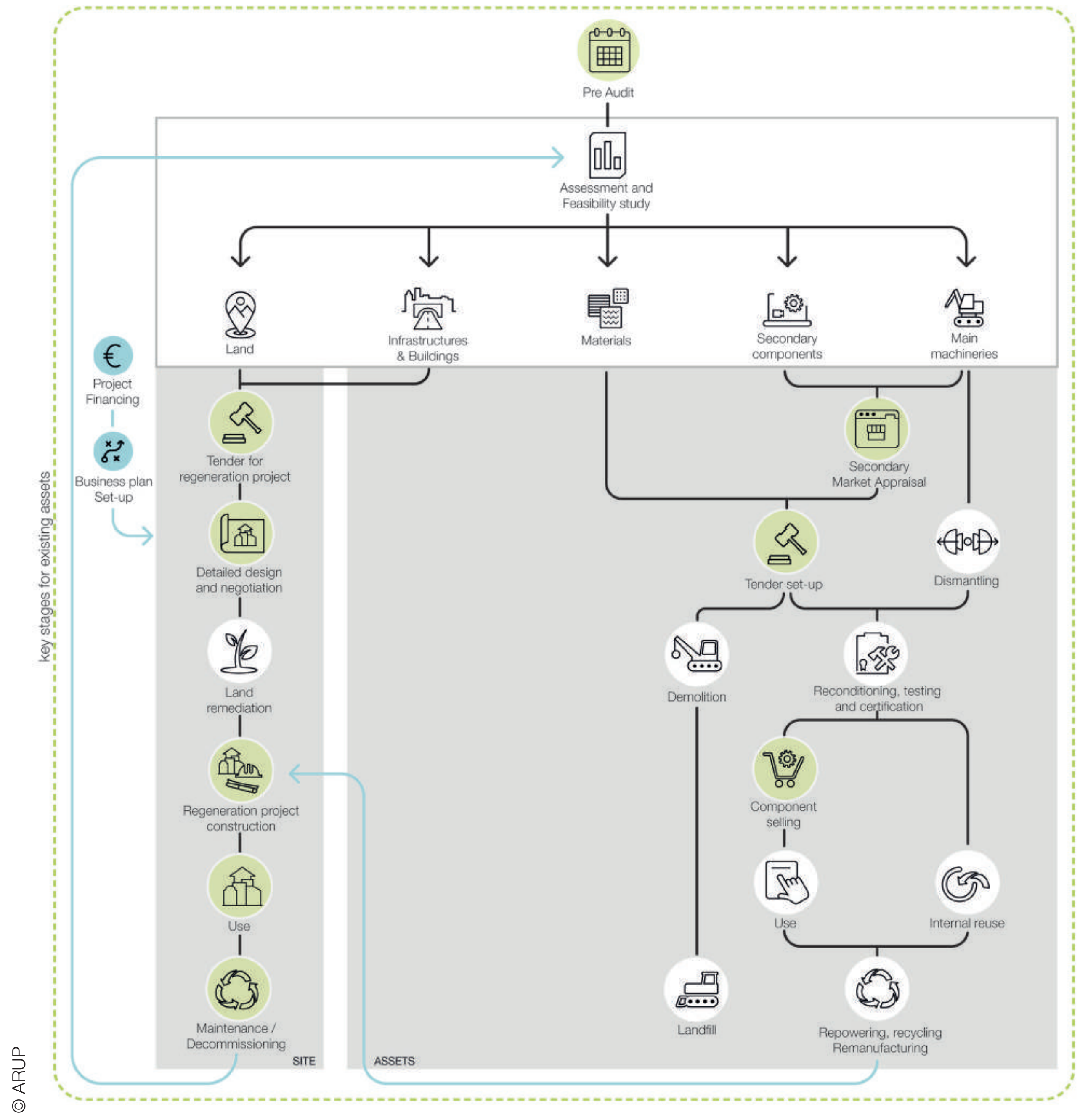
The diagram included in the following page explains the main differences with respect to both a linear process and compared to the other two scenarios.

With respect to the main phases of the process, the following shall be considered.

Pre Audit:

- Before tender launching, structural and technical analysis (e.g. non-destructive tests, materials sampling and testing, visual inspections) are carried out on the infrastructure to evaluate their conditions and to arrange appropriate future refurbishments according to the potential project.
- Also before tender, typically an environmental analysis (coring) is performed close to the possibly polluted areas, in order to assess the environmental situation of the site and provide such data to the potential investors, who would need them to assess the environmental and economic feasibility of the regeneration project.

33) American Clean Skies Foundation. Repurposing Legacy Power Plants: Lessons for the Future. Washington D.C., 2011



The different stages that summarize the regeneration process. Green stages are peculiar for the scenario.

$\$250/m^2$

The potential increase in real estate values if the plant redevelopment is implemented[34]

Tender for regeneration project:

- A tender for new project construction and operation is set-up with the aim of evaluating different projects from different developers;
- The new project has to be compliant with CE principles, to promote material re-use and project sustainability from the social, economical and environmental point of view.
- Therefore, project evaluation criteria should include material percentage to be re-used and type/variety of materials to be recovered. The greater the materials recovery, the more competitive the offer will be;
- New virgin materials required for the regeneration project have to include characteristics that could be helpful for the future asset decommissioning (e.g. better durability performance). The possibility for the project to be financed by Equity and/or Lenders is discussed at this stage and a business plan related to the project (including capital and operational expenditures and revenues) is developed and analysed in order to assess its economical feasibility;
- Project(s) analysis and selection shall be carried out as much as possible with the support of local institutions and stakeholders, in order to mitigate the permitting risk;
- Negotiation phase is a crucial point at this stage: parties define criteria to be included in the agreement;
- From the financial point of view, plant acquisition cost, dismantling costs and revenues collected from the plant sale are defined;
- Parties responsibilities for each required activity are defined.

34) Malley, Ed. Coal Power Plant Post-Retirement Options. http://www.powermag.com/coal-power-plant-post-retirement-options/?pagenum=3, (accessed June 26, 2018)

Regeneration project assessment and design (negotiation phase)/ Project construction:

- Once the winner is appointed, the regeneration project is designed and then built;
- The regeneration project should aim at creating an innovative, energy-efficient, sustainable and bankable business for both involved parties;
- The new asset design and construction should reflect those best practices (attention to materials and components inventory, etc.) to avoid potential difficulties and risks highlighted in the traditional decommissioning description once the new project will reach its end of life;
- Please note that land remediation activities are appropriately defined in relation to the regeneration project since they may vary depending on the nature of the new asset.

Up to 20%

The advantage of income tax credits offered to redevelopers in US, by adding the power plant to the National Registers of Historic Places[35]

35) Raimi, Daniel, RFF Report. Decommissioning US Power Plants: Decisions, Cost, and key Issues, 2017

Best Practices

Regeneration of a power plant - consisting in the transformation of the site to host a different business than energy production - has the potential to maximize the return for the local community as well as to minimize the cost of decommissioning with respect to the Total Decommissioning scenario.

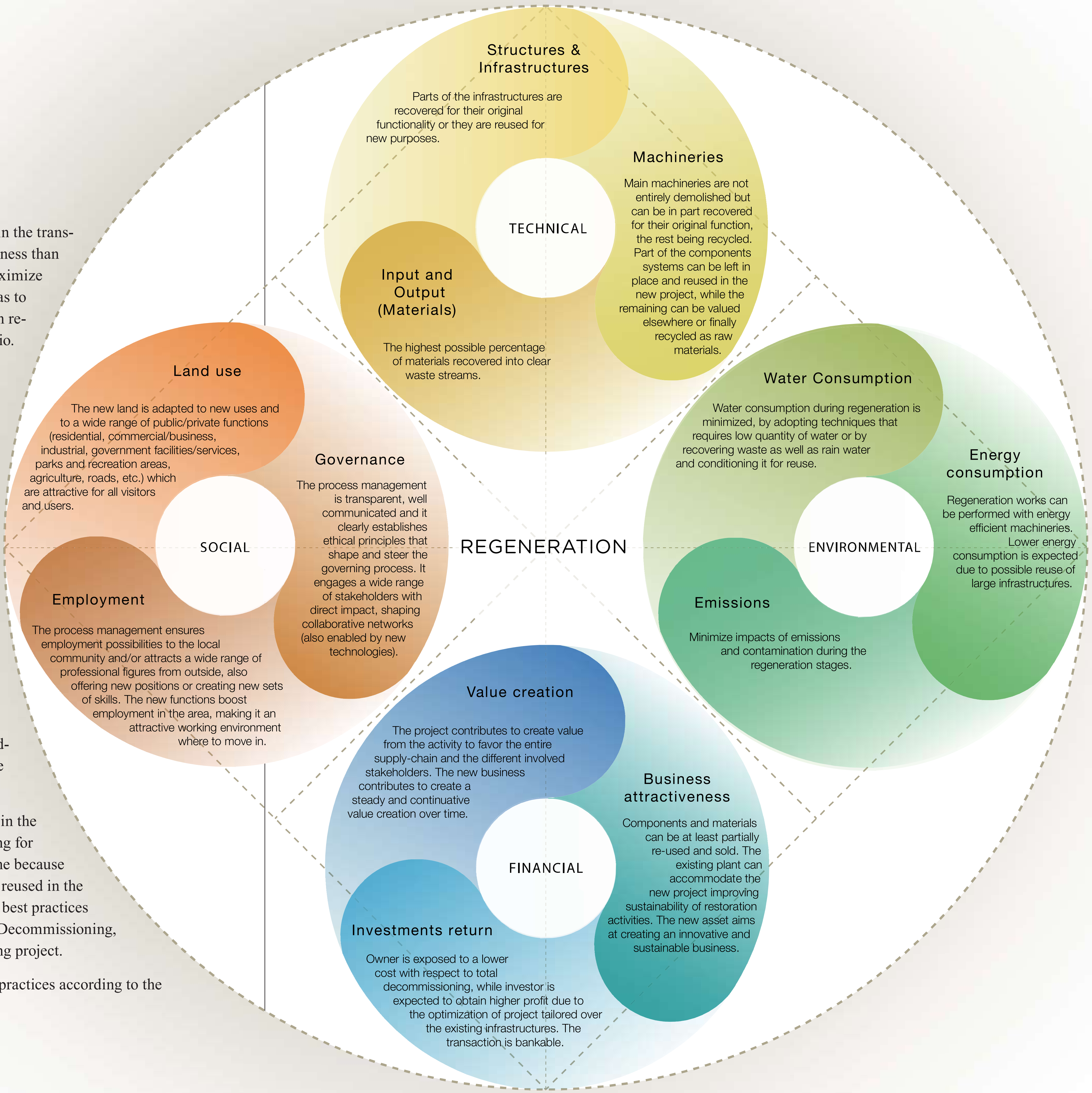
On the other hand the application of this scenario requires a bigger organizational effort, especially because it involves a higher number of stakeholders including public authorities - which also means often longer planning procedures.

In this case, best practices consist in the reuse maximization of existing assets in the new facility, that usually have a destination completely different from the original one, in most cases even different from industrial.

Roads, buildings and structures can represent an added value for an investor who has a vision and imagines the existing assets with a completely different function. Usually these assets have high quality standard and can give a strong added value to the new project.

On the other hand, each asset incorporated in the new project gives to the plant owner a saving for reduction of demolition costs, and an income because of the value of the asset itself. All parts not reused in the new project can be treated according to the best practices already presented for the scenario of Total Decommissioning, adding further value to the decommissioning project.

The diagram on the right summarizes best practices according to the four pillars of the analysis.



+25%

Increase in performance for a wind farm thanks to re-powering[36]

20y

Potential life-time extention thanks to re-powering of wind farms[36]

4.3 Re-Power

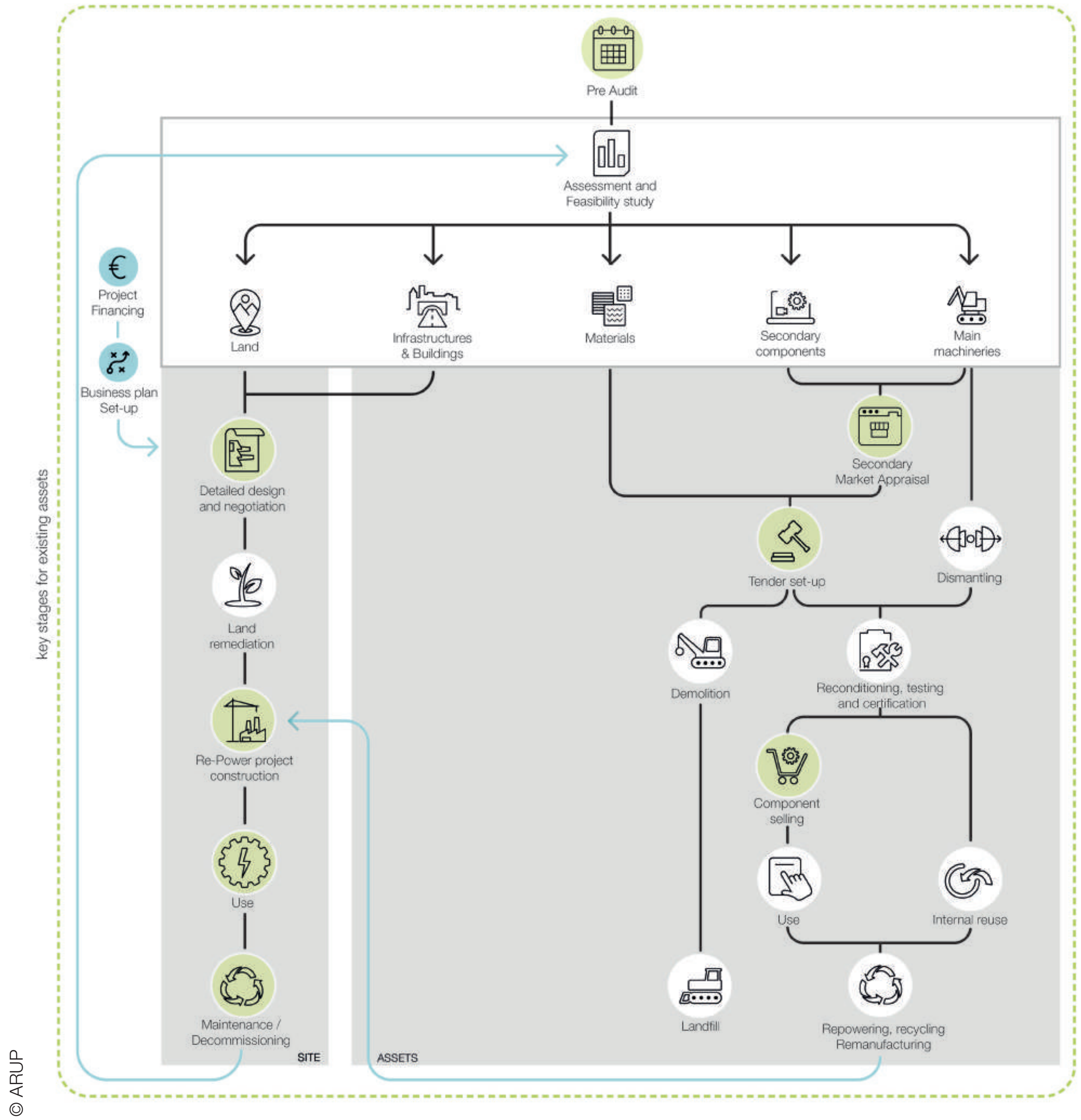
This scenario entails the plant repowering: the existing plant accommodates a new power plant generally related to renewable energy technologies thus promoting the internal re-use of infrastructures, main machineries and components together with new machinery and technology.

As depicted above, the present scenario is mostly similar to the previous one related to the Regeneration. Therefore all considerations made for the second scenario are still valid. In addition, attention should be drawn on the following phase.

Project assessment and construction:

- The project aims at integrating and converting the existing plant into a renewable and innovative one therefore limiting non sustainable restoration activities;
- The purpose of the project is to create an energy-efficient and sustainable business, with revenues from new plant higher than dismantling and restoration costs;
- The re-power project should be in line with the national energy strategy and integrated into the national distribution system;
- The project is based on CE principles, exploring internal and external re-use, setting a minimum material percentage and the type and variety of components to be recovered and promoting future materials re-use;
- New virgin materials and technology required for the regeneration project have to include characteristics that could be helpful to the future asset decommissioning.

36) Kover, Amy, GE Reports. Renewables: Comeback Kids: This Company Gives Old Wind Turbine Blades A Second Life. https://www.ge.com/reports/comeback-kids-company-gives-old-wind-turbine-blades-secondlife/ (accessed June 26, 2018)



The different stages that summarize the re-power process. Green stages are peculiar for the scenario.

Best Practices

Re-Power in a renewable energy power plant typically pertains wind turbines. Therefore, it considers replacing the old turbines with new ones.

Usually the new turbine ensures to improve the energy production either due to a better performing technology and to a higher size of the turbine.

The capacity of the plant is generally kept the same but the number of turbines is reduced thus minimizing the costs associated to operations and maintenance as well as the visual impact of the plant. As a consequence, the level of acceptance of the local stakeholders improves.

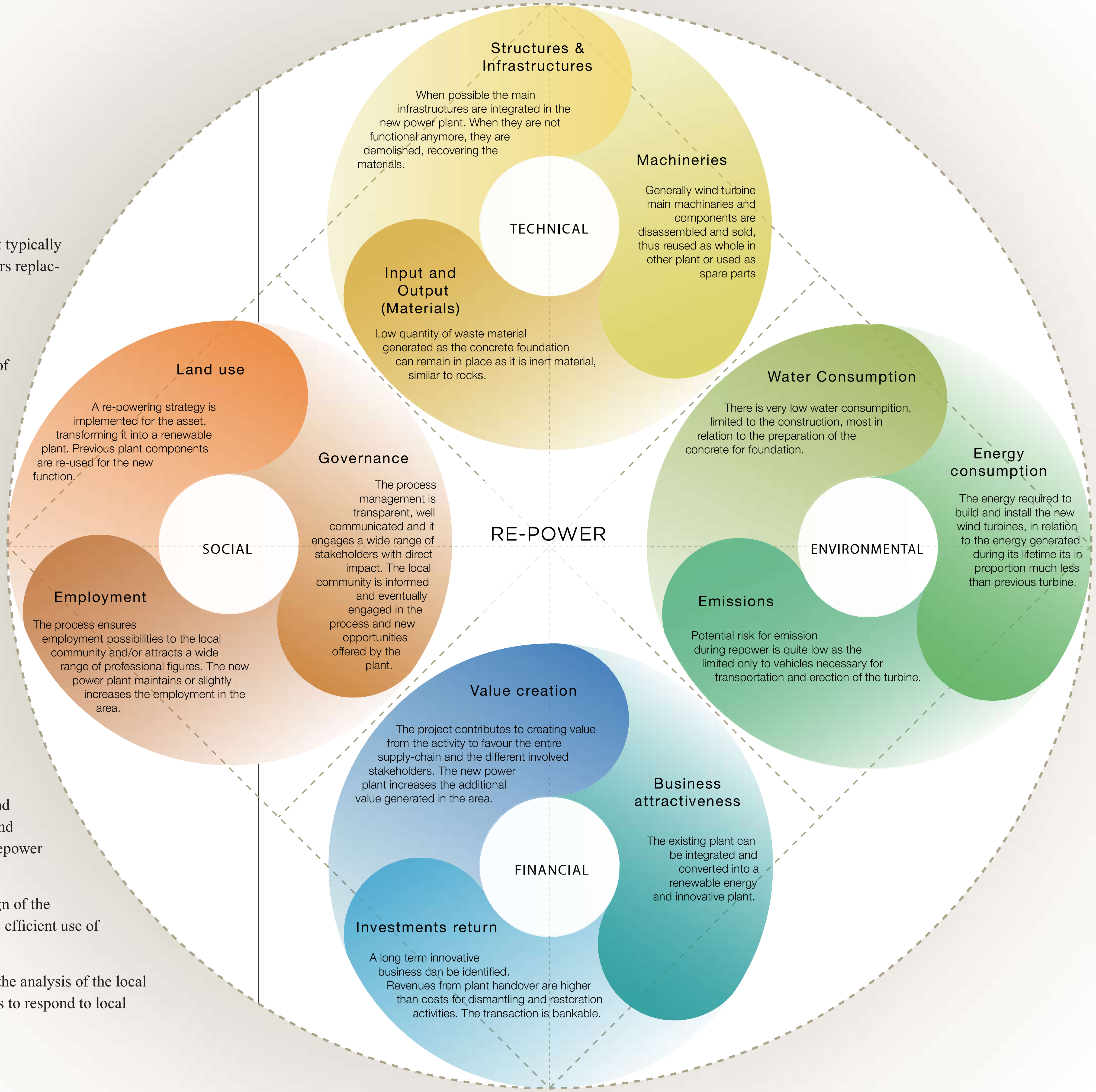
In any case the logistic, orography and technical aspects can limit the size of the new turbines, reducing also the benefit of a re-powering.

The drivers for re-power are generally the country regulations, the stakeholders interest and the economic feasibility.

The regulatory framework of a country can be favorable or disadvantageous to such scenario. It all depends on the environmental and regulatory policies that define the requests and processes of the Country for a company to repower its plant.

It is very important to consider the just design of the project to reduce the impact and improve the efficient use of the available resources and assets.

Another important item is the mapping and the analysis of the local stakeholders so to plan activities and projects to respond to local needs.



Focus 4 | Technologies and tools for Decommissioning

-33%

The reduction in costs at organizational level thanks to the use of BIM, due to faster delivery and reduced whole-life costs[37]

$14.6bn

The minimum projected global economic impacts associated with the spread of virtual and augmented reality by 2020[38]

The use of advanced technologies and tools would be essential to perform an effective decommissioning process. These would intervene at the different stages of an asset life cycle. Starting from the concept and design, through the maintenance and to the end of life operations.

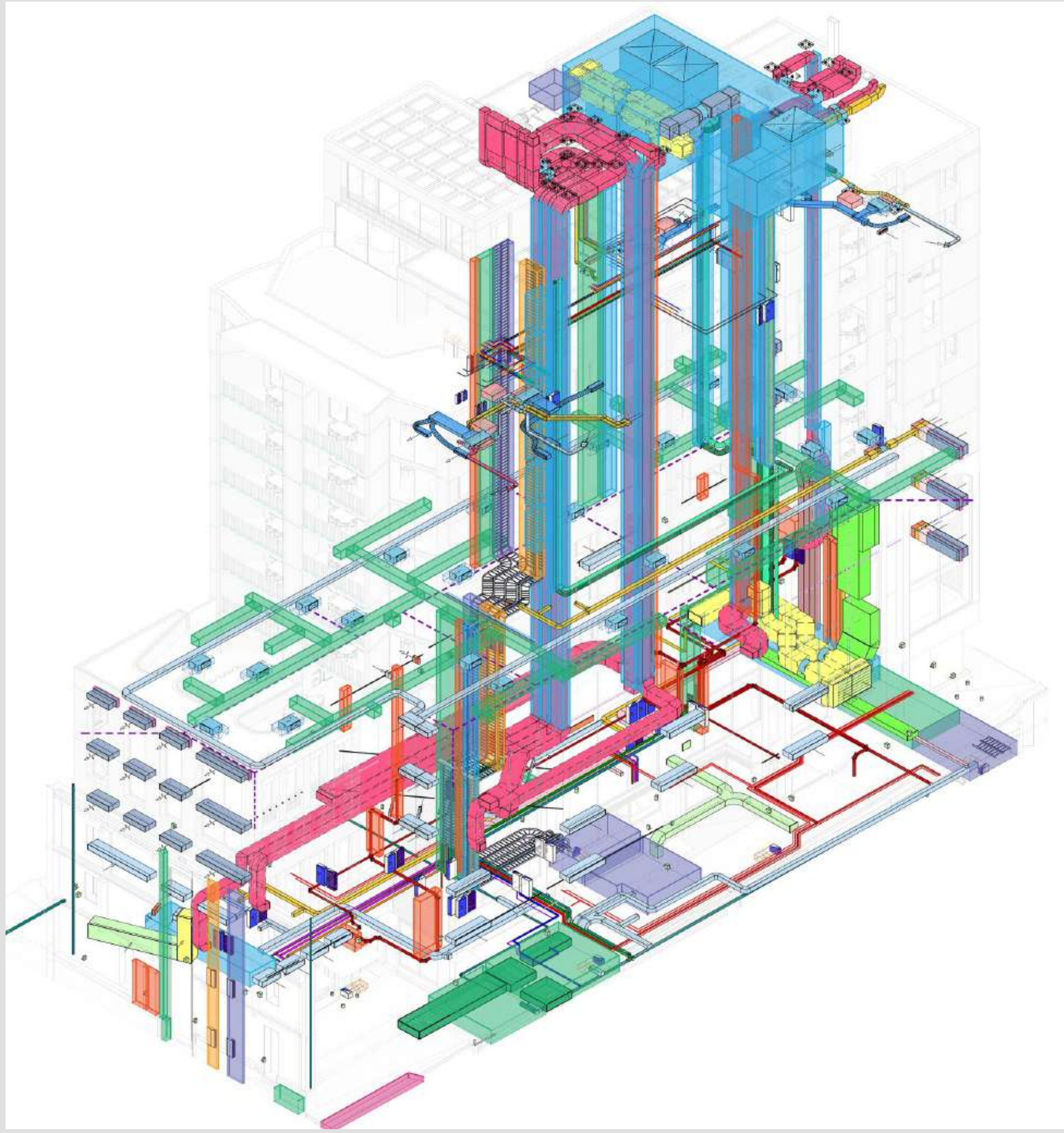
At the design stage the use of data rich platforms - such as Building Information Modeling (BIM) software - will be essential to provide a detailed set of information related to the items available within the plant.

The relevance of dataset to be associated to items to provide a detailed description of the materials composition, the type of components and all the information helpful to creating an item history is debated. That is the so-called Materials Passport.

Advanced visualization tools - such as Augmented Reality - will be relevant as well to identify - for example - the exact location of the items within the plant particularly for locations with limited accessibility. With this respect also the use of Virtual Reality might reveal beneficial as well to increase the level of understanding of the asset and its digital monitoring.

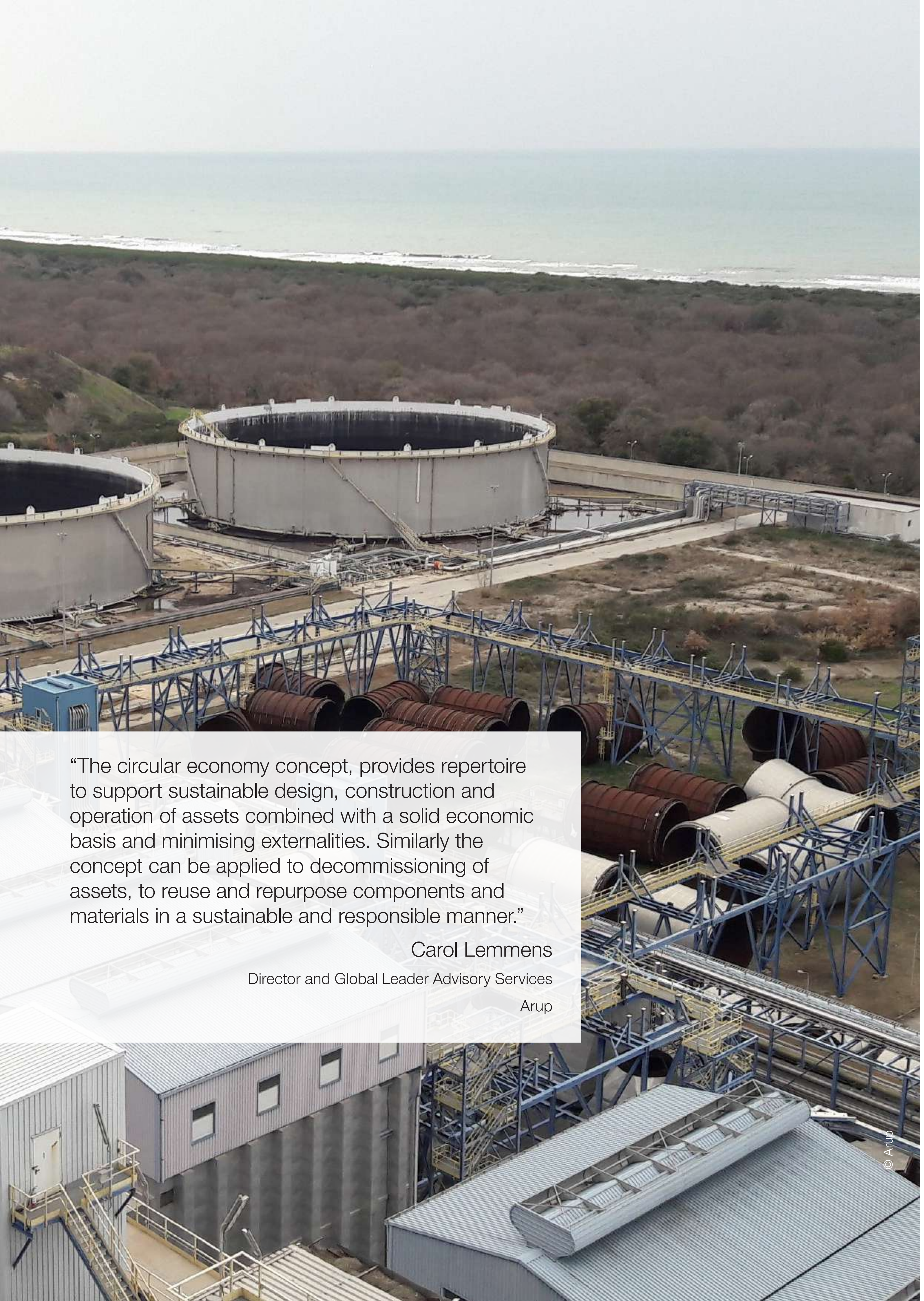
The concept of Digital Twin might play a role in the valorization of the asset and particularly in augmenting the capacity to include materials passports and to foresee the power plant as a Materials Bank. These digital models might be linked to digital platforms - such as Online Bidding and Auctions Platforms - that can be used to successfully create a market for secondary equipment.

In the case of existing power plants and assets not specifically planned with digital tools a different set of technologies might reveal beneficial in optimising the time and costs associated to the decommissioning process and particularly to identify location and type of items. In this case, technologies like Laser Scanning (e.g. LiDAR) might be helpful to scan in multi-dimension complex environments with a high precision. Consequently the scanned environment can be rebuilt in a BIM model so to include and associate the right set of information to be used during the asset life cycle to all items.



3D View of a building BIM model.

37) Construction National. Why Contractors & FM Providers can use BIM to gain an advantage. http://www.constructionnational.co.uk/news-menu/3495-why-contractors-fm-providers-can-use-bim-to-gain-an-advantage (accessed June 26, 2018)
38) Christensen, Laurits R. et al., Analysisgroup. The Global Economic Impacts Associated with Virtual and Augmented Reality, n.d.



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"The circular economy concept, provides repertoire to support sustainable design, construction and operation of assets combined with a solid economic basis and minimising externalities. Similarly the concept can be applied to decommissioning of assets, to reuse and repurpose components and materials in a sustainable and responsible manner."

Carol Lemmens

Director and Global Leader Advisory Services

Arup

05 From Waste to Resources

Excluding those infrastructures that will be reused in the new project on the site, there are three broad categories of resources generated from a decommissioning process. These imply different opportunities on the secondary market according to their embedded value and technical complexity.

- **Materials:** it includes a formed material or component that can be re-used in any number of industries. The key feature of this category is that the asset is reduced to its material parts - as far as possible - so that it can be re-manufactured. Examples of material recycling are the use of crushed concrete as aggregate or the re-smelting of steel. The sales proposition for these materials is relatively low unit value, high volume or weight materials. Material recycling can be considered 'business as usual' and the latter option to exploit the value of resources out of decommissioning;
- **Components:** it refers to parts of a system that can be reused either in the same or other industries without significant reprocessing. The items falling into this category are characterized by the relative simplicity of the components, such as structural steel members or pipes. Components tend to have high embodied energy and are largely available in a power plant. Their value is higher than scrap: e.g. the cost per ton of a steel beam is around ten times the spot price of scrap steel;
- **Equipment:** it includes the reconditioning and re-use of specialized equipment characterized by having several components working together in a system. Equipment often has high embodied and operational energy impacts. These items generally have high value and low volume: the cost per ton is around ten times that of a steel beam.

x10

The cost per ton of a steel beam compared to the spot price of scrap steel[39]

x10

The market cost of equipment made of steel compared to the cost of steel beams with same weight[39]

39) The Royal Society for Arts Manufacture and Commerce (RSA). Great Recovery & Zero Waste Scotland Programme. North Sea Oil and Gas Rig Decommissioning & Re-use Opportunity Report, 2015

5.1 New Value to Second Hand Items

+700%

The estimated increase of value for equipment and structures re-used rather than recycled in UK[40]

Reconditioning involves the refurbishment of equipment and components and any testing or certification required to address barriers to uptake in target markets. Not all sales routes will require product certification, and so a distinction shall be drawn between refurbishment and reconditioning.

Currently, in some cases the materials are recycled back into secondary raw materials at the end of their life with only a small fraction of the components being recovered for re-use. This is a straightforward EoL solution to waste reduction. As the approach has become more efficient with time and experience, the industry has become 'locked in' to this recycling approach and has developed a path dependent inertia. Overcoming this inertia and opening access to the higher values available through component and equipment re-use requires investment and intervention that can help to develop a new product pathways.

The final product value is expected to increase as we move from material recycling through component and equipment re-use.

Re-use has more value than recycling from both a financial and resource perspective because it preserves some or all of the functions of the product.

The significant barriers, also cultural, inhibiting greater re-use of components shouldn't be underestimated. They may be overcome if there is strategical view and a political will and commitment to support this approach. From this point of view, there may be considerable opportunity to reuse products and create value in industrial fields more geared to innovative solutions.

Given the high reported rates of material recycling, the perceived barriers lead to an inadequate consideration of re-use over recycling. Nevertheless, the requirement to apply the Waste Hierarchy (including re-use before recycling) is driven by 'Directive 2008/98/ EC on waste (Waste Framework Directive)'.

40) The Royal Society for Arts Manufacture and Commerce (RSA). Great Recovery & Zero Waste Scotland Programme. North Sea Oil and Gas Rig Decommissioning & Re-use Opportunity Report, 2015

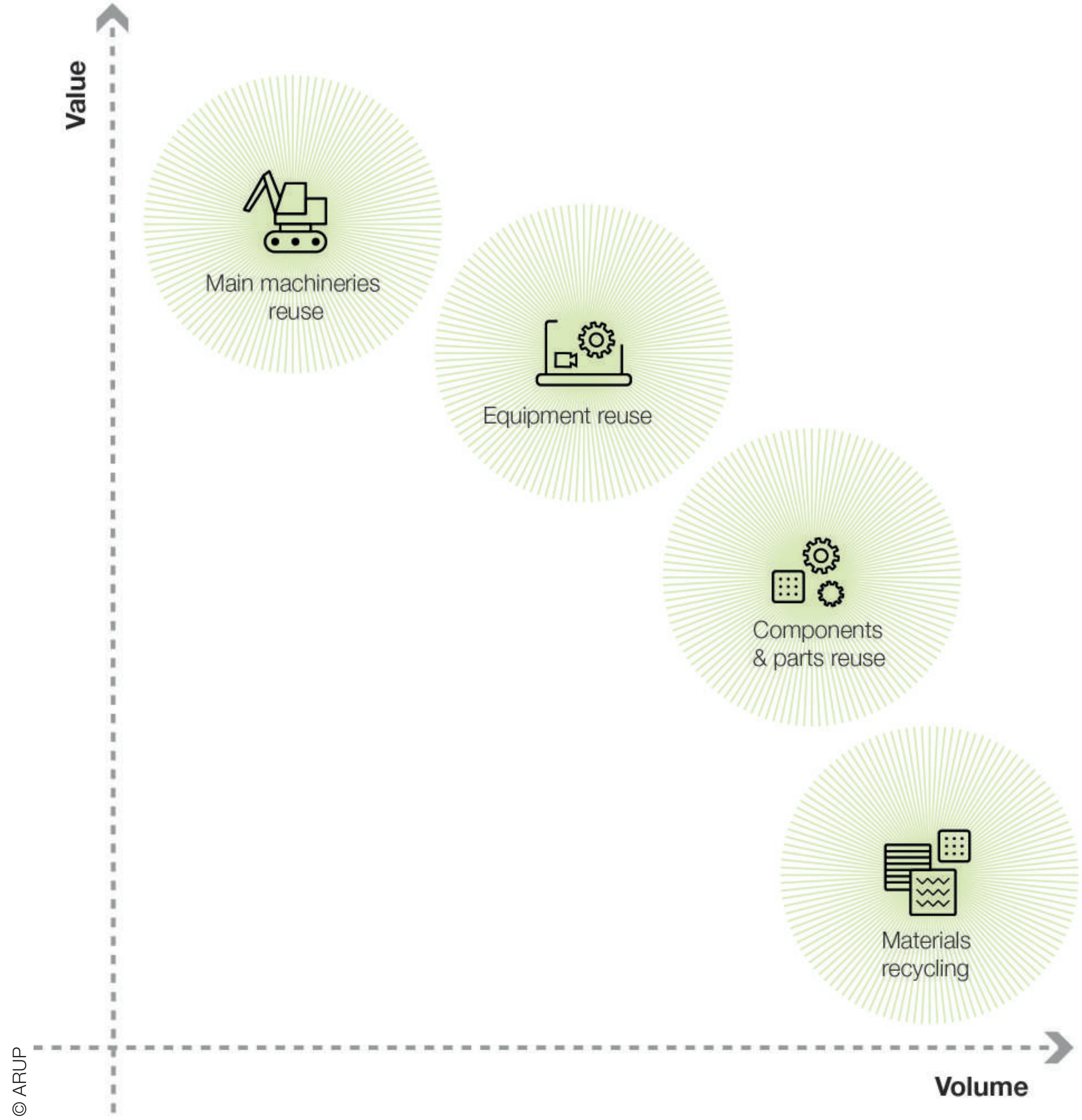


Diagram showcasing respective value and availability for items in a power plant.

30%

The amount of steel and aluminum that can be potentially reduced in buildings globally[41]

To step towards a circular approach, various and not conflictive threads can be adopted. In general, a flexible and gradual approach is recommended to fit specific needs of the projects (destination, schedule and progress of the selling process and dismantling activities, extent of dismantling, etc.).

A process for increasing the amount of materials and components that are re-used as opposed to recycled must be set out. This process will be applied to specific opportunities according to the peculiarity of each. Each step of this process may be undertaken by different companies, according to the contractual scheme adopted, and the companies involved are likely to vary depending on the material/product being re-used, adding a layer to supply chain complexity. The need to build and define the relationships between the involved companies is a key challenge.

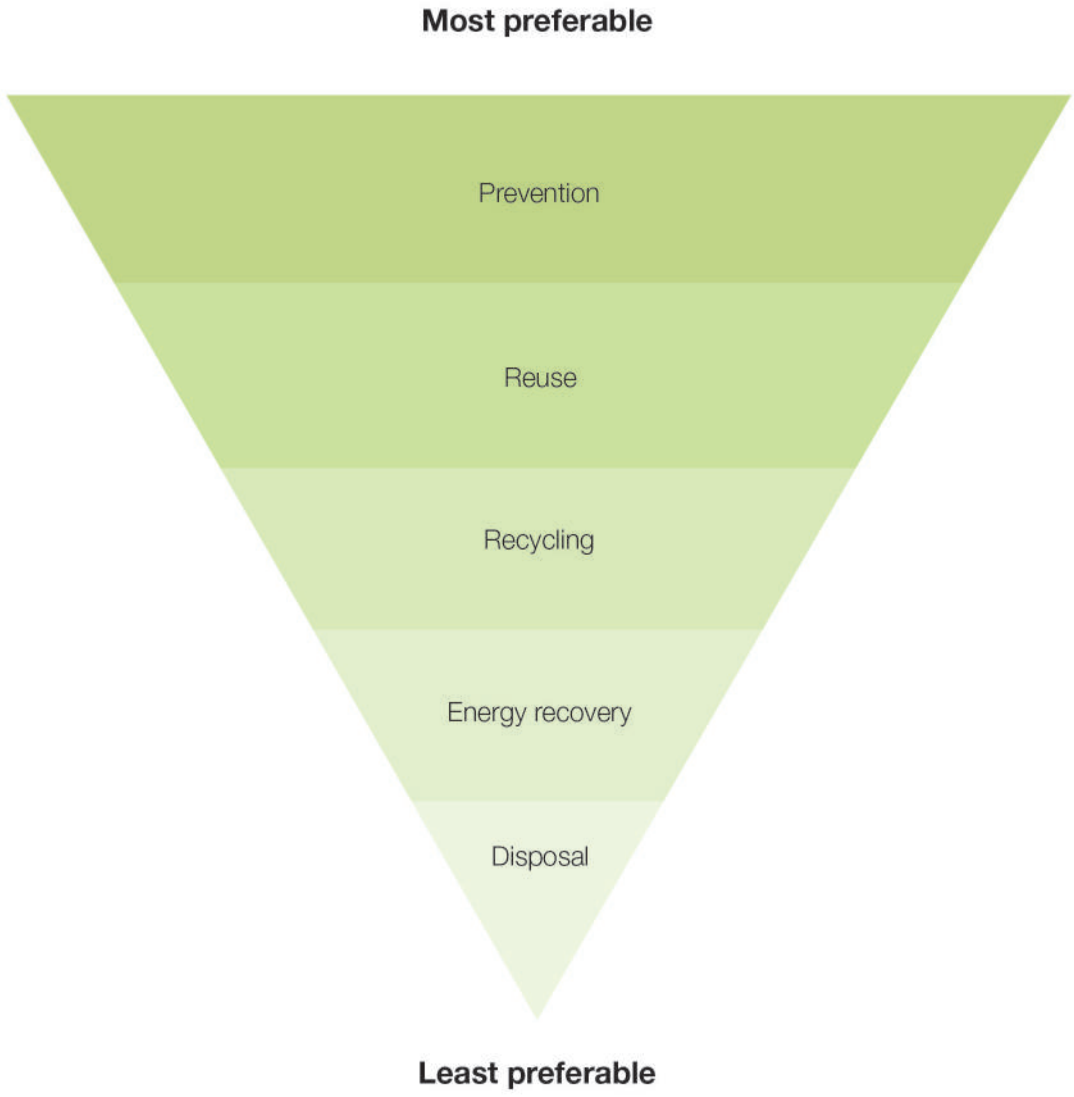
First of all, it has to be identified which equipment/components could be re-used, refurbished or reconditioned and which approaches could be adopted for this purpose. Given their wide variety in a power plant, it is conceivable that most of them may find interest in very different fields from the energy sector with a correspondingly larger potential market.

The reuse in fields that have less demanding requirements than the original one represents a favorable potential. While many parts of a plant could be usefully reused elsewhere, meeting the offer with a potential global demand that can come from geographical and industrial contexts different from the original one, is not an easy task. It requires suitable tools and a knowledge of the secondary market to identify which are more appealing.

The increasing attention to Circular Economy principles has led to a significant development of the second-hand industrial components market where a large number of specialized traders operate.

Given the above, the involvement of specialized companies can facilitate and optimize the recovery process as demonstrated by previous experiences that shown how the identification of correct interlocutors brings out opportunities that otherwise do not occur.

41) Cooper, Daniel R. et al. Reusing Aluminium and Steel Components at End of Product Life. Environmental Science and Technology, 2012



The waste hierarchy: from the avoidance and reduction to the disposal of waste.

70%

The amount of Construction and Demolition waste aimed to be recycled by 2020 in EU[42]

5.2 The Regulatory Framework

The regulatory framework related to the decommissioning of a Power Plant involves a wide range of environmental, health and safety aspects, actors and levels of actions, with most of them having specific technical and economical interlinking challenges.

The applicable legislation includes among others the Waste Framework Directive (2008/98/CE), the Water Framework Directive (2000/60/EC), the Environmental Liability Directive (2004/35/CE) and the Habitat Directive (92/43/EEC).

The regulatory framework concerns specific macro aspects such as waste management, secondary raw materials or byproduct deriving from excavated soil or debris generation and reuse and equipment's norms and technical standards.

Occasionally, some legal requirements could be a barrier to implement the CE initiatives. An example is the the lack of certainties and the uneven interpretation across different regions and countries concerning the end-of-waste criteria and the reuse and possibly sale to other industry/sectors. This is particularly true for multinational companies trying to standardize the approach to a Circular Economy across the organization.

Current end-of-waste regulations run the risk of promoting low value recycling rather than the adoption of more valuable approaches for secondary raw materials.

Mapping existing legislations and looking closely at its impact on Circular Economy models as well as on how they interact with each other is a necessary starting point to avoid inconsistencies or overlaps.

42) European Commission. EU Construction and Demolition Waste Protocol, 2016

5.3 Stakeholders Map

Preliminary to the start of a decommissioning activity, there is the identification of the main stakeholders and their priorities, in order to define actions and projects aimed at maximizing the benefits deriving from the activity both towards the company and towards the stakeholders.

Actions with significant territorial impact in terms of the environment, the social and economic aspects, such as those of the decomissioning of a power plant in fact can not disregard the sharing of objectives and goals of the project with the main stakeholders, especially at local level. These will include local institutions, trade associations, associations representing civil society, universities and training and research centers.

The subsequent interaction with these subjects will allow the identification of the most appropriate solutions for the development of the territory and the minimization of possible negative impacts.

An essential part of the mapping of the stakeholders will also pertain the entire supply chain, regardless of the choice of the scenario (regeneration, repowering, total decommissionig). This is useful to identify suppliers that can contribute maximizing the circular potential of the project and make choices that minimize the impact on the activities of suppliers already operating on the plant.

5.4 Financing requirements

75%

The number of senior executives in investment firms that sees company's sustainability performance as important to their investment decisions[43]

Finance is one of the major enabler of the transition towards a Circular Economy. It is not an easy task to achieve a Circular Economy without fundamental changes in the way we produce, design and consume. This is the reason why huge investments are needed at a global level. Innovation is playing a fundamental role in stimulating these changes, by helping to maximize their potential and mitigate risks.

Circular Economy business models introduce new implications for financing requirements that are still to be fully understood. Finding the more effective way to mobilize investments is clearly a priority for all the actors in the finance sector for this reason, new models in credit scoring technology need to be put in place to eliminate the barriers to innovation within a banking organization.

In fact, considering the usual drivers applied in financial markets, large and well-established companies can easily raise finance to support new projects in the Circular Economy field because they can rely on strong track records and available collaterals.

It is possible to assume that a well-established company can leverage on its linear assets and results to financially support its circular projects internally through cash flow retention and externally through its creditworthiness.

Circular Economy can be considered an investment opportunity addressing at least three main objectives:

- Portfolio re-generation - proactively manage the forthcoming stranded assets (loans from linear companies which are more exposed to some sources of volatility);
- Risk-return improvement - a lower level of credit risk for circular counterparts in relation with their linear peers;
- Revenue growth - developing new product/service lines that focus on the transition toward the Circular Economy.

43) The Boston Consulting Group. Investors Care More About Sustainability Than Many Executives Believe. https://www.bcg.com/publications/2016/sustainability-strategy-investors-care-more-about-sustainability-than-many-executives-believe.aspx (accessed June 26, 2018), 2016

In order to assess the possible additional bankability of the circular components of a project, lenders need to receive, by the Sponsor, a business plan containing an estimate of typical revenue/cost items such as, inter alia:

- Revenues from the sale of materials and components on secondary markets;
- Pure dismantling costs;
- Dismantling costs with a view to the reuse of part of the materials and components;
- Costs for reconditioning and testing of materials and components intended for sale on secondary markets;
- Site reclamation costs;
- Costs of reconditioning of infrastructures and constructions to adapt them to a new use;
- Costs of technical/engineering design and of the various consultants/professionals necessary to undertake the activities mentioned above and of the related permissions (soft capex).

90%

The number of investor executives that considers sustainability as an important theme[44]

On the basis of these estimates and standard structuring principles (Debt Service Coverage Ratio - DSCR - and tenor of financing), lenders can check the financial sustainability of the cash flows generated by the project, establishing the debt service capacity and, indirectly, the amount of the debt financing.

In addition to the forecasts of the plan, it will be necessary for banks to identify risk mitigation instruments such as, for example, capitalization commitments by Sponsor/Sponsor guarantees for delays, increases in costs and/or any cash shortfall.

The possible enhancement of the circular component will be interdependent, inter alia, on the following elements:

- The time horizon;
- The reference market;
- Any contractual agreements with third parties.

€1.8tn

The potential benefits in EU by 2030 thanks to a circular model[44]

€115bn

Potential investment unlocked for the built environment in EU by 2025 thanks to circular innovations[45]

Focus 5 | Supporting the Transition to a Circular Economy

Financial institutions could have an important role in supporting a new circular upstream supply chain model. Such a model is fundamental in providing the circular inputs to realize circular projects, including energy, materials, components, etc.

This new paradigm is going to change not only the way circular companies perform their businesses but also their accounting systems with possible impacts on their financial ratings.

As risk assessment metrics and models are structurally resilient and need time and backwards data to change their approach and results, new additional systems of evaluation are envisaged. Investments in R&D, changes in business models and intangible assets should be correctly evaluated.

Widening the view at the level of the supply chain and highlighting all the potential for join value creation, can also help to better understand the opportunities of innovative companies in the sector and finding the right financial instruments to support them.

When it comes to the features that a project developed in a circular perspective should have, the following applies:

- The realization of the project should see a containment of costs considering the use of reconditioned materials;
- The completion of the construction or completion phase should be completed more quickly with an attenuation of the risks linked to the increase in costs and the duration of this phase;
- The terminal value of the product/plant should be significantly higher than zero and tends to be estimated ex ante;
- The project could benefit from a faster authorization process than the standard;
- The project could have a significant and positive "social" impact.

Some important conditions shall be fulfilled so that the benefits (in terms of funding) of a project can be implemented.

Launch of a supply chain that operates in a Circular Economy perspective:

- Full traceability of the materials used for the project;
- Starting a secondary market, sufficiently often and responsive in terms of prompt determination of the price of used materials and their easy liquidation;
- Development on the market of Operators who make available to the Sponsor or Lender guarantees aimed at compensating the material used in the project in case of claims;
- Development of a regulatory framework that facilitates the launch of projects with a view to the Circular Economy.

The Sponsor, on its side, can provide a number of advantages - in terms of financing – with respect to the Circular Economy. These include:

- The reduction in the cost of the project may favor a reduction in financial needs with the same generated cash flow;
- Potential lengthening of the duration of the loan by counting on a longer useful life of the materials used in the project or the ex-ante definition of a debt amortization plan that takes into consideration the definition of a portion of the balloon debt correlated to the terminal value of the asset;
- Overall reduction of project risks resulting in improved access to credit.

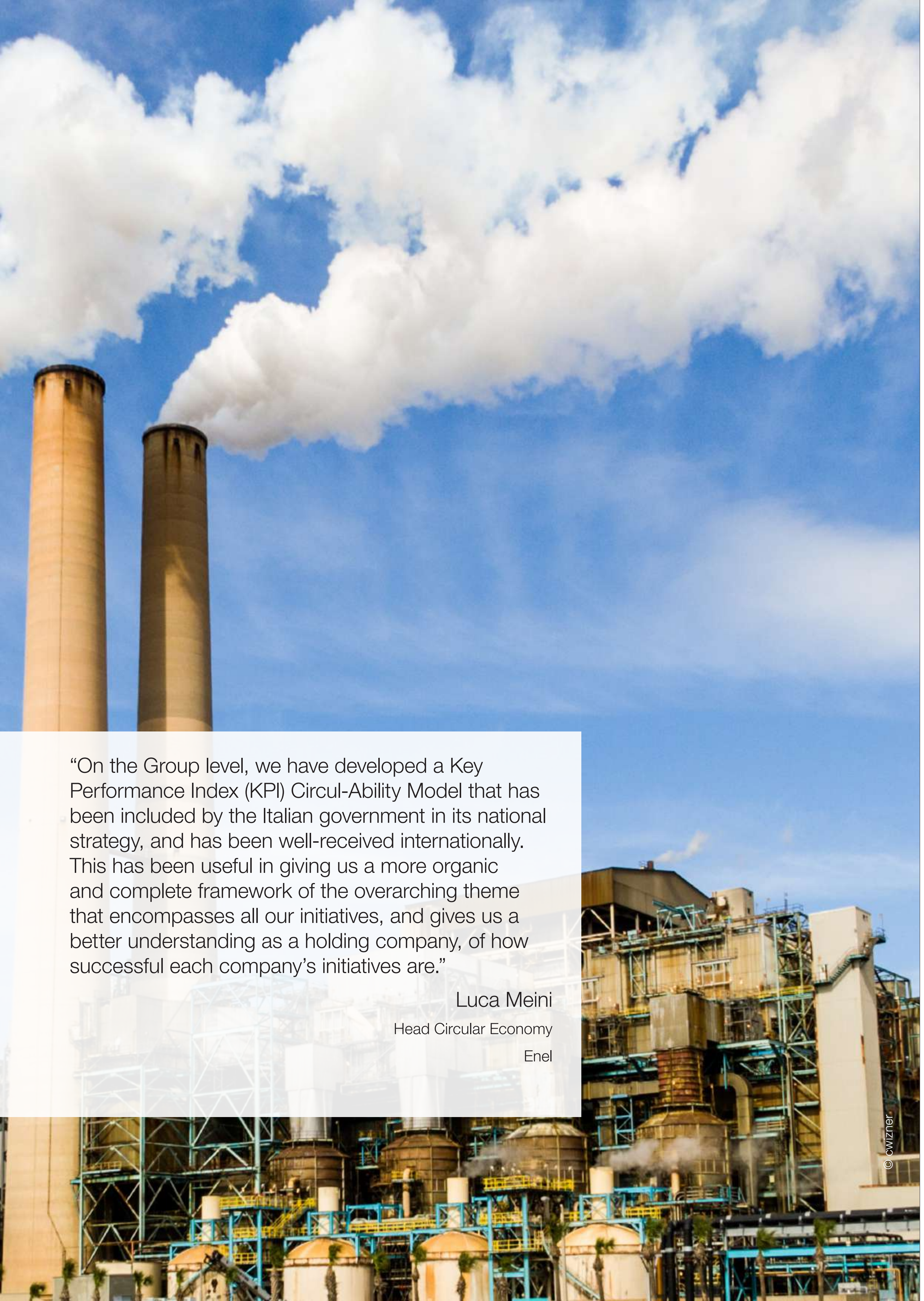
€2bn

The amount needed to scale up the number of construction and demolition waste recovery plants in EU between now and 2025[45]

€105bn

The investment required up to 2025 to design and produce circular buildings in EU[45]

44) Ellen MacArthur Foundation, Sun and McKinsey Center for Business and Environment. Growth Within: a Circular Economy vision for a competitive Europe, 2015
45) Ellen MacArthur Foundation, Sun and SystemiQ. Achieving "Growth Within", 2017



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"On the Group level, we have developed a Key Performance Index (KPI) Circul-Ability Model that has been included by the Italian government in its national strategy, and has been well-received internationally. This has been useful in giving us a more organic and complete framework of the overarching theme that encompasses all our initiatives, and gives us a better understanding as a holding company, of how successful each company's initiatives are."

Luca Meini
Head Circular Economy
Enel

06 Case study

A case study has been identified and analyzed with the aim of testing out the set of KPIs defined in the report. The case study relates to a power plant included in the framework of the Futur-e initiative (please refer to Focus 2). For such asset Enel made a call of ideas for regeneration projects.

The plant is located close to the seashore, in an area scarcely populated and with peculiar natural attractions around it. Moreover, the surrounding area is known for agricultural and sea products, sectors that are driving a touristic new vocation to the territory. During the period in which the plant was fully operating it contributed to the local occupation with about 300 equivalent external workers, employed mainly in the plant maintenance activity. It is clear that its decommissioning represents a critical issue in the occupation of the local communities.

Two projects in particular met the requirements of the call. They have been analyzed with respect to the brief set at the competition stage by using the KPIs and the best practices defined in present report. The data used in the following refer to the planning phase of intervention, therefore need to be verified and consolidated in future project development.

At the conclusion of the Chapter - to get a more qualitative understanding of stakeholder perspectives - a set of interviews have been undertaken. Stakeholders include investment banks, developers, asset owners and designers involved in the regeneration process of energy assets. This allow to get relevant point of views related to social, environmental and financial impact of a circular decommissioning process.

2M m^3

The total volume of the buildings of the power plant

40 km

The total length of infrastructures

10k

The total number of components

6.1 The First Proposal

900k m³

The volume of the existing buildings reused for the first proposal

700

The new number of employees reached at regime for the first proposal

The first project proposes the transformation of the entire site in a theme park based on water sport and adventure, joined to facilities for research and commercial areas. An important aspect relates to the valorization of local agricultural and ichthyic production, as well as to the accommodations facilities.

The project of transformation focuses on the maximization of reuse of existing assets while minimizing the impact of new constructions. More than 900.000 m^3 of existing buildings are reused (45% in volume of existing buildings), while new constructions sum 190.000 m^3. About 27% of existing road network is reused.

The transformation is meant to respect the surrounding landscape and environment. Water is a general guideline of the theme park and use of green areas is maximized, being almost 65% of the total site area.

Almost 85% of waste material produced through the decommissioning is planned to be reused as raw material, part of it directly on site (concrete), while it is foreseen the enforcement of specific programs dedicated to the reuse of existing machineries and components for their original purpose.

A little part of the components will be reused in the regeneration project, being part of auxiliary systems that will be refurbished and left in place (e.g. fire fighting systems, waste water treatment, etc.). Part of the major mechanical and electrical components would find a new use in Enel's industrial facilities, while secondary components would be in part repurposed in other industrial context or sent to the raw material recovery chain.

Regarding the business plan of the initiative the ROI is estimated to be 19% after 5 years. Concerning the social impact the project claims to employ around 700 workers at regime.

Following page includes the main parameters for this proposal of regeneration.

SOCIAL

UDM[-]	KPI
Land use	
0,64	Green / buildings total area
Governance	
0,4	Stakeholders involved in the process [Total / Actual]
0,63	Local stakeholders involved
Employment	
2,55	Employment offered after the transformation / employment offered previously by the power plant
1,00	Short term/total employment during the process
0,00	Long term/total employment during the process
0,75	Short term/total employment after the transformation
0,25	Long term/total employment after the transformation

TECHNICAL

UDM[-]	KPI
Infrastructures	
0,28	Length of infrastructures reused after the intervention / total length of infrastructures before the intervention
0,45	Number of reused buildings / total existing buildings before intervention
Machineries	
0,02	Number of components reused after decommissioning / total number of components
0,28	Number of components repurposed after decommissioning / total number of components
0,7	Number of components recycled (raw materials) - after decommissioning / total number of components
Materials	
0,15	Waste material / total material generated through the decommissioning
0,75	Virgin material / total material introduced through the decommissioning

FINANCIAL

UDM[-]	KPI
Investment Return (ROI)	
0,19	ROI = (gain from investment - cost of investment) / cost of investment
Business attractiveness	
0,12	Development of innovative business [% of GDP created by innovative -"virtuous" businesses / on total GDP variation]

ENVIRONMENTAL

UDM[-]	KPI
Water consumption	
0,5	Raw water / total water consumption
Energy Consumption	
0,08	Energy from renewable sources / total energy used

Key performance indicators addressed by the first proposal.

6.2 The Second Proposal

790k m^3

The volume of the existing buildings reused for the second proposal

200

The new number of employee reached at regime for the second proposal

The second project meets the expectations of local communities both with respect to sustainability and continuity with local culture.

An open-air touristic facility, including 1200 high level wooden villas and relevant services, along with commercial activities aims at valorizing local products and a theme park dedicated to water sports.

The project, once in operation, is expected to host around 360 workers, beside the indirect impact on local economy.

Due to the nature of the project, the extent of green areas is further increased, up to a coverage of almost 95% of the total area.

The demolition works will be carried out maximizing the reuse of existing equipment and components as well as considering the reuse and recycling of waste materials (almost 85%).

Same considerations as for the first project apply to the recycling of both main and secondary components.

In this case the existing internal road network is reused for a large part (55% in length), alongside existing buildings (790.000 m3 equal to 39% of total). A large part of the new constructions (90%) is made of wooden houses.

The ROI is estimated to be 25% after 5 years.

SOCIAL

UDM[-]	KPI
	Land use
0,96	Green / buildings total area
	Governance
0,4	Stakeholders involved in the process [Total / Actual]
0,63	Local stakeholders involved
	Employment
0,67	Employment offered after the transformation / employment offered previously by the power plant
1,00	Short term/total employment during the process
0,00	Long term/total employment during the process
0,92	Short term/total employment after the transformation
0,08	Long term/total employment after the transformation

TECHNICAL

UDM[-]	KPI
	Infrastructures
0,55	Length of infrastructures reused after the intervention / total length of infrastructures before the intervention
0,395	Number of reused buildings / total existing buildings before intervention
	Machineries
0,02	Number of components reused after decommissioning / total number of components
0,28	Number of components repurposed after decommissioning / total number of components
0,7	Number of components recycled (raw materials) - after decommissioning / total number of components
	Materials
0,15	Waste material / total material generated through the decommissioning
0,8	Virgin material / total material introduced through the decommissioning

FINANCIAL

UDM[-]	KPI
	Investment Return (ROI)
0,25	ROI = (gain from investment - cost of investment) / cost of investment
	Business attractiveness
0,07	Development of innovative business [% of GDP created by innovative -"virtuous" businesses / on total GDP variation]

ENVIRONMENTAL

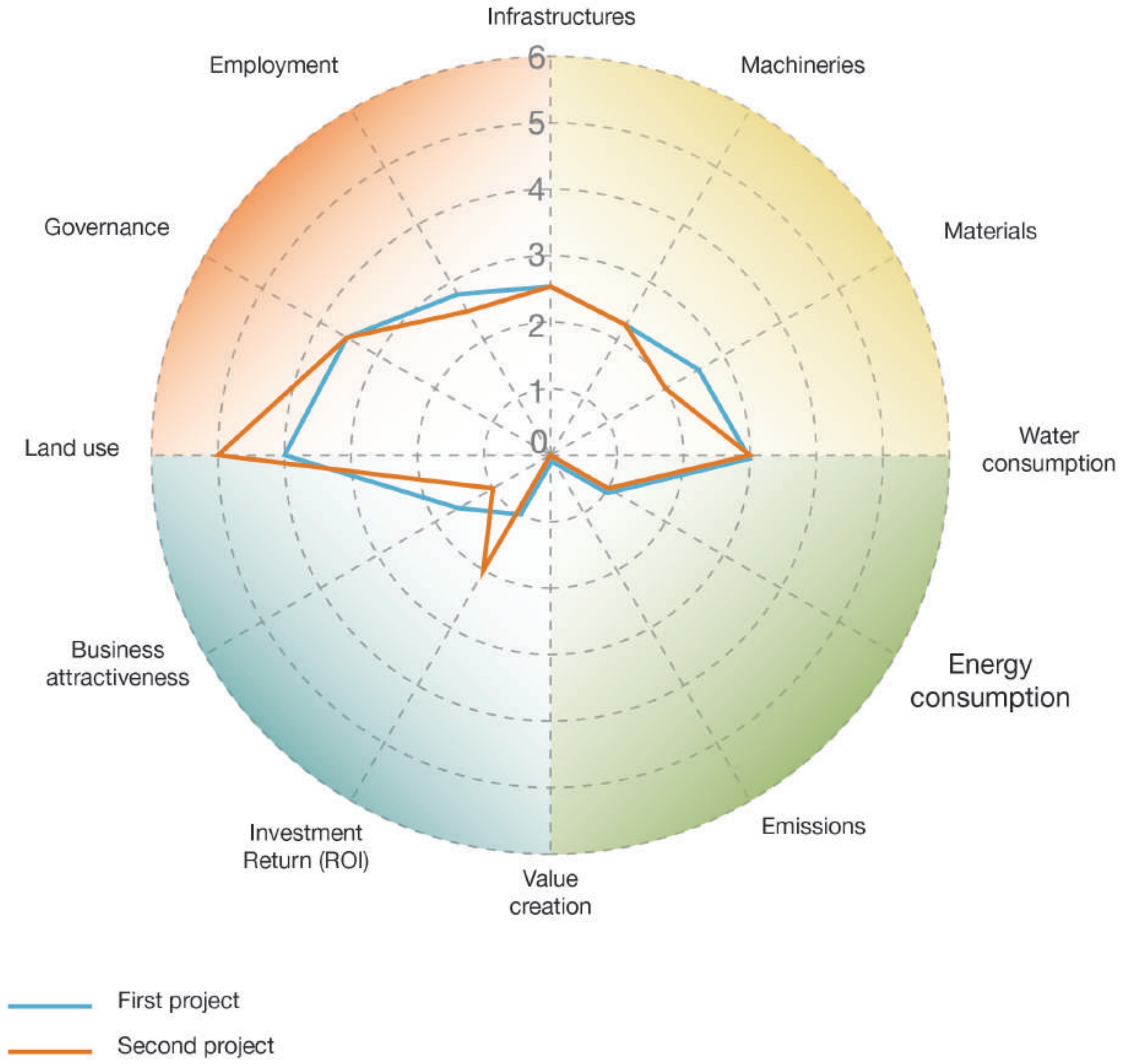
UDM[-]	KPI
	Water consumption
0,5	Raw water / total water consumption
	Energy Consumption
0,13	Energy from renewable sources / total energy used

Key performance indicators addressed by the second proposal.

6.3 Main Outcomes

The methodology set in present report allows to compare the two transformation projects by using the set of KPIs. These indicators alongside other key considerations - such as the solidity of investor, the alignment with local regulations, the alignment with strategic goals for the key stakeholders - would allow the asset owner to make an informed and objective decision. The following considerations can be made:

- Technical KPIs: both proposals have an overall good performance from the technical point of view, being the reuse of waste materials has been up to 85% in both cases. On the other side the low quantity of components reused in the regeneration projects suggests that the proposals have not been focused on these aspects. With this respect the use of the relevant KPIs set in present report might be instrumental when defining the brief to encourage a particular focus on such aspects as well. The two projects appear aligned from the point of view of machineries reuse being the demolition works and waste management performed by the Owner.
- Social KPIs: both proposals focus on the needs of the local community since this was a requirement present also in the tender brief. This explains the positive results obtained by the two proposals respect the employment, governance and land use KPIs. For example, the employment offered after the transformation is well above the employment offered previously by the plant, since this was an explicit requirement of the call. On the contrary the land use KPI highlights a more intense use of land for the first proposal respect to the second. On the one hand this allows a higher occupation, but on the other hand it forces to move away from the natural vocation of the place.
- Financial KPIs: the ROI has been required by the tender brief with the two projects scoring differently with that respect. KPIs shows a direct correlation in between the higher use of land and a higher ROI. However the two projects do not consider explicitly the



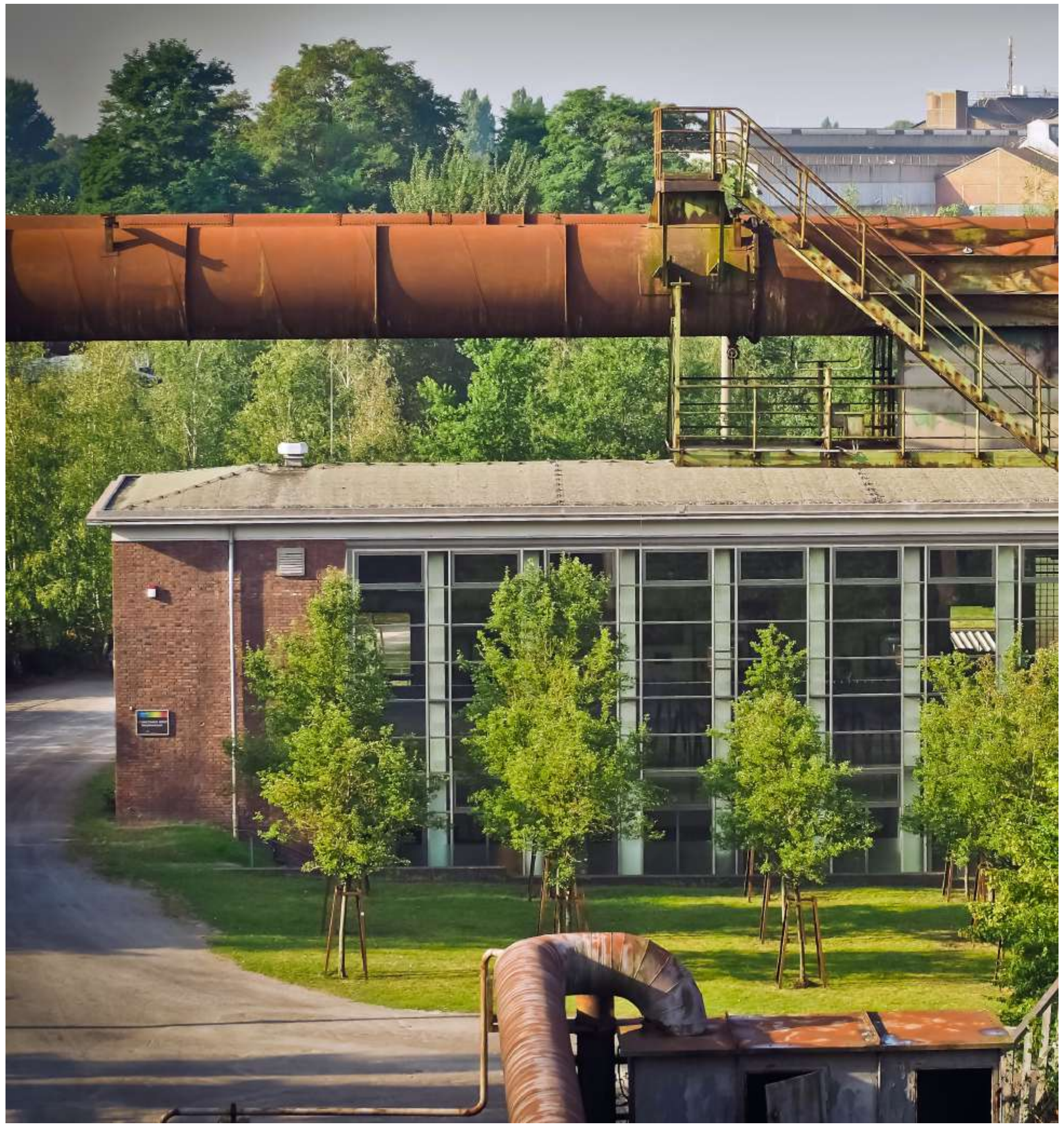
Comparison through a synthetic indicator based on the available KPIs.

business attractiveness and the value creation. Such KPIs would allow to better evaluate the financial aspects of the two proposals also in the medium-long term as well as to better understand the opportunities created on the local economy in the area of the site. In fact allowing a local financial return which is very relevant in a circular economy based initiative.

- Environmental KPIs: the call requires to assess the environmental sustainability, without defining explicitly the related indicators. If present from the beginning, the KPIs here defined, would have allowed to propose since the design stage lower emissions and a greater energy consumption from renewable energies with respect to the total energy. Although not explicit in the tender, a very positive result has been obtained by the water consumption indicator, as emerged from the KPI calculated for the two proposals.

As a conclusion, it can be stated that in the case study under examination, the proposed model allowed to highlight the main peculiarities for the two projects, from a quantitative and a qualitative point of view.

Bearing in mind that this has been an ex post evaluation, the defined KPIs might help to guide the final choice by the Owner concerning the technical, social, financial and environmental aspects of the renovation process. More importantly the methodology set in present document allows to refine and detail the assessment by providing further indicators that can be used both at the assessment stage as well as to possibly to set future tenders.



Industrial plant after an intervention of regeneration.

Massimiano
Tellini

Global Head Circular Economy,
Intesa Sanpaolo Innovation Center

Intesa Sanpaolo

Italian bank.

Challenges in financing the Circular Economy

'Despite the increasing awareness on how Circular Economy might be the engine for a positive development, obstacles to this systemic transition still exist. Circular Economy suffers from the uncertainty and risks that always affect innovative ideas. This becomes even more relevant when applied to a cultural concept, such as Circular Economy, aiming at positively disrupt the standard concept of the economic system lasted for more than a century.'

Economic potential of a circular decommissioning

'The concept of "material bank" is fundamental and positively disrupts what we think about design, development and construction in the built environment. For a financial institution, shifting the focus from the value of buildings themselves to the value of materials, ultimately results in a higher return of investments over time. Intesa Sanpaolo is highly interested in supporting such projects and is confident that circular construction activities will soon become the "new normal".'

Tilman
Latz

Partner & Design Director

Latz + Partner

Landscape architecture and urban planning firm.

Societal obstacles to a circular decommissioning

'The main obstacles for circular decommissioning processes do lie in a growing tendency to drastically regulate all human activities, products and processes, whether it concerns nature and heritage protection, regulations on accessibility, ecology, recycling, social usability. Whilst the desire to make our planet a better world is an understandable and principally good impulse (which we highly support), it seems to be a given drama of mankind, that the more we try to organize a good co-operation, the more our world becomes bare of attractiveness and charm.'

Circular transformation of an industrial site

'Latz + Partners specific process is based on an evaluation of spaces and structural issues, materiality and their characteristics, water and climate – all with the intention to invent new functions and processes into the given territories. A decommissioning process should always be supportive to the integration of an infrastructure into a larger environment. Such sites usually share a common economic as well as social history. And if decommissioning is developed as an integrative process, a successful transformation can usually be expected.'

Enel Green Power

Energy company operators.

Circular Economy applied to the renewable sector

'The theme can be applied along the whole value chain: starting from the development phase, with the definition of renewable plant type and with the design, construction and operation phases, incorporating the Circular Economy principles. This implies maximizing the use of renewable energies and materials and the reuse of components and assets so that they can have a second life with different function, also promoting the assets sharing and the implementation of projects with local communities.'

Transformation into a circular business

'The circular vision of the company was born internally from a series of different ideas, with the coordination and support of Innovation and Sustainability unit on the Holding level. Together with the development and organizational aspects, business opportunities were identified and an strategy was created, taking advantage of the company's know-how, finding new opportunities and collaborating with all external counterparts, from peers and institutions to research centers and associations.'

Nicoletta
Dante

Innovation & Sustainability,
Enel Green Power

Human Company

Development company.

A zero consumption real estate

'The concept of Circular Economy for us is about aiming at a zero consumption real estate. Our group considers important to enhance the logic and the philosophies of reuse of the existing assets that in the real estate sectors means defining new sustainable models of value creation. This concept, connected with our open air tourism activity - that requires minimum land consumption - is combined to the most modern territorial regeneration strategies without land use.'

Regenerating industrial areas

'The regeneration of some industrial areas is considered an operation of strategic cultural value. The success of the redevelopment of former industrial areas depends strongly on the degree of integration that the site has with the city and its surrounding area. It is important to plan, above all, the ability of a site to create economic, cultural and social activities on the territory to be regenerated and recovered with a new and sustainable industrial project.'

Marco
Galletti

CEO, Human Company

07 Conclusions

To date the approach to decommissioning of energy power plants has mainly followed a linear model. Therefore, the assets to be decommissioned are considered as an aggregate of waste materials and the main target for energy companies is to minimize the costs associated to the decommissioning activities.

This research reverts this paradigm explaining that both materials and the energy assets shall not be seen as a liability for the energy companies but rather as an important set of resources with a high potential value to be exploited. These resources may also generate benefits for local communities in terms of social and financial opportunities.

Through the report it is proposed a methodology based on Circular Economy principles - applicable to both existing and new built plants - that would guide the decommissioning of mainland power plants towards their regeneration.

To do so the research defines a set of KPIs that can be used at different stages of the decommissioning process. They would be a tool at the many levels of intervention to strategically create call for tenders and trigger circular proposals, as well as they can be used at planning stage to set the objectives of intervention.

Very importantly - as showcased in the case study included in the publication - these KPIs can be used to measure the success of a regeneration process by highlighting the benefits produced in environmental, social and economical terms.

Glossary

Auctions Platforms: it refers to the digital platforms used to sell any materials, components and parts via online auctions.

Augmented Reality: it is an interactive experience of a real-world environment whose elements are “augmented” by computer-generated perceptual information.

Balance of plant (BOP): it refers to all the supporting components and auxiliary systems of a power plant needed to deliver the energy, other than the generating unit itself.

Building Information Modeling (BIM): it is an intelligent 3D model-based process that gives architecture, engineering and construction (AEC) professionals the insight and tools to plan, design, construct and manage buildings and infrastructure more efficiently.

Commercial Operation Date (COD): it is the date from which a commercial/industrial activity begins to generate revenues.

Debt Service Coverage Ratio (DSCR): it calculates the repayment capacity of a borrower.

Digital Twin: it refers to a digital replica of physical assets, processes and systems that can be used for various purposes.

Environmental, Social and Governance Criteria (ESG): it is a set of standards for a company’s operations that socially conscious investors use to screen potential investments.

Global Reporting Initiative (GRI): the GRI Standards represent the global best practice for reporting on a range of economic, environmental and social impacts.

Gross Floor Area (GFA): in real estate, it is the total floor area inside the building envelope, including the external walls, and excluding the roof.

Light Detection and Ranging (LiDAR): it is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth.

Materials Banks: typically referring to buildings seen as materials banks that are functional to support secondary marketing and novel end of life strategies, by reducing the virgin resource consumption and by preventing the production of construction and demolition waste.

Materials Passports: a material passport is a document consisting of all relevant information related to the materials that are included in a product, construction item or project.

Online Bidding: online bidding is a modern, cost effective and paperless digital process of bidding needed in the secondary market for the construction industry.

Return On Investment (ROI): it is a performance measure, used to evaluate the efficiency of an investment or to compare the efficiency of different investments.

Virtual Reality: it is an interactive computer-generated experience taking place within a simulated environment.

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The concept of Circular Economy and its founding principles have emerged over the past few years as the best option to design and realize a sustainable economic system. Moreover, the fast technological transformation and the growing awareness on environmental challenges have helped accelerating its adoption.

Institutions at any level - regional, national and local - have the Circular Economy as a key topic in their agenda. At the same time companies in many industry sectors are assessing potential benefits provided by a circular approach to their business.

At the short-term - the Circular Economy applied to the decommissioning of existing Energy Power plants could provide social, economic and environmental benefits to the local communities and surrounding areas. Additionally when applied to the design of new power plants - including renewable energy - Circular Economy could provide a set of tools and best practices that will both improve the design and operations of the asset as well as influence the future decommissioning operations by making it more efficient and effective.

Present publication offers an approach to measure the potential benefits that such approach could deliver to project and processes through the full life cycle of an energy power plant and the assets it is constituted.

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