CHAPTER

7

RE-USE OF REHABILITATED SITES

7.1. Introduction

The rehabilitation of open dump sites is a complex process that considers both technical and biological aspects. Equally complex is the environmental impact of open dumps and the harmful effects that may occur long after their closure and rehabilitation. These negative impacts can be mitigated and minimized through the application of good design and implementation of the rehabilitation process but also, through a long-term after-care of the open dump sites.

The approaches and means for efficient post-closure practices need the establishment and put in action of an adequate strategy for after-care that can further minimize the potential of any unfavourable impacts from the rehabilitated open dump. Such strategy must envisage a conceptual plan for re-use of the rehabilitated sites and the relevant after-care quite early, during the design and early operational phases of the rehabilitation process. The conceptual plan has to deal with the after-use options of the rehabilitated site and commonly includes:

- Possible after-use of the rehabilitated open dump in respect to both current and anticipated land use in the area around the site;
- All technical and operational requirements that guarantee proper capping design and laying to fit the intended after-use, incl. materials to be applied;
- Landscape/surface outlines before and post-settlement;
- Setting up/preserving installations for performance of environmental monitoring/control activities.

The open dump rehabilitation activities include capping and re-vegetation in compliance with local regulatory requirements, followed by installation and further maintenance or replacement of existing gas/leachate collection systems, and demolition/decomposition of any infrastructure that is no longer needed. These activities lead to environmental, public health, and management benefits, especially now, when the societies are implementing post-COVID 19 recovery policies, measures and actions. The main benefits are:

- Diminishing the leachate generation, ground and surface water contamination, soil contamination;
- Restricting air pollution due to black smoke from burning, weakening the negative climate impacts from black smoke and methane;
- Minimizing the invasive odours, pests and spread of diseases, incl. vector transmission;
- Minimizing the risk of health and safety issues due to waste pickers accessing the open dump, namely minimizing the public health costs;
- Gas collection and treatment, especially during its strongest production period;
- Minimizing the costs related to putative loss of potable water and other resources, costs in land value, clean-up costs;
- Realization of cost recovery during the post-closure life of the rehabilitated open dump.

When planning the after-use of the rehabilitated open dump, several important factors have to be considered: the site location, the needs of the society/community at local level, the open dump surroundings in terms of landscape and land use, the nature of the rehabilitation activities. All these factors stipulate the design limits and determine the activities/structures to be performed/built on the rehabilitated site (Grudziecki and Buachoom, 2016).

In this context, the authorities that are responsible for planning and regulation minding have to be consulted as well, since the after-use of the rehabilitated site must comply with the local/regional strategic development plans and the anticipated ways of use of the land under rehabilitation. The rehabilitated site should not be isolated; it has to fit its topographic and eco-environment and must be considered as a design option rather than isolated and ignored piece of land (Jenkins, 2016).

All suggestions for after-use of the filled open dump have to be flexible enough to guarantee sustainability of this after-use regardless of changes in society planning or attitudes in a long-term perspective. In addition, regular reviews and (if necessary) updates of the after-use opportunities have to be envisaged, since this is a nice approach to ensure coherence between the rehabilitation activities and anticipated after-use of the site.

Currently, an innovative concept is emerging that considers not only the design of a simple site for waste collection but rather the planning of community desirable spaces and structures associated with the site after-use. Keeping in mind the potential after-use is a helpful clue to perform proper operations to align the final site profile with the desired after-use. For instance, land forms comprising slopes are not suitable for making parks and other open-space public areas (Artuso and Cossu, 2018).

The most popular after-uses of rehabilitated open dumps are related to recreational (incl. sport facilities, public open spaces, natural habitats), agricultural (crops growing, making pastures, for energy recovery), and specialized construction activities (Figure 7.1).

When planning the type of after-use, one has to consider that the rehabilitated open dump is a contaminated site and the after-use developments of any kind concerning the site land (plus the land of the site surroundings) have to be assessed by the relevant environment protection authorities. Moreover, any after-use developments should take place after profound risk assessment of the closed sites (*e.g.* risks of gas emissions, impact on water supply, etc.), and confirmation that they do not present risk any more.

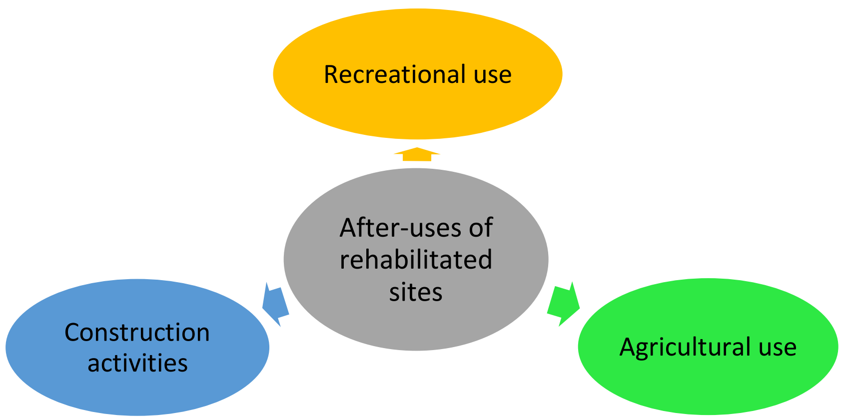

Figure 7.1. Most common after-uses of rehabilitated sites.

Considering the potential end-users of a closed facility for disposal of municipal solid waste (MSW), those engaged with the after-use of the rehabilitated facility – from owners, to local government officers, to community planners have to consider the above-mentioned options. The most appropriate end-use of the rehabilitated site must be decided upon regarding landscape impact, environmental sustainability, and societal agreement (Artuso and Cossu, 2018a). The societal and environmental benefits from the above-mentioned options are summarized in Figure 7.2. All of them can be treated as an asset to the local community in different ways (see sections 7.2 to 7.4 below). These assets may also serve in a different way: with direct benefits for the society (new land areas, wildlife habitats, commercial purposes, etc.) or with indirect impact (energy and materials recovery).

7.2. Recreational use

The recreational use option for the rehabilitated sites exploitation is a good opportunity for the society to improve the facilities for community leisure activities and thus, indirectly to enhance property values in the site surroundings. The recreational use, in fact, is the most exploited choice for closed open dumps after-use. Especially, when the rehabilitated site is located adjacent to heavy urban areas with dense population, the creation of a public recreational space that offers green zones suitable for natural tracks or open space sport activities is a big advantage since it promotes societal wellness and health. Additionally, this type of use contributes to national habitats restoration, support of local wildlife maintenance, observation and study.

Recreational activities vary not only in their character but also in their complexity: from plain open space to highly structured multipart facilities. The variations depend as well on the rehabilitated site landscape and on the requirements of the community regarding activities' characteristics. Consequently, a rehabilitated site may combine several recreational uses. Thus, determining the most relevant recreational use one has to consider diverse issues and find the proper balance between advantages and concerns. Both criteria are accounted for in the subsections 2.1 to 2.4 below.

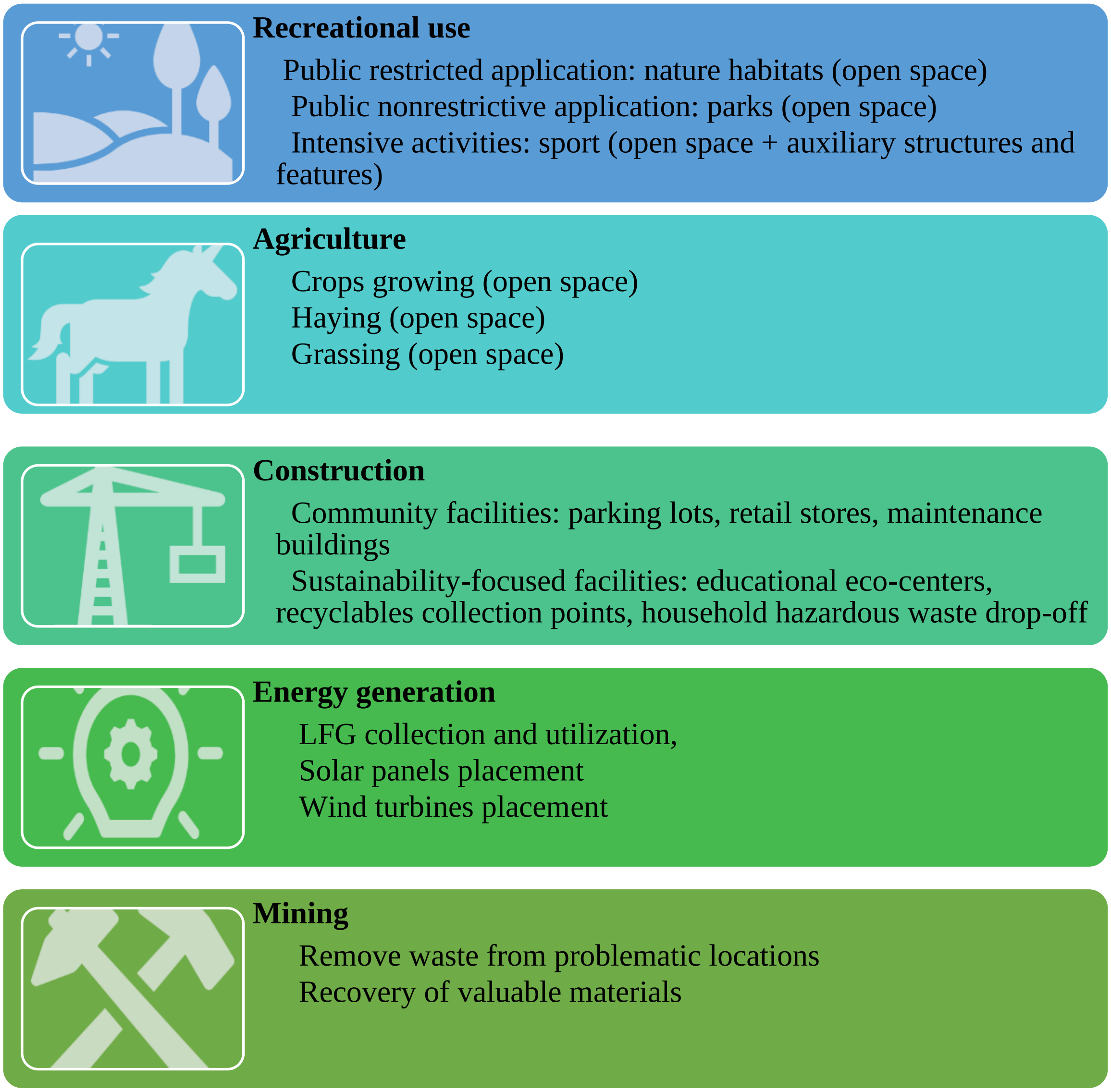

Figure 7.2. Options for after-use of rehabilitated sites.

7.2.1. Creation of Nature Sanctuary/Habitat

Establishing a nature sanctuary/habitat on a rehabilitated site provides for important advantages as compared to grassing or planting of monoculture (more or less a standard recultivation practice). For this establishment, diverse features of vegetation and landscaping have to be considered to successfully reach the objectives of a complete cover system including minimization of liquid infiltration in the underlying waste. Besides, these features have to fit as well the goal for provision of settings for wildlife and recreational delights that are as close as possible to the natural ones.

The selection of vegetation has to be done in a way that it fits the following requirements:

- To be adapted to the resident environmental conditions;
- To be native and/or drought-resistant;
- To exhibit limited mowing needs;
- To exhibit reduced fertilizer needs;
- To allow proper maintenance control: easy weeds/invasive plants inspection and removal.

This approach not only contributes to the natural appearance of the wildlife habitat but also counts for better management of the operational costs for maintenance of the vegetation cover (Simmons, 1999).

Before starting nature habitat creation activities, a dedicated survey has to be performed intended to gather useful preliminary information about the resident plant species in the rehabilitated area and surroundings, and the dominant conditions needed for the natural habitat. On the basis of the survey results, the construction of the natural habitat can be organized through the following approaches (Simmons, 1999):

- Natural regeneration: with little, if any efforts and interfering by humans;
- Creation of basic natural habitats elements (vegetation establishment, general landscaping) followed by restricted human interfering along natural development and for maintenance purposes;
- Establishment of the natural habitat main features and their maintenance over time to fit directly the anticipated by the humans' outcomes.

Whatever approach for the creation of the nature habitat is selected, a primary task that needs attention is the care about the integrity of functions of the vegetation cover system, protection of the site infrastructure, and satisfaction of the end-users' desires. This is a complex problem to be solved with various putative options. For instance, the components of the open dump closure system elements to be designed in a way that respect the wildlife habitat. The pre-development survey is very useful for this purpose, since its data can present information for possible negative relationships between the natural flora and fauna and the site infrastructure (e.g., evaluation of the damage risks by the wildlife species to the cover system and infrastructure).

7.2.2. Parks and sports facilities

Parks and sports grounds share the common feature of being open spaced, which in turn is an advantage over the recreational amenities that include buildings. It is due to the fact that these open spaces are not threatened by accumulation of gases that are of primary concern in indoor situations. As regards the water management, the activities in the open space recreational areas do not violate the standards for the open dumps closure. Namely, the runoff water has to be drained off and the formation of water ponds have to be avoided through careful selection of proper conditions for water flow management.

In general, the open recreational sites do not have structural buildings. However, light facilities, like sites for picnic, trails, benches, observational sites, pavilions, etc., may be present. When the recreational open space is located near a heavily urbanized area, precaution measures have to be taken to protect the cover system and the infrastructure associated with it. These measures commonly include placement of signs or notes to point out areas that are prohibited for some activities or should be treated with special attention.

In case of anticipated recreational activities that encompass the participation of many users, more structured buildings have to be envisaged. Here, administrative constructions, storage facilities, restrooms, etc., have to be planned that may require among the others lighting systems. It is advisable such construction facilities to be located outside the limits of the rehabilitated site. However, the efficient recreational use may need the positioning of some construction buildings right over the site. In this case, there are requirements for the foundations of these buildings and for their auxiliary elements (benches, pavilions, playgrounds), such as additional soil quantities and stabilizers of the existing foundation. Proper control of the LFG is also needed to avoid putative explosions.

One of the most practiced uses of the rehabilitated sites is the golf course. Although the golf course requires a relatively large area (about 700 000 m^2) (Golf, 2013), it is regarded as a good investment and potential net revenue generator (Wallace, 2000). The costliest part in the building of a golf course over a rehabilitated site is the large amount of soil that has to be relocated and laid to shape the ideal conditions for golfing. That is why those engaged with the after-use of rehabilitated sites have to consider the golf course building goal and integrate it in their pre-development plans for rehabilitated sites after-use.

In the design of a golf course, a collection system for LFG has to be implemented with the prospect to operate for a long period of time. This system has to fit both the technical features of the gas collecting device and the aesthetic needs of the golf course.

The anticipated place of the golf course must be assessed along the facility construction to assure the proper slopes of the playing surface that are important for the game rules and avoid any differential settlements that can lead to ponding or surface grades negatively with negative effect of the overall view of the golf course.

A specific feature of the golf course that differs it from the other recreational uses is the requirement for proper irrigation. Keeping in mind that the open dump cover systems aim to minimize the water infiltration in the facility body, the planning, design and operation of the irrigation system should be of particular importance, synchronized with the overall objectives of the site. The stability of the irrigation lines and the large and steady water supply are among the main challenges for arrangement of the irrigation. The option to use treated water for these purposes should be also considered.

7.2.3. Other recreational uses

Other recreational uses of the rehabilitated site may include open space facilities for sport activities like slopes for skiing and sledging, ice skating rings, archery ranges, cycle tracks, etc. Although these types of uses are not as common as the parks and sport playgrounds, they should be considered as a non-traditional option. It is true that these sport activities are risky because they are less practiced and the recreational area developers or regulators may be concerned about the end-user health. Nevertheless, if such a project answers the society's needs and meets the local regulations, it can be accepted and implemented.

7.3. Use for agricultural purpose

7.3.1. Grassing, growing crops, grazing animals

There are several agricultural uses that are suitable for the after-use of rehabilitated sites (Kovac and Goodburn, 2010). Among the others, grassing, animals grazing, planting and growing crops and silviculture can be listed.

Grassing is a good approach to post-closure agricultural use of the sites, since it offers the advantages of relatively easy performance and maintenance. However, there are several important characteristics of the grassing species that have to be taken in mind when planning a grassing project. For instance, the grassing species must be of rhizome-tuft type to form even, dense and sustainable sward. It is preferable they to be disease- and drought-resistant, tolerant in respect to nutrients availability, and adaptable to extremities in environmental conditions. If the grassing areas are not foreseen for grazing, the grassing species have to be unattractive for the animals. For the purpose of easy maintenance, species that do not require frequent mowing and possess good capacity for easy recovery after mowing are preferable (Maiti and Maiti, 2015).

For grazing purposes, the plants' species have to be fast growing and attractive to the animals (Grazing former landfills. Legacy Grazing case studies https://www.legacygrazing.org.uk/case-studies/landfills).

For silviculture, shrubs and trees are commonly planned to be planted at the peripherals and the slopes to allow protection against erosion and also to protect the grassland from other damages like illegal mowing, grazing or people interference (Moffat and McNeill, 1994).

7.3.2. Concerns with agricultural use

There are two main concerns associated with agricultural use of the rehabilitated sites:

- Transmission of putative contamination along the food chain through contaminated food sources from site's emissions;
- Maintenance of the integrity of the cover layers form damage due to agricultural activities.

To avoid such situations, good planting, harvesting and grazing practices should be applied. The efficiently rehabilitated sites supported by after-use care should not allow transmission of pollutants from the site to the flora and fauna on the site surface. The maintenance of Gas Collection and Control System (GCCS) and the water run-on and run-off is also very important. The interference with the cover system and site infrastructure could lead to damages and is dependent to a great extent on the on the thickness of the soil layer over the site coverings. This soil horizon should be deep enough to allow proper rooting of the plants while keeping the root system away from the critical elements of the cover layers and the underlying waste. The same is valid for agricultural machinery and/or wild animals. That is why the site infrastructure should be properly positioned underground and if located on the surface – adequately marked.

The use of rehabilitated sites for agricultural purposes is not a common practice everywhere. In some countries the national regulations do not specifically address the use of the closed sited for such purposes although the cover system maintenance and stormwater control are active. There are cases where agricultural use is highly prohibited. And finally, other countries' regulations do address agricultural applications in terms of animals grazing, crop production, silviculture with the precondition several important considerations of both technical and agro-meliorative character to be minded. Most of them are listed in Table 7.1.

Table 7.1. Technical and agro-meliorative considerations for agricultural use of rehabilitated sites.

Consideration types	Description
Agro-meliorative	Crops to be used for planting
	Requirements for addition soil in terms of soil layer thickness, supporting capability in respect to the root zone
	Depth of the ploughing
	Rates of the planting application
	Rates of the fertilizer application
	Establishment of crop production – time frame
	Measures to control the erosion processes
	Soil management
	Plant cultures rotation schedule
	Schedules for animals grazing
	Irrigation water supply
Technical	Necessary equipment
	Necessary facilities for storage and their location
	Intended changes for reuse of the land compared to current conditions

7.3.3. Use oriented towards resources and energy recovery

The rehabilitated sites can be used as energy generating facilities. There are three main renewable energy types that can be exploited: gas to electricity, solar and wind energy (Figure 7.3). The sites' re-use for energy gaining purposes can be either combined with other uses (e.g., recreational use) or be performed alone. In this second case, the risks for the potential end-users of the activities are smaller since only authorized personnel have access to the site.

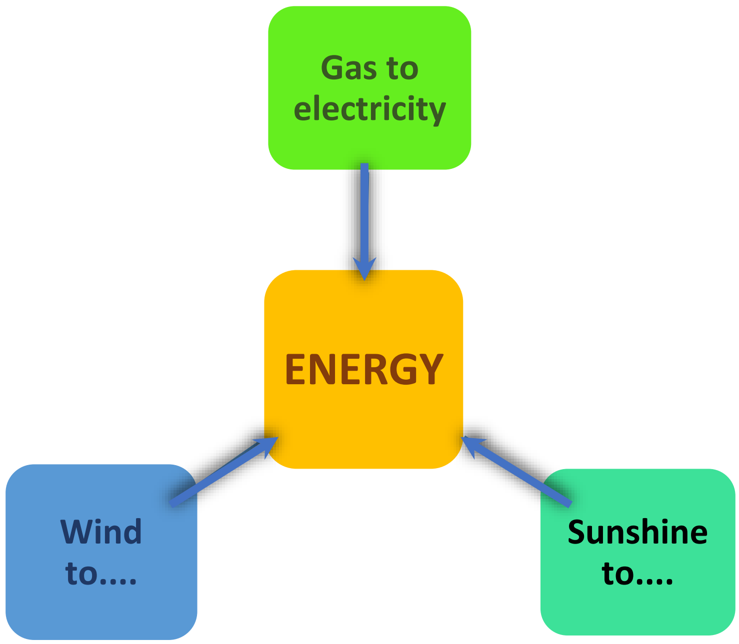

Figure 7.3. Renewable energy types associated with re-se of rehabilitated sites.

The main energy source for a rehabilitated site is the methane gas. It is converted to electricity that surpasses the explosion risk conferred by the methane itself. Additionally, solar panels and/or wind turbines may be dispositioned as another potential energy option. The energy production brings important advantages to the rehabilitated site and to the local community, like covering the needs of electricity (partly or entirely), equipoising the non-renewable energy sources, raising motivation for gas collection, all of which contribute in their turn to environmental protection through reduction of Green House Gases (GHG) and nuisance emissions.

The key considerations of implementing these technologies in rehabilitated sites are discussed in more details here below.

<u>Recovery of gas</u>

Methane and carbon dioxide are the main constituents in the gas that is extracted and collected through a GCCS. Its further use may be directed to two options: direct burning or utilization for electricity. In a second option, the raw gas can be transformed into fuel to produce electricity through few processing steps. A third option is to clean the gas to increase its energy content for other useful applications. Some of these energy converging technologies and their characteristics are listed in Table 7.2.

Table 7.2. Gas to energy converging technologies
(source:https://www.globalmethane.org/documents/toolsres_lfg_ibpgcomplete.pdf)

Technology	**Characteristics**
Gas turbine	– Operates at low gas concentrations – Damage resistant – Electrical efficiency: 40-80% – Low economic feasibility - requires high gas amount
Engine with internal combustion	– Electricity generation in a traditional manner with moderate efficiency
External combustion engine	– Mixes fuel and air to facilitate combustion – Gas pre-treatment is not needed due to its high tolerance to impurities – Electrical efficiency: 30%
Combined Cycle Engine	– Use gas and steam turbines – The gas turbine produces the heat to generate steam – Operates at large scale
Combined Heat & Power	– Generates thermal energy and electricity from steam/hot water – Can recapture heat, lost from turbines and engines increasing their efficiency

Microturbine (small combustion turbines)	– Operates with smaller gas flow at small gas concentrations – Needs gas pre-treatment to discard moisture and remove impurities – Electrical efficiency: 20-30%
Steam turbine (Boiler)	– Direct gas usage – Generates steam via combustion to feed steam turbines – Not very popular for electricity applications
Fuel cell	– Combines two flows (of gas and air) that enter two cells to produce electrons that are further transferred to an acceptor atmospheric oxygen – The efficiency depends on the gas quality: high methane concentration and small amounts of impurities

The energy generation efficiency of gas usage is influenced by many factors. Some of the most important include the size of the site, the type and age of waste, the GCCS efficacy, and the technology used to transform gas to energy. The amount of gas produced is often the crucial factor determining the economy of the convergence process and it influences for instance the electricity prices, and indirectly – impacts the environmental conditions.

The gas to energy conversion usually starts during site operation but it can continue for years after its closure. Thus, the asset value of the gas-to-energy systems can be enhanced through good planning of technologies that enhance the gas collecting rate during its strong periods of accumulation along the waste collecting activities. The planning of the GCCS in the view point of further site beneficial uses will guarantee better site utilization as a public asset.

Solar energy

The sites' utilization as a place for performance of solar energy projects is a relatively new initiative. The interest in this type of energy gaining is increasing recently since the costs of the solar systems is progressively decreasing (Millbrandt et al., 2013). Generally, the rehabilitated sites encompass large areas of open space that are very suitable for the placement of solar systems. Moreover, these sites are basically equipped with infrastructure for electricity distribution which facilitates the overall process of electricity generation and transmission.

The solar system operates on the principle: conversion of solar energy (cached by the solar energy panels) into usable electricity. There are two key types of solar power technologies:

- Photovoltaics (PV): semiconductors are applied that generate electric charge via PV effect. PV is the predominantly used solar technology.
- Concentrated Solar Power (CSP): lens & mirrors system is used that focusses and concentrates the sunlight.

To realize efficient solar energy production on rehabilitated sites several important factors have to be considered.

- The amount of available solar energy in the site area. This means that the average annual solar radiation on a daily basis has to be considered. For this purpose, the relevant solar radiation maps have to be explored for a period of about 10 years to have reasonable data for the solar system establishment cost effectiveness.
- Economic and political motivation. Here, the relationships with the electricity suppliers at local level have to be discussed. Another subject for discussion is the site logistics for transmission of the generated power as well as the site security.
  To determine if a solar project is feasible or not, a series of factors has to be taken to attention (EPA/600/R-14/349).
- **Location of the solar system**: the construction approach for a solar system depends on its positioning on the site – on top of a closed open dump or mounted in the ground. In the first case, the construction has to mind the integrity of the cover system and the other closure elements. In the second one, the excavations in the cover system and the placement of supporting the solar elements structures, have to be performed with precautions for

maintenance of the cover layer in intact form, avoidance of any damage of the site cap, and interference with the ACCS or stormwater management systems. In general, the flat landscape is preferred to the mounting approach. The positioning of the solar panels on flat site surface in a south-facing direction is a good option from an economic point of view, since any additional construction efforts can potentially increase costs and rise additional maintenance problems with the stormwater management systems.

- **Location of the site**: areas with a good solar potential and unblocked sunlight.
- **Security of the site**: the solar panels have to be placed in a zone free of physical dangers, such as rock-throwing.
- **Power logistics**: there must be connection to the power grid, an access road, and cover layers thick enough to host the electric lines. In addition, an electric company to facilitate reasonable costs and supply schedules
- **Economics and financial motivation**: these energy generating systems allow both visibility and flexibility in labour cost control. Both characteristics are important for marketing purposes. People will be motivated to pay more for solar power through tax credits, grants or incentives.
- **Policies related to energy provision**: energy policy motivations for solar power, e.g. a requirement 2 or more percentage of the energy to be of solar origin.

7.4. Use for construction purposes

Buildings' construction, as a part of the recreational use of rehabilitated sites has been discussed in section 7.2 above. In general, these buildings are light constructions assembled on modular principle and readily portable. The large permanent structures are another option for re-use of rehabilitated closed sites, although it is not the best one. There are concerns, the major of which is the strength of the foundation for the buildings and the gas migration.

The use of closed sites for construction of buildings is less popular than their recreational exploitation because of the great challenges that must be overcome to ensure both adequate performance of the structures and minding environmental rules. The obstacles that have to be considered are related to regulatory, design, economic, and safety issues.

In some countries regulations exist that stipulate the requirements specific to the buildings' construction on closed rehabilitated sites.

There are three issues of primarily importance related to the buildings on closed open dumps:

- Maintaining cover system integrity;
- Gas control;
- Building Foundation and Settlement.

7.4.1. Buildings maintaining the cover system integrity

The final cover system of the closed sites is the main factor, which all types of re-use have to consider. Its integrity depends on the moisture infiltration, gas control, and stormwater drainage systems.

Along the construction process, the foundation of the building is positioned directly on the site surface threatening the final cover system components with damaging. No penetration or deterioration of the penultima layers in the cover system is allowed. The physical stress to the cover and drainage systems must be minimized.

To avoid such stresses and mitigate the negative consequences, an additional soil layer is required to be poisoned on the final cover top. It will avoid interference with the stormwater drainage system.

7.4.2. Gas control

The chemical composition and physical properties of the gas make it explosive and potentially dangerous. Therefore, the buildings positioned on the rehabilitated sites must be designed, constructed, and maintained in a way that all precautionary measures regarding their interference with GCCS of the facility and putative explosive or toxic effects are taken into consideration. The obligatory requirements encompass:

- Gas ventilation. A wide-practiced measure in this context is to arrange a venting layer between the building slab and the subgrade. It is most commonly composed of a geomembrane covered by a permeable layer and a system of perforated pipes whose end location is outside the buildings. Such venting layers help avoiding gas intrusion through the buildings' foundation. A possible penetration is further secured by placement of a sealing cover.

- Gas monitoring. Permanent or recurrent monitoring of the buildings constructed on rehabilitated sites is another important measure. Usually, methane sensors are placed inside or under (in the foundation venting system) the buildings. These sensors indicate specific methane levels threshold (about 25% of the lower explosive limit) and duly alarm about it. The same approach is used for other dangerous gases, e.g. hydrogen sulphide. As an additional precaution, gas samples may be collected at certain time intervals for evaluation of gas chemical composition through laboratory analysis.

7.4.3. Requirements for building foundations and settlement

The construction of the buildings located on closed sites has to be performed in compliance with the engineering and construction techniques envisaged for foundation materials with lower quality. The compressed waste in the site body represents such a type of material since it does not have the same strength as the soil.

At the stage of building foundation design, two important factors have to be taken in mind (Sharma and Anirban 2007). These are:

- The bearing capacity of the site surface. This technical parameter accounts for the ability of the building foundation to support loads weighting down the ground surface through a structure. It is a short-term evaluation of the capacity for supporting the weight of a building. The bearing capacity must be calculated along the construction design, based on the data for the soil overlying the waste. In some cases, additional soil layer may be needed.
- The potential of the site for long-term settlement. In a long-term perspective, the rehabilitated site undergoes decrease of its waste volume and height resulting in surface settlement. It is due to the changes with the waste over time. The process of settlement is a multifaceted one. The reasons may be:
    - Physical and mechanical – particles reorientation and movement into void places or collapse of void spaces;

- Chemical – oxidation, liquid penetration that dissolves soluble substances and leads to leachate formation;
- Biological – organic matter decomposition of various rates depending on temperature, organic substrate presence, humidity.

The process of settlement encompasses two stages: primary and secondary. The primary one, known as well as initial settlement, covers the first few months after waste deposition. During it, a settlement due to physical and mechanical processes occurs. The secondary settlement is due to biochemical and physical-chemical decay that takes place over larger periods of time, at relatively constant load after primary stage termination. Logically, the older the site is, the fewer the settlement issues.

There are various techniques that help predicting the settlement in a long-term recourse. To avoid settlement issues after construction, at the design stage, a predicted settlement map and monitoring plan have to be prepared to enhance the design and the issue of operational and maintenance plans. The possible problems associated with the long-term settlements are related to sloping of the supporting system of the buildings, ponding of water, utilities line breakings, among the others. The technical decisions that can prevent the appearance of such problems encompass specific design to accommodate settlements, use of appropriate materials for the building foundations, flexible connections in the utilities, soil strengthening/stabilization.

7.5. Challenges to after-use of rehabilitated sites

The assessment of the efficiency of the after-use of rehabilitated sites as a community' asset indicates some challenges in reaching the desired objectives and imposes the implementation of corrective or preventive measures.

The list of the most commonly met challenges and their features are presented in Table 7.3.

Table 7.3. Challenges of after-use of rehabilitated sites.

Challenge	Characteristics
Cover system integrity preservation	Closed open dumps possess a cover system that is purposefully engineered. This system requires maintenance activities at regular intervals which aim is to control the conditions of the cover system, to detect and repair any damages. This

	maintenance is important as well for the management of the leachate generation, gas migration and waste materials exposure. In addition, a beneficial after-use may also cause cover system damage. That is why, monitoring and maintenance of the cover system is mandatory for all after-uses of the rehabilitated sites.
Gas management	The migration of gas from the site must be kept to minimal levels. For this purpose, the site must be equipped with an active gas collecting and controlling system or at least, a passive gas venting one. The proper functioning of these systems prevents explosive conditions since it does not allow gas accumulation in narrow places or within buildings. The putative gas accumulation is of special concern for the structures positioned on the top of a rehabilitated site. These systems for collection, treatment (if needed, e.g. for energy gaining applications), and use of the gas have to operate until the gas amounts reach very low levels. This is valid for all cases, regardless of final gas utilization.
Leachate management	Leachate is formed when water and waste fall in close contact. This liquid is a potential risk for human health and an environmental problem, thus it must be collected and removed from the site during its operation and post-closure. The activities related to collection, removal, and subsequent treatment are subjected to leachate management operational components. The leachate system has to be monitored and maintained to prevent environmental release.
Ground/surface water monitoring and protection	Groundwater has to be monitored at a regular basis, since accidental release of chemical substances for different site activities may lead to unfavourable conditions and therefor, must be prevented. For this purpose, the site groundwater resources must be accessible through monitoring well from which samples for chemical analysis can be gathered.

	Surface water quality has to be monitored and controlled as well, since contamination due to leachate leaking may occur. Besides, improper stormwater and erosion control and cover system damages also contribute to this negative impact.
Stormwater management / erosion control	The stormwater must be redirected to the surface water management amenities to prevent damage of the cover system. For this reason, stormwater and erosion control plans have to be prepared and followed. The control activities must be included into any planned post-closure site uses and reconfigurations.
Settlement and buildings stability	As a result of waste compacting and decomposing in the site body settlement of the waste and the cover layers of the site can be encountered. Settlement can negatively impact the buildings or other structures' foundations; it can compromise the utilities connections, and damage the cover layers. In brief, it can create unsafe conditions at the site surface. To prevent this, design approaches must be implemented that consider the putative harmful impacts of settlements on site uses and human life. Site use for construction purposes is a challenge, since buildings situated on the top of the closed site have to be designed in a way to resist settling (and gas leakage) and avoid interference with the covering system.
Site infrastructure	Rehabilitated sites possess complex infrastructure arranged before, during and after waste placement. These components are important for the facility operation and any interference of their functioning may threaten the site operational capacity. The effective performance of the infrastructure control guarantees proper management of the listed above challenges and successful site operation.
Public health assurance	The direct (minimized contaminated soil and water resources) and indirect (minimized spread of diseases and pests' control) impact of rehabilitated waste depositing sites in socioeconomic recourse

	represents an integral part of the COVID 19 recovery policy at European level. Nowadays, the global COVID-19 pandemic has necessitated the reconsidering of solid waste and open dumps rehabilitation management practices and approaches (Das et al., 2021).

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