IMPROVING DECISION-MAKING FOR THE ENERGY TRANSITION

Guidance for using Strategic Environmental Assessment

CHAPTER 13

INFRASTRUCTURE ASSOCIATED WITH RENEWABLE ENERGY DEVELOPMENT, AND SUPPLY CHAINS

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CHAPTER 13

INFRASTRUCTURE ASSOCIATED WITH RENEWABLE ENERGY DEVELOPMENT AND SUPPLY CHAINS

This chapter focuses on infrastructure that is associated with the energy transition, particularly new infrastructure required to support the development of renewable energy, such as transmission lines (trunk lines, new connections), sub-stations, access roads, and the development of smart grids with energy storage systems and facilities. The chapters in this guidance concerned with types of renewable energy (Chapters 5-11) all highlight that the construction of transmission lines, substations, and access roads is among the main causes of environmental and social impacts.

New transmission lines will be required to connect new renewable energy facilities to the national grid (where there is one) or to end-users, and the impacts of these should be assessed as part of a strategic environmental assessment (SEA) for any renewable energy plan, policy, or program (PPP) and subsequently for project-level EIAs. But equally, where renewable energy development is likely to require developing a new grid (or elements of a grid) or major upgrading of an existing national energy grid, it would be prudent to conduct a bespoke SEA of such a development or upgrading.

13.1 EXISTING SEA GUIDANCE/GUIDELINES FOR INFRASTRUCTURE ASSOCIATED WITH THE ENERGY TRANSITION

An international survey of existing SEA guidelines conducted for the International Association for Impact Assessment was unable to identify any guidelines specifically focused on infrastructure specifically associated with the energy transition and specifically with the development of renewable energy. However, many EIA and some SEA guidelines refer to the general impacts of roads, transmission lines, substations and ports, harbors, and terminals.

Roads

The Mekong River Commission has produced guidelines for the integrated planning and design of economically sound and environmentally friendly roads in the Mekong River floodplains.[1]

Transmission lines and sub-stations

EIA and SEA guidelines for transmission lines and sub-stations have been published for several countries: Germany, Southern Africa, Surinam, Canada, and the USA.[2] The International Finance Corporation's *Environmental, Health, and Safety Guidelines for Electric Power Transmission and Distribution* are a very useful reference document with general and industry-specific examples of good international industry practice.[3] Some recent academic papers have discussed the concrete benefits that SEA may deliver to private companies, e.g., where it is applied in Scotland in relation to regional electricity transmission planning in a tiered system.[4]

Ports, harbors, and terminals

With regard to the energy transition, ports, harbors and terminals are likely to be developed or upgraded/expanded mainly in connection with exporting green hydrogen and ammonia. The International Finance Corporation's *Environmental, Health, and Safety Guidelines for Ports, Harbors, and Terminals* provide a useful reference source with general and industry specific examples of good international industry practice.[5]

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[1] MRC (2011

[2] Bundesnetzagentur (2021) EnvSC (1999); Bundesnetzagentur (2021) MRC (2011); NIMOS (2005); USAID/CCAD/EPA (2011a, b, c);

[3] IFC (2007c)

[4] Marshall and Fischer (2006)

[5] IFC (2017)

13.2 TYPES OF TRANSMISSION LINES AND POWER GRIDS

A transmission line is the long conductor (either overground supported by pylons or underground/submarine) with a special design (bundled) to carry bulk amounts of generated power at very high voltage from one station to another as per variation of the voltage level. Design must take account of key factors, including voltage drop, transmission efficiency, line loss, etc. These values are affected by line parameters (resistance (R), inductance (L) and capacitance (C)[6]) of the transmission line. There are three types of transmission line length (Table 13.1). These different types of power lines have various types of posts or pylons, distance between them, and right-of-way width, which create various environmental and social impacts.

Table 13.1: Lengths categories of transmission lines

Source: Electrical4U (2024)

Type of transmission line	Features
Short line distribution	• A length less than 80km (50 miles) • Voltage level less than 69 kV (low voltage) • Capacitance effect is negligible • Only resistance and inductance are taken in calculation; capacitance is neglected
Medium line (transmission)	• A length more than 80 km (50 miles) but less than 250 km (150 miles) • Operational voltage level is from 69 kV to approximately 133/168 kV (medium voltage) • Capacitance effect is present • Distributed capacitance form is used for calculation purpose
Long line (transmission)	• A length more than 250 km (150 miles) • Voltage level is above 133/168 kV to 735 kV (high voltage) • Line constants are considered as distributed over the length of the line

The electric power system consists of production, transmission, distribution, and consumers. A ***power grid*** is a country's network of transmission and delivery, conducting electricity from power plants to homes and businesses across a country (e.g., Figures 13.1 (USA)). It includes energy utility companies and energy suppliers and the infrastructure to generate and distribute power. The grid may be a single national network or several regional grids that may be interconnected within the country or with neighboring countries.

A grid ensures best practice use of energy resources, provides greater power supply capacity, and makes the power system operations more economical and reliable. The generating stations (power plants) are interconnected to reduce the reserve generation capacity, known as a spinning reserve, in each area.

A ***smart grid*** (including new smart grids) is an electricity network that uses digital and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end users. Grids coordinate the needs and capabilities of all generators, grid operators, end users, and electricity market stakeholders to operate all parts of the system as efficiently as possible, minimizing costs and environmental impacts while maximizing system reliability, resilience, flexibility, and stability.

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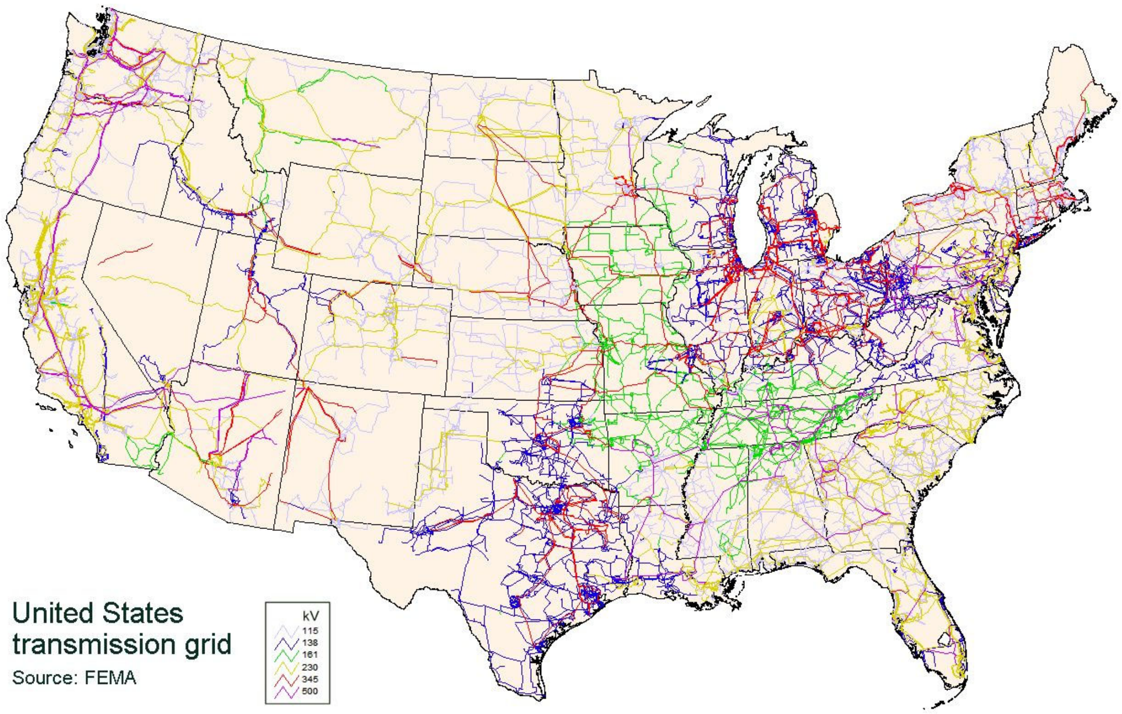
[6] A transmission line is modeled with a resistance (R) and inductance (L) in series with a capacitance (C) and conductance (G) in parallel. The resistance and conductance contribute to the loss in a transmission line.

Figure 13.1: USA power grid

Source: Federal Emergency Management Agency (FEMA) (n.d.)



Despite some recovery from the economic disruption caused by the Covid-19 pandemic, investment in smart grids needs to more than double through 2030 to get on track with the Net Zero Emissions by 2050 Scenario, especially in emerging markets and developing economies.[7]

According to analysis of available data[8], the total length of transmission circuits worldwide is estimated at 4.7 million kilometers, and the length of distribution grids is between 88 and 104 million km. China accounts for 41% of the expansion of global transmission grids and 32% of the expansion of distribution grids since 1980. In 2017, China's electricity grids were approximately as large as the grids of all western industrialized countries combined. The globally installed capacity of transformers is estimated between 36 and 45 teravolt-amperes, with transmission and distribution transformers accounting for above 40% each, and generator step-up transformers for the rest.

In 2023, worldwide, there were 7 million circuit km[9] of power transmission lines and 110 million km of power distribution lines.[10] As a "rule of thumb," each TWH of electricity used globally is supported by 225 km of power transmission lines (interquartile range of 175-275 km per TWH pa). Another "rule of thumb" is that each TWH pa of electricity used is supported by almost 4,000 km of distribution lines. The cut-off between transmission and distribution is a little bit blurry, but, generally, 100kV and greater lines can be considered as transmission lines and <70kV lines as distribution lines. Globally,

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[7] Drtil, M., Pastore, A., Evangelopoulou, S. (2023)

[8] Kalt *et al.* (2021)

[9] *What are circuit kilometers?* One "network kilometer" of power transmission lines may carry one circuit kilometer, two circuit kilometers or sometimes (rarely) three circuit kilometers, suspended from the same towers. In turn, each circuit kilometer may contain two large conductors (e.g., a high voltage direct current, HVDC), three conductors (3-phase AC) or sometimes (rarely) six conductors where the 3-phase AC is disaggregated to promote transmission efficiency. This makes the length of a transmission line a somewhat debatable concept.

[10] Thundersaid Energy (n.d.)

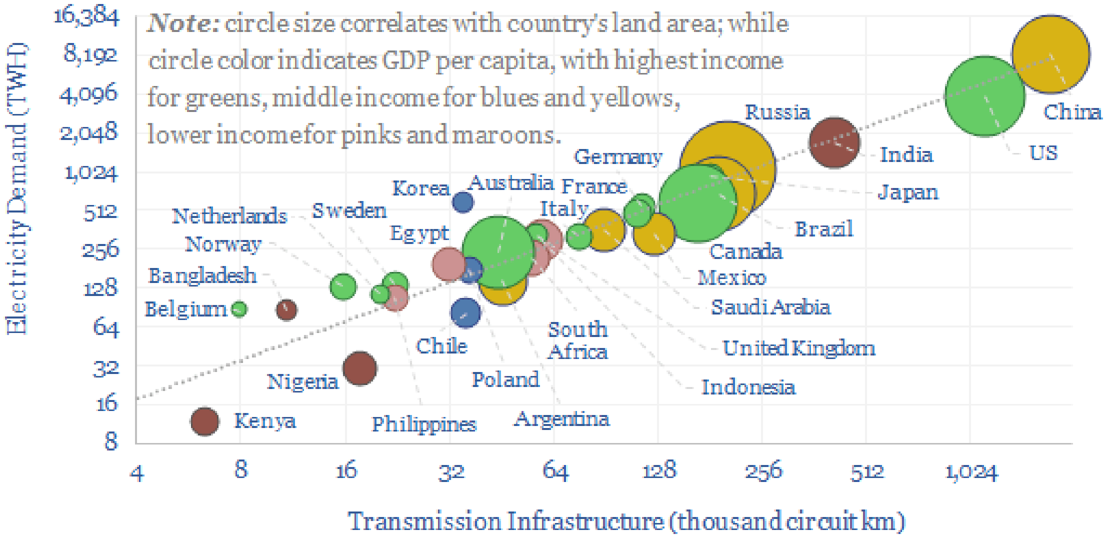
on average, countries have 16 km of distribution lines per km of transmission lines.[11] Generally, large, developed countries tend to have a higher share of large-scale transmission due to greater availability of financing for larger and more efficient grid infrastructure. Countries tend to have longer power transmission networks per unit of delivered electricity when (a) population density is lower, (b) GDP per capita is lower, and (c) average voltages of the transmission system are lower.

Using the above rules of thumb, Thunder Said Energy (a research consultancy for energy technologies) estimates that each 1 GW of new, utility-scale renewables might warrant constructing or upgrading around 500 km of transmission lines and 8,000 km of distribution infrastructure. However, the requirements will clearly vary case by case and depend on regional backlogs. A far-offshore wind project clearly has different network impacts from rooftop solar.[12]

Figure 13.2 shows power transmission and distribution km by country across 30 key countries, which comprise 80% of global electricity use.

Figure 13.2: Transmission infrastructure and electricity demand for a range of countries

Source: Thundersaid Energy (n.d.)



To achieve the energy transition, most electricity transmission systems around the world will need massive expansion, upgrades, shifts in technology used, and accommodation to the type of electricity that is transmitted, such as high voltage dc. Investments in the types of transmission systems taking place now may limit future options. There may be issues for projects to connect to electricity grids (so that they are on-grid or grid-tied) that are designed for larger utility-scale projects. Also, the potential for grid connections between countries could have huge benefits (financial, environmental, social) if done properly. There are already examples of essentially "stranded" renewable energy projects that cannot get their energy to markets due to grid constraints. After 20 years of effort, the USA has only recently finalized the first decision on a grid expansion.

For the timely implementation of the energy transition, it is necessary to strengthen the existing transmission network for the transfer of large amounts of electricity from areas of renewable energy sources to areas where this energy will be consumed or stored locally in another form of energy. For the efficient integration of renewable sources into the power grid, it is necessary to consider the connection line to the existing grid as a functional part of this source. The impacts of the renewable energy source and the connecting transmission line must be assessed together in a national or international context.

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[11] Thundersaid Energy (n.d.)

[12] Thundersaid Energy (n.d.)

13.3 SUBSTATIONS

The transmission of electricity requires substations (electrical transformer stations) to increase the voltage at the outlet of the generation equipment or to gradually lower it throughout its transmission to consumption centers. Substation sizes vary depending on their voltage, and some can occupy large areas. They include a control building, transformers, and different electrical equipment.

A variety of substation types are in use, e.g., step-up or step-down (of voltage); transformer, switching, and converter; high and extra and ultra-high voltage; grid and town; indoor and outdoor.[13]

13.4 ACCESS ROADS

All renewable energy developments are likely to require access roads (including bridges), particularly in the preparatory stage, e.g., to bring in equipment (e.g., drilling rigs for geological investigation of selected sites, earth-moving equipment, and construction materials), to transport labor to sites, and for maintenance purposes. In an inhabited area, existing roads may be capable of being used but may require upgrading (e.g., to accommodate wide or heavy loads). But there may be a need to extend the existing road network. In many cases, new renewable energy facilities may be located in remote areas, requiring the construction of new access roads. Such roads may require to be constructed across difficult terrain (e.g., mountainous land), and it may not be possible to avoid traversing sensitive and protected areas.

There are no internationally agreed specifications for such access roads. But they certainly can lead to serious environmental and socioeconomic impacts (discussed in Section 13.6) which need to be mitigated and managed. But it must also be recognized that access roads can also bring benefits to local populations and communities.

Some authorities (national or local) may set out specifications for such access roads (e.g., national standard specifications in South Africa[14], and specifications set by county councils in the UK[15]) setting out requirements covering, for example, design issues, management of materials (e.g., for blasting), safety, fences and barriers, drainage, earthworks, surfacing, footways, traffic signs, lighting, etc.).

13.4 ENERGY STORAGE FACILITIES

An electric power grid operates based on a delicate balance between supply (generation) and demand (consumer use). One way to achieve this balance is to store electricity during periods of relatively high production and low demand, then release it back to the electric power grid during periods of lower production or higher demand. In some cases, storage may provide economic reliability and environmental benefits. Depending on the extent to which it is deployed, electricity storage can help the utility grid to operate more efficiently, reduce the likelihood of drops in voltage in the electrical power supply system (brownouts) during peak demand, and allow for more renewable resources to be built and used.

The need for storage is a particular concern with regard to solar and wind power. In the past, nuclear, thermal, and hydroelectric power plants were operated and output adjusted to meet fluctuating consumer demand for electricity, and there was no need for energy storage. When the electric grid has all the energy it needs at a given time, but it’s a sunny or windy day and solar and wind energy systems are still generating electricity, it makes sense to store the surplus. Then, when the sun has set and the wind isn’t blowing, that stored surplus energy can be discharged to continue supporting power needs.

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[13] How Engineering Works (2017)

[14] Department of Transport for the Republic of South Africa (2020)

[15] Leicestershire County Council (2019)

Energy can be stored in a variety of ways, including:

- ***Hydroelectric complex with reservoir***. When solar and wind energy are generating electricity, water can be maintained in the reservoir for a period when the sun is not shining or there is no wind. It is a very efficient combination.
- ***Pumped hydroelectric*** (currently the most widely used technology with significant additional potential in several regions) Electricity is used to pump water up to a reservoir. When water is released from the reservoir, it flows down through a turbine to generate electricity.
- ***Compressed air***. Electricity is used to compress air at up to 1,000 pounds per square inch and store it, often in underground caverns. When electricity demand is high, pressurized air is released to generate electricity through an expansion turbine generator.
- ***Flywheels***. Electricity is used to accelerate a flywheel (a type of rotor), through which the energy is conserved as kinetic rotational energy. When the energy is needed, the spinning force of the flywheel is used to turn a generator. Some flywheels use magnetic bearings, operate in a vacuum to reduce drag, and can attain rotational speeds up to 60,000 revolutions per minute.
- ***Batteries***. Batteries are the most scalable type of grid-scale storage, and the market has seen strong growth in recent years. Similar to common rechargeable batteries, very large batteries can store electricity until it is needed. These systems can use lithium ion, lead acid, lithium iron, or other battery technologies (see Box 13.1).
- ***Thermal energy storage***. Electricity can be used to produce thermal energy, which can be stored until it is needed. For example, electricity can be used to produce chilled water or ice during times of low demand and later used for cooling during periods of peak electricity consumption.
- ***Others***: In addition to these technologies, new technologies are currently under development, such as flow batteries, supercapacitors, superconducting magnetic energy storage, molten salt[16] and hydrogen (discussed separately in Chapter 14).

Box 13.1: Batteries

The most common type of battery used in grid energy storage systems are lithium-ion batteries. Lithium-ion batteries include five components:

- an anode (typically graphite coated onto aluminum foil);
- a cathode (either nickel-magnesium-cobalt or nickel-cobalt-aluminum; lithium-iron-phosphate; and blended onto copper foil);
- a separate barrier between the anode and cathode;
- an electrolyte solution to transport lithium ions; and
- current collectors made of copper and aluminum that connect the battery to wires.

In some countries (e.g., USA), instead of batteries, fossil fuel-powered “peaker plants” are often used to supply energy during high-demand periods. Despite being used infrequently, these plants are inefficient and highly polluting and contribute greatly to carbon emissions.

The USA is predicted to have deployed 20.5 GwH of energy storage capacity between 2013 and 2023, followed by China (10 GwH) and Japan (8.3 GwH) (see Table 13.2).

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[16] Bauer, T., Odenthal, C., Bonk, A. (2021)

Table 3.2: Projected energy storage deployment between 2013 and 2023
Source: Statista (2024b)

Country	Projected capacity (GwH)
USA	20.5
China	10
Japan	8.3
Australia	6.6
Germany	4.3
UK	2.6
India	2
South Korea	1.5
Canada	1.3
Rest of World	8.1

According to the U.S. Department of Energy, the USA had more than 25 gigawatts of electrical energy storage capacity as of March 2018. Of that total, 94% was in the form of pumped hydroelectric storage, and most of the latter capacity was installed in the 1970s. The 6% of other storage capacity was in the form of battery, thermal storage, compressed air and flywheel.[17]

13.5 PORTS, HARBORS, AND TERMINALS

The energy transition will involve reducing (and ideally eliminating) our dependence on fossil fuels as energy sources. Coal, oil, and gas need to be transported from where they are extracted to where they are consumed (within countries or internationally) by road, rail, sea, and pipelines. Where fossil fuels are exported or imported by sea, this involves ports, harbors, and terminals. Sometimes these are dedicated stand-alone facilities, e.g., Richard Bay coal terminal in South Africa (Box 13.2); in other cases, they are part of general ports that handle a wide range of other cargo.

Regarding fossil fuels, this guidance focuses only on retiring coal-fired power plants, the closure of associated coal mines, and the cessation of use of ports, harbors, and terminals for coal transport.

Box 13.2: Richards Bay Coal Terminal, South Africa
Source: Mozambique Resources Post (2015)

Richards Bay Coal Terminal (RBCT) in South Africa is one of the leading coal export terminals in the world. RBCT was established in 1976 with an original capacity of 12 million tons per annum (Mt/a). It has since expanded to an advanced 24-hour operation with a design capacity of 91 Mt/a, and handles coal from 65 collieries and brought by rail. RBCT is positioned at one of the world's deep seaports and handles large volumes of coal and vessels. The 276-ha site is currently 2.2 km long, has 6 berths and 4 ship loaders, with a stockyard capacity of 8.2 Mt. It is currently visited by more than 900 vessels per year.

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[17] US EPA (2024)

13.6 IMPACTS OF TRANSMISSION LINES AND ACCESS ROADS

The environmental and socioeconomic impacts of both transmission lines and access roads are discussed in detail for different types of renewable energy development in chapters 5 (hydropower), 6 (wind), 7 (solar), 8 (bioenergy), 9 (geothermal) and 10 (tidal).

13.6.1 Environmental and socioeconomic issues and impacts of transmission lines and access roads

Tables 13.3 and 13.4 summarize, respectively, the main environmental and socioeconomic issues and impacts associated with transmission lines and substations, while Tables 13.5 and 13.6 summarize the main issues and impacts associated with access roads.

Table 13.3: Environmental issues and impacts associated with transmission lines and substations

Issue	Impacts
Land clearing/ deforestation	• Soil erosion; • Landslips; • Sedimentation of rivers; • Loss of and fragmentation of habitats (including wetlands), and loss of biodiversity (including endangered fauna and flora); • Loss of ecosystem services (terrestrial and aquatic).
Biodiversity	• Fragmentation of habitats caused by single and multiple linear disturbances. Often transmission lines may be placed together in a corridor; • Increased access to protected areas; • Poaching and wildlife trafficking
Quarries and borrow-pits	• Digging for rock/gravel can release pollutants and other harmful substances into the surrounding environment (particularly surface and ground water); • Land degradation and loss of vegetation; • Noise from blasting and crushing; • Dust; • Waste from unwanted materials; • Lack of restoration to prevailing conditions,
Marine habitat disturbance	• Seabed and marine habitat disturbance/scouring and water quality impacts (when constructing underwater cable foundations associated with offshore wind).
Wildlife deaths	• Bird and bat collisions with power lines and electrocutions; • Increased access leading to poaching.
Waste	• Waste soil and rock (spoil) from excavation/routing works and leveling transmission pylon sites; • PCB may remain in some old transformers at substations or may have been disposed of on site.
Noise	• Noise (during road and line construction) and underwater noise, and due to vessel movement in case of off-shore wind; • Noise during substation operation; • Vibration and dust during construction.
Visual & aesthetic impacts	• Impacts on landscape.
Herbicide use	• Impacts of herbicides used to control vegetation on right-of-way or in substation area.
Accidental oil spills	• From transformers in substations.
Fires	• Wildfires can result from downed lines, vegetation contact, conductor slap, downed lines, repetitive faults, and equipment failures.

Table 13.4: Socioeconomic issues and impacts associated with transmission lines

Issue	Impacts
Land use	• Limitations/restrictions on land use along easement routes and beneath transmission lines (e.g., restrictions on agriculture, tree planting or constructing buildings). For Indigenous Peoples, this can include impeded access to spiritual, cultural, and economic relationships with their land.
Fishing	• Effects on fishing (e.g., reduced yields/catches) and other aquatic-based activities or reliant livelihoods (for offshore wind transmission cables).
Health and safety	• Health and safety issues related to high overhead voltage cables during construction of lines or underground/underwater cables; and due to roads, quarries and borrow-pits (accidents due to increased presence of vehicles – particularly during construction, and operation of equipment); • Health effects associated with electromagnetic fields (EMF).
Jobs	• Job opportunities for local people; • Opportunity for vulnerable groups and Indigenous communities to acquire new skills through working on transmission line construction and tower building; • There may be gender gaps with women where they are under-represented.
Labor rights	• Infringement of labor rights during transmission line construction, mainly where there is a demand to undertake excessive overtime and successive days of work without sufficient rest.
Tensions and conflicts	• Tensions can arise when transmission lines are built, particularly since the electricity generated is not distributed locally (hydropower projects are typically permitted as generating facilities and are not allowed to distribute electricity to local communities); • Conflicts between the workforce and the local population and exposure to anti-social behavior; • Conflicts within the local population can arise for a range of reasons, often relating to issues of inequity, including, for example: o compensation measures (which may arise from a lack of clarity on cut-off dates); o eligibility criteria or entitlement provisions (e.g., duration); o access to and extent of training and support; and o access to and extent of project benefits. • There is a risk of conflict between communities and project developers if the latter do not secure the free prior and informed consent (FPIC) to projects and their associated transmission lines from Indigenous communities.
Community cohesion and engagement	• Impacts to or loss of community resources (e.g., gardens, land, forest, fisheries) and community assets (e.g., community meeting areas, culturally significant features).
Land acquisition risks	• Associated with acquiring land for substations and transmission lines.
Cultural	• Cultural, religious, and archaeological sites can be destroyed, or access to them restricted when land is acquired.

Table 13.5: Environmental issues and impacts associated with roads

Issue	Impacts
Land clearing/ deforestation	• Soil erosion; • Landslips; • Sedimentation of rivers • Loss of and fragmentation of habitats (including wetlands), and loss of biodiversity (including endangered fauna and flora); • Loss of services (terrestrial and aquatic).
Biodiversity	• Fragmentation of habitats caused by the road corridor. Often transmission lines and roads occur together in the same corridor; • Increased access to protected areas; • Poaching and wildlife trafficking.
Quarries and borrow-pits	• Digging for rock or gravel can also release pollutants or other harmful substances into the surrounding environment (particularly surface and ground water); • Land degradation and loss of vegetation; • Noise from blasting and crushing; • Dust; • Waste from unwanted materials; • Lack of restoration to prevailing conditions.
Wildlife deaths	• Collisions with vehicles; • Increased access leading to poaching.
Waste	• Waste soil and rock (spoil) from excavation/routing works and leveling transmission pylon sites.
Noise	• Noise (during road and line construction and including underwater) and due to vessel movement in case of off-shore wind; • Noise during sub-station operation; • Vibration and dust during construction.
Visual and aesthetic impacts	• Impacts on landscape.
Herbicide use	• Impacts of herbicides used to control vegetation on the road right-of-way.
Accidental oil and other spills	• During construction and also during operations.

Table 13.6: Socioeconomic issues and impacts associated with access roads

Issue	Impacts
Land use	• Limitations/restrictions on land use along road corridors (e.g., restrictions on agriculture, tree planting or constructing buildings). For indigenous peoples, this can include impeded access to spiritual, cultural, and economic relationships with their land.
Health and safety	• Health and safety issues related to road construction.
In-migration	• Roads can open up previously inaccessible areas to local and remoter populations. This may create a pressure on natural resources and affect the livelihoods of Indigenous communities.
Jobs	• Job opportunities for local people; • Opportunity for vulnerable groups and Indigenous communities to acquire new skills through working on road building; • There may be gender gaps with women where they are under-represented.
Labor rights	• Infringement of labor rights during transmission line and road construction, mainly where there is a demand to undertake excessive overtime and successive days of work without sufficient rest.

Issue	Impacts
Tensions and conflicts	- Conflicts between the workforce and the local population and exposure to anti-social behavior; - Conflicts within the local population can arise for a range of reasons, often relating to issues of inequity, including, for example: o compensation measures (which may arise from a lack of clarity on cut-off dates); o eligibility criteria or entitlement provisions (e.g., duration); o access to and extent of training and support; and o access to and extent of project benefits. - There is a risk of conflict between communities and project developers if the latter do not secure the free prior and informed consent (FPIC) on road projects from Indigenous communities.
Community cohesion and engagement	- Impacts to or loss of community resources (e.g., gardens, land, forest) and community assets (e.g., community meeting areas, culturally significant features).
Land acquisition risks	- Associated with acquiring land for roads.
Cultural	- Cultural, religious, and archaeological sites can be destroyed or access to them restricted when land is acquired for roads.

Box 13.1 discusses some of the challenges associated with transmission lines in Nepal.

Box 13.1: Challenges of constructing transmission lines in Nepal and the case of the New Butwal – Lamahi 400 kV transmission line

Source: Mathema, A. (n.d.)

Transition lines are prioritized. The Government of Nepal (GoN) has prioritized the construction of transmission lines to "evacuate" or transport electricity generated by hydropower projects across the country. Environmental requirements for transmission line projects have been eased. The Environmental Protection Regulations 2020 now require only an Initial Environmental Examination (IEE) rather than a full EIA for all sizes and scales of transmission lines.

Land acquisition (for Rights of Way, RoW) across private land is a major challenge. Electricity Rules require both vertical and horizontal clearance beneath and adjacent to conductor wires to ensure safety and smooth operation of transmission lines. A right-of-way (RoW) is negotiated with the landowner that imposes restrictions on the use of land (e.g., on the height of vegetation and buildings that can be constructed) and offers compensation (typically 15-25% of the land's value) to landowners. The restrictions significantly depress the value of the land, and financial institutions will not accept such land as collateral, further limiting its financial potential. As a result, many landowners are reluctant to have the transmission line pass through their land, and transmission line projects have faced strong resistance from the public, significantly delaying construction and leading to uncertainties in the overall energy infrastructure development. Land is purchased from landowners for towers and substations.

Routing transmission lines through forest areas. This alternative has given rise to a new set of concerns and trade-offs, particularly related to the environment, the integrity of forest ecosystem (through land clearing), and the loss of habitats and biodiversity, as exemplified by the proposed New Butwal – Landhi 400 kV transmission line (see below). Many animal species rely on forested areas for shelter, food, and breeding, and their displacement and habitat fragmentation due to the transmission line can disturb the delicate ecological balance.

The proposed 400 kV New Butwal – Lamahi transmission line project in Lumbini Province, Nepal

This 160km transmission line is estimated to require the clearing of about 180,000 trees along its corridor. Nearly 97% of the transmission line alignment passes through the forests on the foothills of the Churiya Hill range. Traditionally, transmission line projects in Nepal clear the vegetation along the RoW to comply with the Electricity Rule 1003 and to ensure the safe and efficient operation of the transmission line while minimizing potential hazards (e.g., fire) and disruption caused by encroachments or incompatible constructions.

The project intends to minimize impacts on the forest by avoiding removal of ground vegetation, as well as to minimize the clearance or trimming of trees (to only those above 20m) by increasing the height of the towers to 90m. Forest sampling showed that 20% out of the 180,000 trees along the transmission line corridor are taller than 20m and will require either removal or trimming.

The project also aims to minimize vegetation removal for tower construction and stringing operations. Drones will be used for stringing. Vegetation clearance will be limited to a 200m stretch of the RoW at every 4 km, requiring 40 clearance sites, which will cover a combined area of 36.8 ha. Taking all factors into account, including trees above 20m, construction work, stringing, and substation sites, the total number of trees expected to be removed along the corridor will be approximately 45,000 (25% of all trees). Most of the trees to be preserved are Sal, a protected species. This approach will also minimize disturbance to forest habitats and the delicate, erosion-prone geology of the Churiya hill range.

It is estimated that the proposed taller towers and using advanced construction technology will increase project costs by 40%, making it one of the most expensive transmission line projects. This significant increase in expenses may not be feasible for the GoN.

13.7 IMPACTS OF ELECTRICITY STORAGE

Storing electricity can provide indirect benefits. For example, electricity storage can be used to help integrate more renewable energy into the electricity grid. Electricity storage can also help generation facilities to operate at optimal levels and reduce use of less efficient generating units that would otherwise run only at peak times. Furthermore, the added capacity provided by electricity storage can delay or avoid the need to build additional power plants, transmission and distribution infrastructure, or access roads, which have associated environmental impacts.

The potential negative impacts of electricity storage will depend on the type and efficiency of storage technology. For example, batteries use raw materials such as lithium and lead, which can present environmental hazards if they are not disposed of or recycled properly. In addition, some electricity is wasted during the storage process. Plus, demand for these rare metals in batteries is leading to a boom in their mining and the associated environmental impacts associated with such mining.

From a social perspective, mining for rare metals is often associated with violations of the human rights of communities (e.g., rights to land and livelihood), the ability to undertake traditional cultural practices, and forced and child labor. Furthermore, the rapid increase in demand for rare earths and the associated boom in mining is also leading to protests and conflicts between mining companies and host communities, e.g., over lithium extraction from salt flats in the Atacama Desert in Argentina.[18]

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[18] Global China Unit (2024)

13.8 IMPACTS OF PORTS, HARBORS, AND TERMINALS ASSOCIATED WITH THE ENERGY TRANSITION

With regard to the energy transition, new ports, harbors, and terminals are likely to be developed or existing ones upgraded/expanded mainly in connection with exporting green hydrogen and ammonia. Liquid natural gas (LNG) terminals are also being built for the transport of natural gas as a transition fuel for electricity generation, away from coal and diesel. But, as pressure and commitments increase to retire coal-fired coal plants and as associated coal mines are closed, existing coal terminals are likely to be closed, possibly repurposed (e.g., to export green hydrogen). Also, they may have potential to be converted to other purposes (e.g., as leisure marinas or industrial tourism sites). Such issues are discussed in the IFC EHS Guidelines for Ports, Harbors, and Terminals.[19]

There are two main types of environmental and social impacts associated with ports and harbors that may affect the port area itself and/or the surrounding area: those arising from construction when developing or upgrading/expanding facilities; and those linked to operating the facilities.

Environmental impacts can include:

- Local air and water pollution (e.g., spillages and discharges from ships);
- Noise from ship engines and machinery used to load/unload cargo and from vehicles/trains delivering to the port;
- Underwater noise and vibration and blasting during construction;
- Dredging required to deepen access to the port and disposal of dredged materials;
- Biodiversity impacts on sensitive marine and terrestrial habitats (e.g., mangroves, seagrass, coral) and protected areas such as important bird areas (IBAs);
- Water quality impacts;
- Hydrology impacts and changes to coastal geomorphology and sedimentation dynamics;
- Waste management (ballast water, slops, wastewater, hazardous materials);
- Air pollution, such as exhausts of greenhouse gases and particles, CO_2, NO_x, and SO_2 from the ship's main and auxiliary engines, and from trains/vehicles;
- Traffic congestion in and around the port and feeder roads;
- Widespread contamination of sediments;
- Vulnerability to climate change impacts such as increased storms and sea level rise;
- Health and safety impacts during construction and operations;
- Impacts at sea due to:
    - Ships' wash;
    - Collisions between vessels and marine animals;
    - Noise from ships engines and propellors;
    - Marine accidents;
    - Anchoring and mooring.

From a social perspective, ports, harbors, and terminals can support and benefit local, regional, and national economies through their role in creating jobs and transporting goods. Their operators/owners can also partner with communities to offer workforce development programs, protect the environment, and provide coordination for land use planning to incorporate community amenities.

However, ports can also create potential challenges for near-port communities who are disproportionately impacted by port operations and related transportation systems. Construction may involve an influx of workers from elsewhere, which carries with it the potential for conflict with local communities. In addition, while ports are major economic engines for local, regional, and national economies, these economic benefits may not be equitably distributed. The near-port communities may not receive a fair share of the economic benefits that flow to the region or national economy.

Ports may also require the acquisition of land, often from nearby communities, and this must be done in a fair and equitable manner consistent with best international practices (e.g., IFC Performance

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[19] IFC (2017)

Standard 5 on land acquisition and involuntary resettlement [20]). Ports can also cause conflicts with local fishing communities regarding access and landing points. Transport congestion can arise during port construction and persist throughout the life of the port.

Ports can also impact important terrestrial and marine areas important to indigenous peoples and their use of those lands. In recognition of indigenous rights and the need for respect, cooperation, partnership, and the need for establishing meaningful dialogue for better informed port decisions, the Government of Canada is amending the Canada Marine Act to recognize indigenous groups alongside port users and communities and to establish new advisory bodies and governance mechanisms to assure environmental and social sustainability of port infrastructure and operations.[21]

Where existing coal ports, harbors, and terminals are closed, this may offer opportunities to restore sites to their former ecological status. Or they may be repurposed for other commercial use or for leisure/tourism.

Closure will inevitably have impacts on the local or regional economy and on jobs and livelihoods. Repurposing may offer new economic and job opportunities, but different skills are likely to be required. In practice, port closures related to coal transport and coal mining are still in their infancy, and many new initiatives are under development to reinvent ports to become “ports of the future” and energy hubs for green hydrogen and ammonia.[22]

13.9 SUPPLY CHAINS

A supply chain is a complex logistics system that consists of facilities that convert raw materials into finished products and distribute them to end consumers or end customers. The elements of a supply chain include producers, vendors, warehouses, transportation companies, distribution centers, and retailers.

All forms of renewable energy development (including their associated infrastructure) will have their associated supply chains, which provide a wide array of equipment, materials, and services. These may include, for example, plant components, construction vehicles and fuels, construction materials (i.e., steel, sand, gravel, and cement), and machinery. Suppliers may vary from large companies to small- and medium-sized enterprises (SMEs).

At a local level, the closure of a coal-fired power plant (CFPP) or coal mine could lead to the closure of many SMEs that have been established to service the CFPP or mine or its workforce (e.g., local engineering companies, shops, food stores, local bus and taxi services, coal trucks, and barges), which will mean loss of jobs and livelihoods.

On the other hand, the rapid global expansion of new renewable energy projects will stimulate demand for materials and equipment and foster opportunities for service providers and SMEs, which will lead to an expansion of job and livelihood prospects.

One of the most contentious aspects of renewable energy development is that, combined with the transition to electric vehicle manufacturing and the expanding use of cell phones, it is driving a massive increase in the demand for metals and rare minerals (e.g., lithium, copper, cadmium, aluminum, antimony, and tellurium), most particular for the construction of wind turbines and solar panels.

A serious concern is that some mining companies are known to practice forced labor, employ children, use unsafe working conditions, and violate rights of communities (e.g., rights to land, livelihoods, ability to undertake traditional cultural practices). In some instances, this has led to

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[20] Read full Performance Standard 5 here: https://www.ifc.org/en/insights-reports/2012/ifc-performance-standard-5

[21] Government of Canada (2022)

[22] Vandermeiren, J. (2022)

conflicts between mining companies and host communities.[23] Mines have also caused damage to ecosystems and created unsafe working conditions.

An OECD briefing note titled "*Responsible is Reliable*" [24] addresses critical issues related to business, human rights, and due diligence in the context of the global transition to renewable energy and electrification. The briefing identifies the following challenges and risks associated with their supply chain:

- *Geopolitical risks*: Transition minerals are not equally distributed globally, leading to concentration in a few countries. For example, the Democratic Republic of the Congo supplies 70% of cobalt, and China dominates the supply of several other minerals. This geopolitical concentration poses risks to the reliability of supply;

- *Conflict-affected and high-risk areas*: Many of these minerals are located in conflict-affected or high-risk regions where issues like corruption, security concerns, and human rights violations are prevalent. Over 70% of cobalt, graphite, and rare earth element resources are in countries perceived as corrupt;

- *Environmental and ethical concerns*: The extraction of transition minerals often has negative environmental and social impacts, including human rights abuses and environmental degradation. The report draws on the over 500 allegations of human rights abuses related to these minerals between 2010 and 2022 and registered in the 2022 Transition Minerals Tracker by the Business and Human Rights Resource Center[25];

- *Market dynamics*: The rapidly growing demand for transition minerals, combined with limited investments in mining capacity, raises concerns about potential supply-demand mismatches and price volatility.

A study by the University of Technology, Sydney[26], links the projected mineral demand at a global scale, the potential to offset demand through recycling, supply risks, and potential environmental and human rights impacts.

13.9.1 Supply chains and the circular economy

The circular economy is a framework of three principles, driven by design: eliminating waste and pollution, keeping products and materials in use, and regenerating natural systems. It is a regenerative approach to manufacturing, taking it away from the traditional, linear, wasteful, “take-make-dispose” approach. The circular economy thus emphasizes instead the sharing, leasing, reusing, part harvesting and remanufacturing, repairing, refurbishing, and recycling of existing materials and products for as long as possible. It encourages manufacturers to design products and business models with durability, repairability, and recyclability in mind. Applying circular economy principles can reduce dependency on scarce resources and component suppliers and build adaptable and resilient supply chains. For manufacturers, this means controlling the management, use, and recovery of materials and components and ensuring that parts and materials within their control never unintentionally exit their sphere of influence. By retaining control over the lifecycle of products, materials, and components, manufacturers can prevent resource loss, ensure efficient reuse, enable capitalization of circular practices, and reduce their environmental and social impact.[27]

The circular economy approach decouples economic growth from resource consumption, fostering a more sustainable and resilient supply chain.[28]

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[23] Global China Unit (2024)
[24] OECD (2023)
[25] Business & Human Rights Resource Center (n.d.)
[26] Dominish E., Florin N. and Teske S. (2019)
[27] Hvid Jensen, H. (2024)
[28] Ibid

From a renewable energy perspective, this means recycling and reusing all components, such as wind turbine blades, solar panels, wiring, etc., and keeping these materials and components out of landfills, particularly in those countries where recycling facilities do not exist. Applying circular economy principles can make a vital contribution to the energy transition in three important ways[29]:

- Recycling can conserve critical minerals, reducing dependence on mining if implemented at scale. It can also help recover critical minerals from e-waste, which can be used in manufacturing components of renewable energy technology;
- Using of low-carbon, recycled materials means that there are fewer carbon emissions;
- Designing circular systems that take a life cycle approach involving recycling and reuse of materials from product design through to the end of product life, maximizing product efficiency across the entire lifecycle of usage.

In practice, an SEA will not be able to analyze and assess in any detail the risks and opportunities associated with the wide range of supply chains associated with the array of renewable energy developments likely to arise when implementing renewable energy PPPs. But an SEA should at least identify that such risks need to be recognized and make appropriate recommendations, e.g., that project developers should purchase wind turbines, solar panels, and batteries, etc. from manufacturers and suppliers that commit to responsible sourcing and oblige manufacturers to adopt a circular economy life cycle approach involving recycling, repurposing, and reuse. It will encourage more mines to engage in responsible practices and sustainability certification throughout the entire mine lifecycle.

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[29] Pennington, J. (2022)