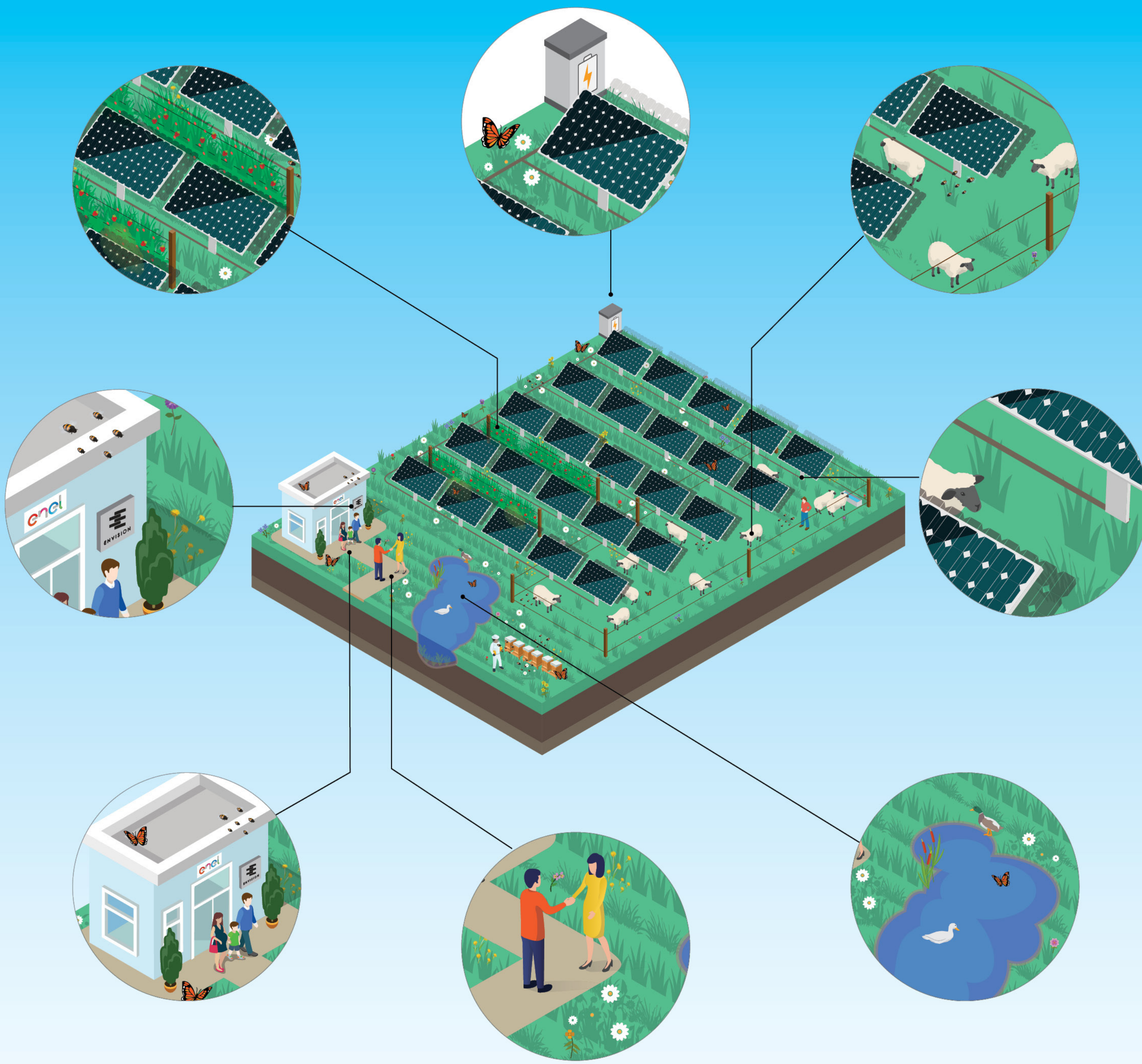
Toward Sustainable Solar Energy

Opportunities in circular economy for dual use solar and energy storage



ARUP enel

“As the solar power industry grows, we’ll see solar energy development become smarter and more sustainable by integrating agricultural elements like crops and livestock.”

Enrico Viale
Head of Enel North America

Photo credit: Enel Green Power's Aurora Solar Farm, MN

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Credits

Arup and Enel are world leaders in circular economy, both being active members of the Ellen Macarthur Foundation for multiple years. This collaboration aims to advance the sector and thinking across the industry, building on the success of previous joint research including the Circle-E paper published in 2019.

Enel North America, having identified dual use solar as a key pillar for improving the circularity of utility scale solar, co-funded this joint research into how to achieve better outcomes.

Photo credit: Enel Green Power's Aurora Solar Farm, MN

Preface

North America has the potential to lead the world in sustainable solar energy production – by providing solar energy development that enhances the land and is built and designed from materials that have a positive impact across society, the economy, and the planet.

The "dual use" of the land for both renewable energy and the delivery of ecosystem services and agriculture leverages the positive impact of rapidly accelerating renewable energy investments. Our review of literature and interviews with those in industry indicate that dual use strategies hold the promise to increase energy production while simultaneously supporting creation of new pollinator habitat and agricultural services, thereby strengthening rural economies and regenerating local ecology.[1] Transitioning to dual use solar therefore presents significant potential for positive impacts in the economy and for land use. The billions of dollars invested in sourcing materials necessary for North American solar energy development presents an additional opportunity to shape a circular economy that considers the whole life cycle of materials and their re-circulation within our planetary boundaries.[2,3]

Sustainable solar energy definition:

A life cycle development strategy maintained to uphold the UN Sustainable Development Goals, with integration of Creating Shared Value (CSV) and circular economy principles. This ensures a constant dialogue with interested parties on the social and economic context, in order to define effective technoecological synergies for long-term value creation.

Recognizing the scale of the opportunity for sustainable energy, Arup and Enel have worked in partnership to examine how dual use and materials sourcing can be improved and achieve greater circular economy, or circularity, outcomes. This work included inputs from leading circular economy specialists and solar industry experts.

The findings summarized here capture a snapshot of how the industry as a whole may advance in the years ahead, and how leaders are charting a new course not only for their business and assets, but also in service to the environment and rural communities, shifting from renewable energy to sustainable energy.

$49.3 billion

was invested in US renewables in 2020 alone. This can be leveraged to enhance our environment and support our rural economy.[4]

This work is intended to aid shared conversation and collaboration between industry peers, communities, discerning purchasers of renewable energy, as well as policy makers. We are grateful for the input and contributions of time and insight from the following partners: National Renewable Energy Laboratory (NREL), The Bee & Butterfly Habitat Fund, and Minnesota Native Landscapes.

Circular Economy & Utility Scale Solar + Storage

Traditionally, consumption and use of natural resources followed a linear approach (take-make-use-dispose). Materials are sourced, consumed, and disposed of, often with little regard for externalized impacts and with singular focus on the optimization of a process. In a circular economy, interrelated systems are optimized rather than a single process, resulting in opportunities for shared benefit and value enhancement. As scarcity rises and awareness and knowledge increases, circularity is emerging as a lower cost and higher benefit approach. Renewable materials are valued, energy is conserved, natural systems are restored, and waste is eliminated. Materials, products, and components are managed in loops, maintaining them at their highest possible intrinsic value within the system.

Solar is fundamental to a circular power system, providing a renewable source of energy. However, solar power can still result in waste products and other impacts created throughout its life cycle when not designed or managed properly and addressed holistically. At year-end 2020, US solar photovoltaic (PV) capacity reached 88.9 GW of total installed capacity, enough to power 16.4 million American homes.[5] Now that solar power is achieving scale, there are growing opportunities and imperatives to apply circular economy principles[6] and ensure growth opportunities and challenges are addressed responsibly.

Realizing the potential of a circular economy requires applying a lens that is not only optimized for speed and immediate cost, but that also includes the wider benefits that can be achieved in the value chain. The circular economy model addresses the sustainability needs of the community, planet, and economy, offering businesses an extraordinary opportunity in terms of competitiveness, innovation, and job creation. This will, in turn, create value for companies, their customers and society.

As a leader in circular economy and the largest private renewable energy player in the world, Enel's circular economy pillars were applied by Arup to evaluate the opportunity to move toward sustainable solar energy (see next page).

Largest renewable private player in the world

Enel Green Power operates over 49GW of renewable power generation globally.

Enel's 5 Pillars of Circular Economy

Enel has defined five pillars that describe the primary focus areas of a circular economy and methods of its application:

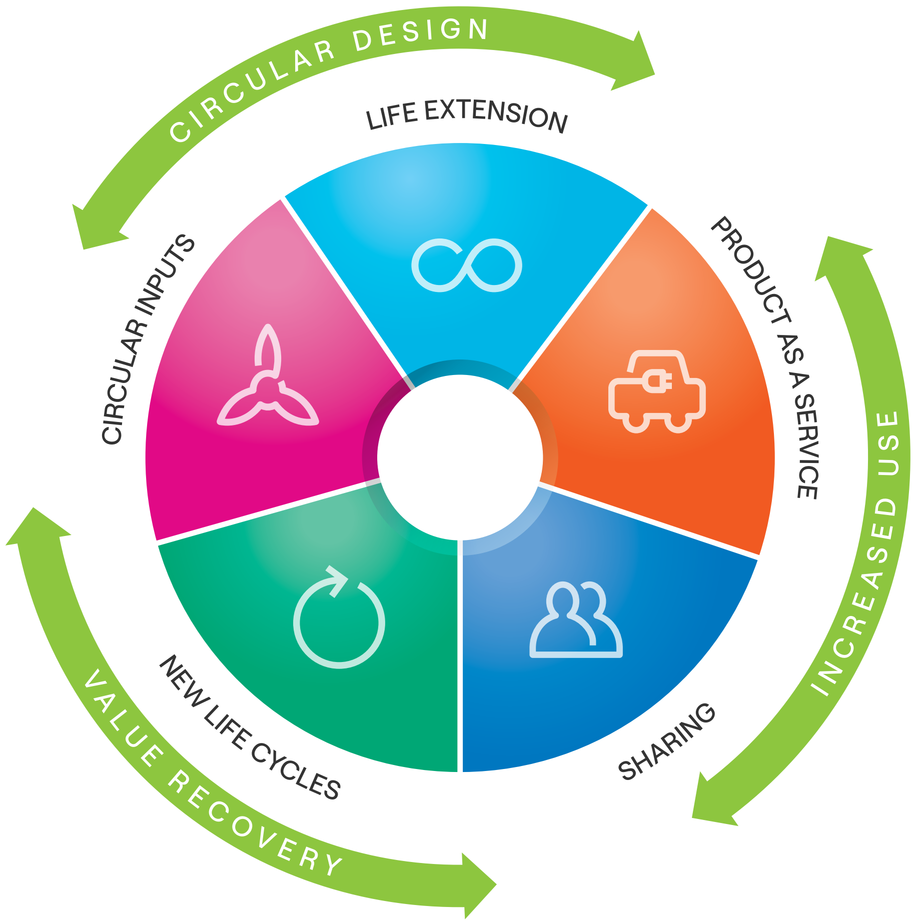
1. **Circular inputs:** production and use models based on inputs from renewables or from previous life cycles (reuse and recycle)

2. **Life extension:** an approach to the planning and management of an asset or a product that intends to extend its useful life (for example: through modular design, simplification of repairs, and predictive maintenance)

3. **Product as a service:** a business model in which the client acquires a service for a limited amount of time while the company retains its ownership of the product, thereby maximizing both the use factor and its useful life

4. **Sharing platforms:** shared management systems accessed by multiple users of products, goods, or services

5. **New life cycles:** in synergy with the other principles, all the solutions aim to preserve the value of a good at the end of its lifecycle through reuse, regeneration, upcycling, or recycling.



Three Perspectives

Arup and Enel developed three visual expressions that define the opportunity – Industry Baseline, Improved Development, and The Future of Solar (Figure 1, Figure 2, and Figure 3).

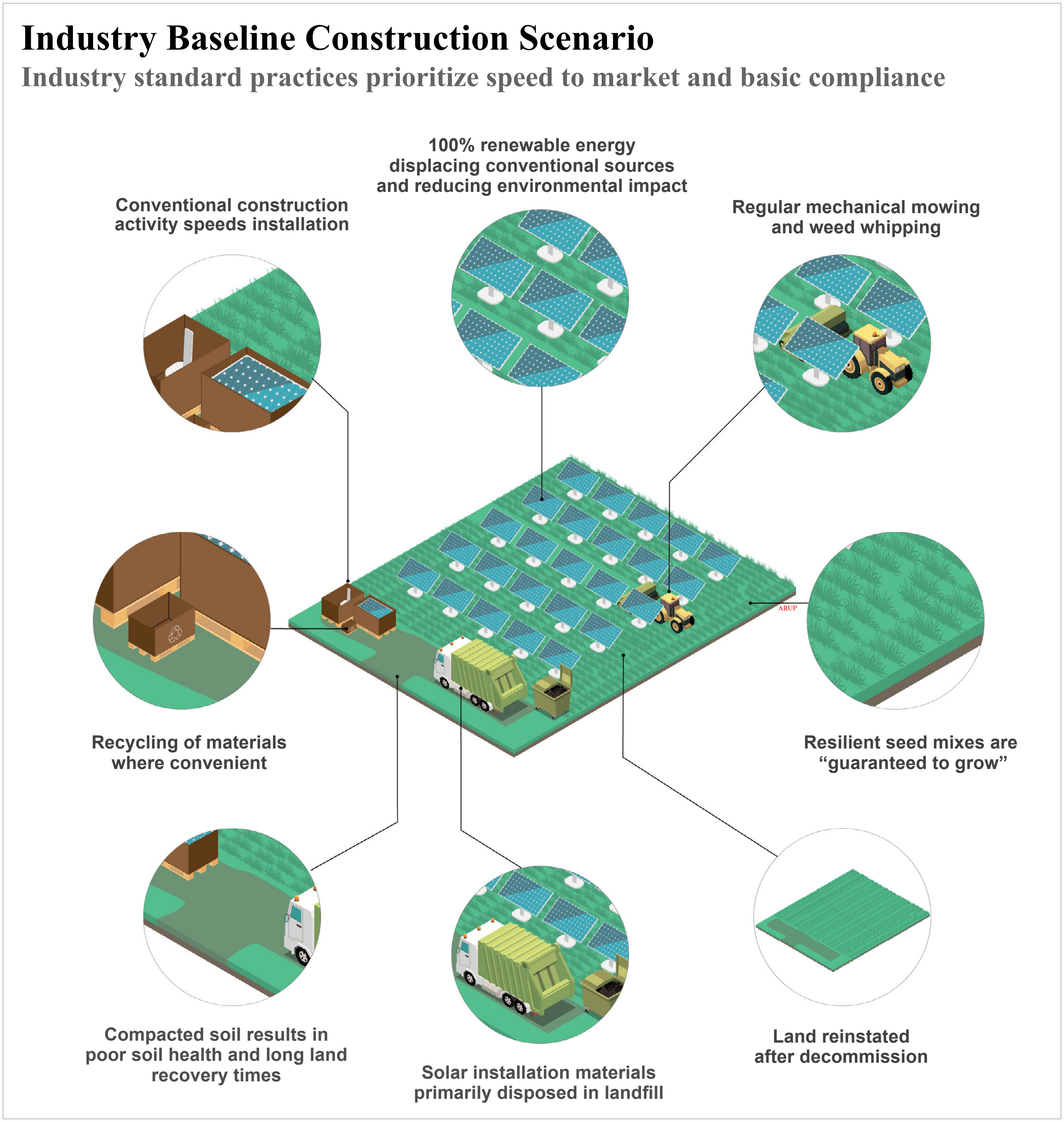


Figure 1– Industry baseline

Improved Development with Forward Considerations

Taking steps to apply circular economy principles has benefits in North America

Toxic chemicals are reduced and sustainability considered in materials selection and contracting

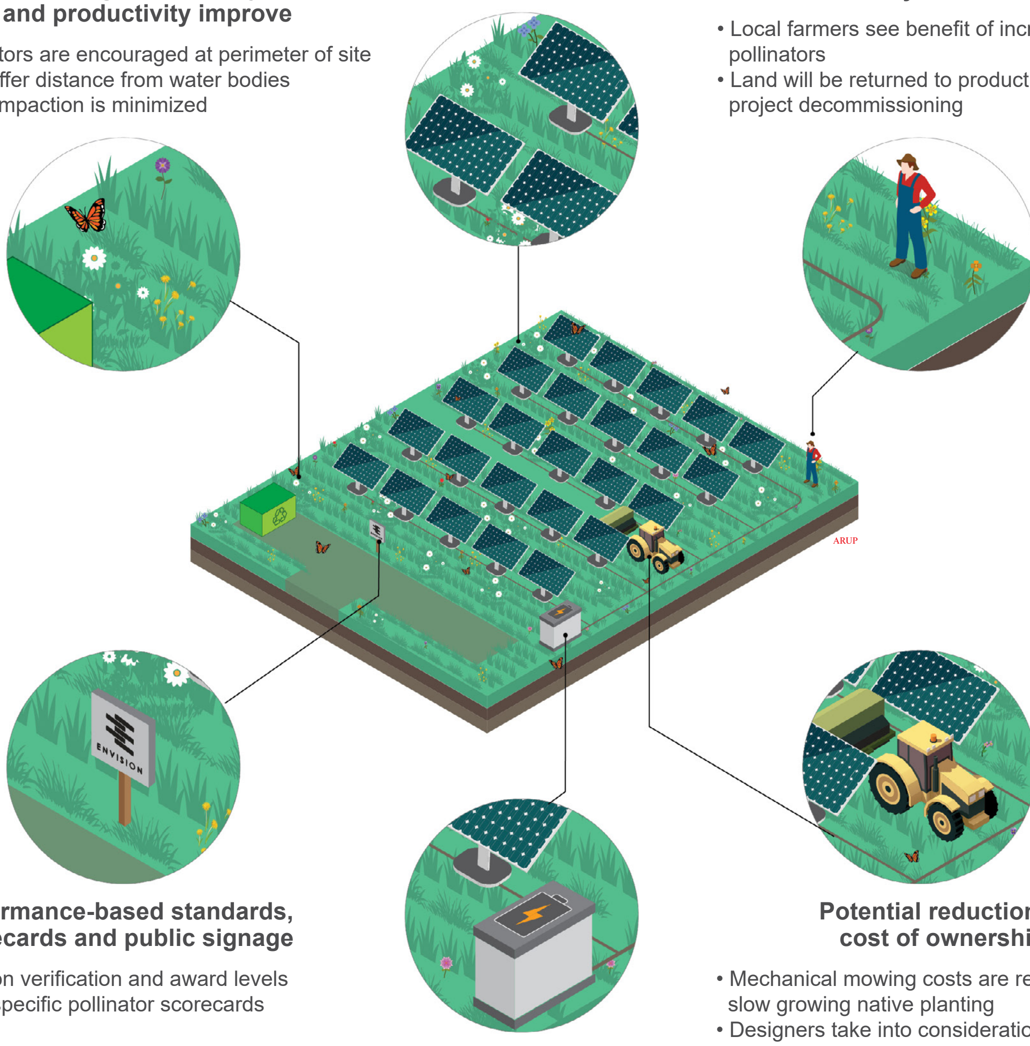
- Priority supply chain sourcing (e.g. no inclusion of Cadmium Telluride)
- Recycling occurs with goals for landfill avoidance.

Land-owners and local community value the sites additional contributions to agriculture, economy and ecology

- Local farmers see benefit of increased pollinators
- Land will be returned to productive use post project decommissioning

Ecological diversity and productivity improve

- Pollinators are encouraged at perimeter of site
- 50ft buffer distance from water bodies
- Soil compaction is minimized



Performance-based standards, scorecards and public signage

- Envision verification and award levels
- State-specific pollinator scorecards

Potential reduction in cost of ownership

- Mechanical mowing costs are reduced due to slow growing native planting
- Designers take into consideration vegetation management

Energy & water operational performance improves

- Bifacial panels improve production and reduce land take
- Battery storage incorporated for grid integration, providing greater resiliency and time-of-use output
- 30% lower on-site energy use
- 50% lower water use

Figure 2– Improved development

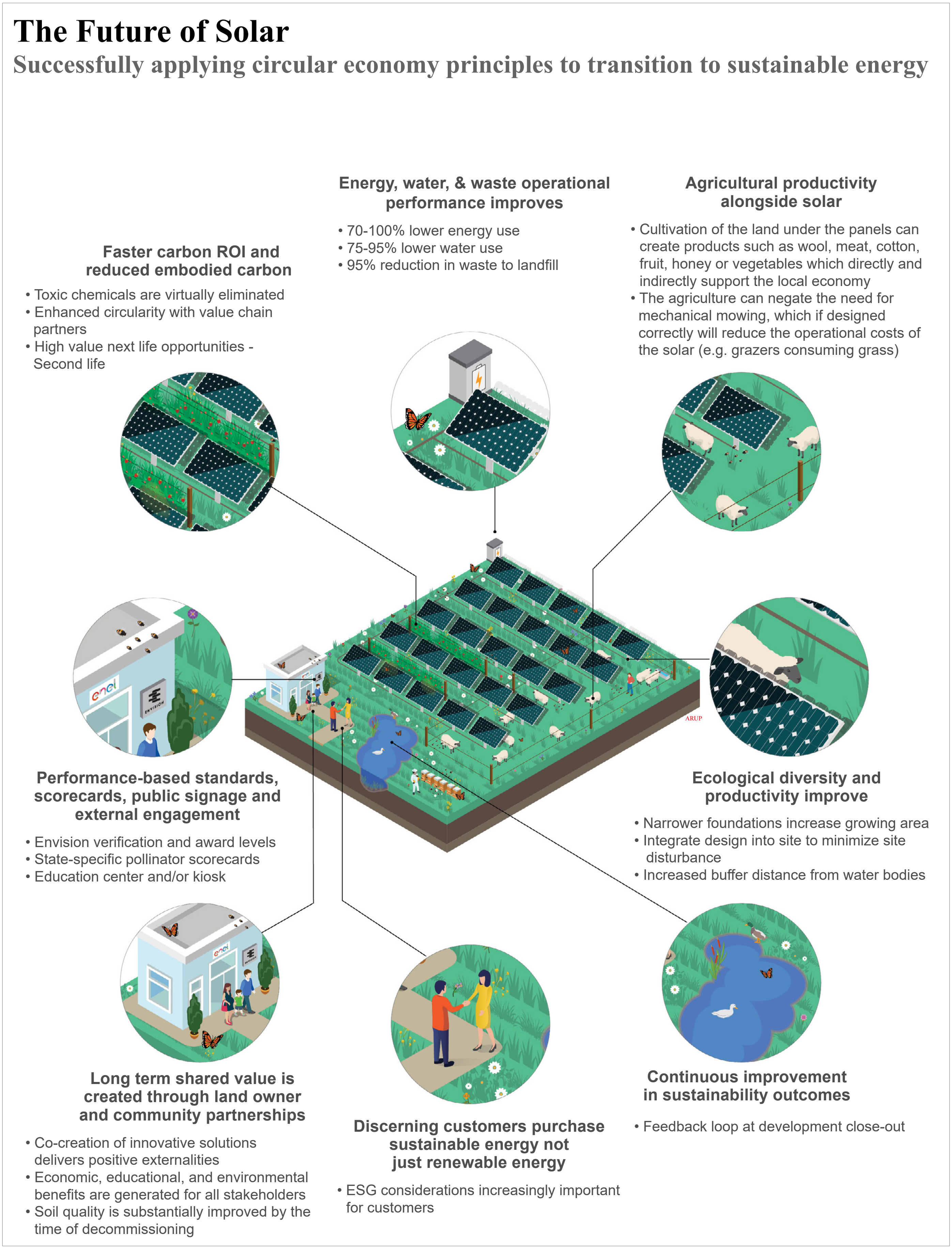


Figure 3– The future of solar

Photo Credit: Enel Green Power's Aurora Solar Farm, Mn

Sustainable Sourcing of Materials

Our work found that there are opportunities to improve the tracking of embodied carbon and ecotoxicity in the materials used in the solar sector through greater engagement with the wider value chain.

Embodied Carbon

Embodied carbon refers to the carbon dioxide equivalent (CO_2e) or greenhouse gas (GHG) emissions associated with the non-operational aspects of a project. The majority of GHG emissions in utility scale solar development occur upstream of operation in materials and module manufacturing (Figure 4).

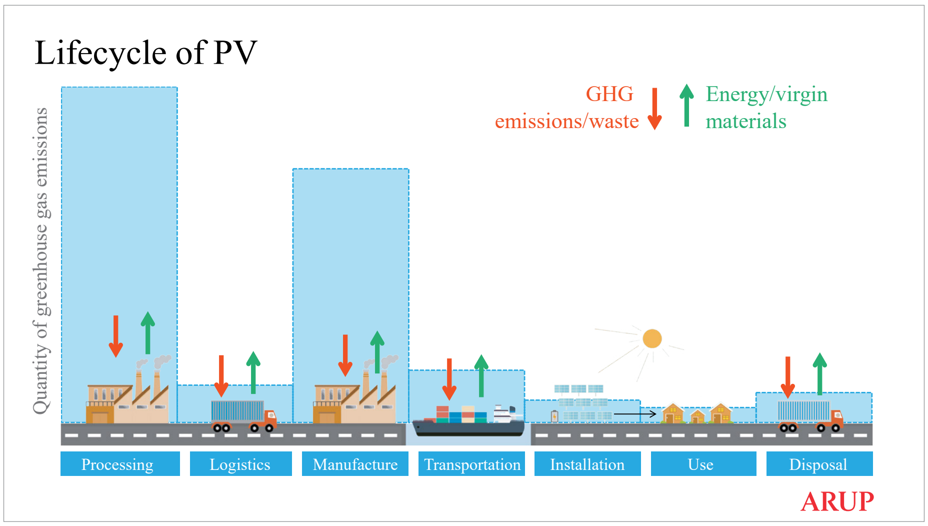


Figure 4 – Embodied carbon of utility scale solar development.
The majority of emissions occur during production of materials but are carried forward.

Innovative procurement strategies

Enel utilizes an innovative metric called a ‘k-factor’ to take into account additional sustainability criteria beyond cost and technical specifications, including embodied carbon. This incentivizes manufacturers to improve their environmental credentials.

To reduce the embodied carbon of the project, it is important to understand what changes can be made at each stage of the project’s life cycle through supply chain improvements or through application of other circular economy principles, such as product life extension.

Ecotoxicity

Ecotoxicity refers to the impact on ecosystems as a result of the emission of toxic substances to the air, water, and soil. Materials can impact the environment and human health before, during, and after their use. In order to better understand how to minimize or eliminate ecotoxicity, the team studied the material breakdown of different components such as photovoltaic panels. Although life cycle assessment (LCA) methodological differences present a challenge for comparison across different specific products, and site baseline conditions vary by location, general opportunities were identified and project-specific design enhancements can be implemented. Sourcing of silicon feedstock and production methods can significantly reduce ecotoxicity due to:

- Impacts most likely to occur during manufacturing and end of life treatment as a result of substances like lead and chromium, and corrosive chemicals produced during manufacturing.
- PV leachate is also a concern if modules are damaged.
- Crystalline silicon wafer production produces harmful waste products.
- Improper handling and disposal during manufacturing and end of life can result in exposures to people and ecosystems.

Minimizing ecotoxicity

By engaging with manufacturers, toxic materials can be avoided without any compromise to energy generation. For example, Cadmium Telluride has been prohibited on Enel solar plants.

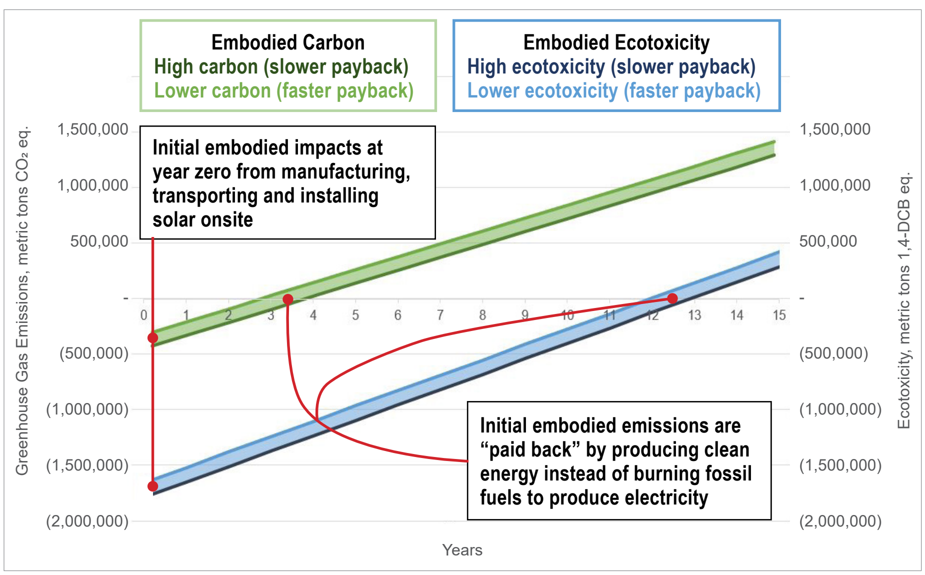


Figure 5 – Embodied Carbon and Ecotoxicity Payback for illustrative project on the ERCOT grid

Transparency helps to drive change throughout a product's supply chain. By calling for transparency in sourcing and manufacturing methods, Enel leverages its purchasing power to send a signal to the market that better chemical content information is important. It is especially important to minimize the ecotoxicity impact either through extending the life or through cycling materials through the value chain.

Dual Use

Dual use solar occurs when land occupied by a solar energy plant, or solar farm, provides additional land value beyond renewable energy generation, whether that be agriculture or the provision of ecological services, such as pollinator habitat or watershed protection. This offers an opportunity for the land to produce additional economic, societal, and environmental benefits, while reducing the costs of development and operational management.

Dual use solar is well aligned to Enel's five pillars of circular economy (Figure 6).

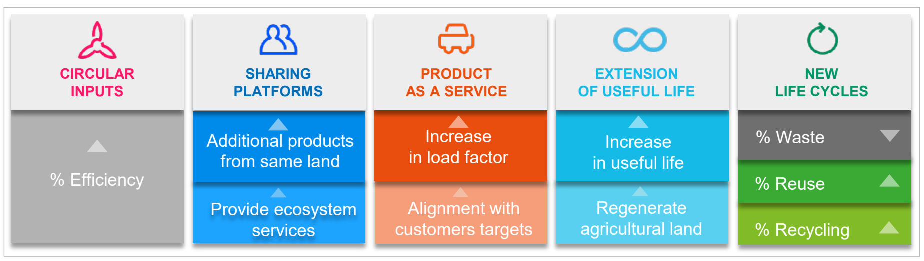


Figure 6 – Alignment of Dual Use Solar to Enel 5 Pillars of Circular Economy

Pollinators add $200 billion to the US economy every year

The United States Department of Agriculture estimates that pollinators provide $200 billion of ecosystem services each year in the United States.[7]

Pollinators

Pollinators play a critical role in local ecosystems and fruit farming by enabling over 80% of flowering plants to reproduce. The United States Department of Agriculture estimates that pollinators provide $200 billion of ecosystem services each year in the United States.[7] Planting seed mixes that are favorable to pollinators can enable a solar farm to provide ecosystem services to the surrounding area. Enel's experience has shown that successful selection of native pollinator habitat can simultaneously reduce maintenance costs by as much as 70% compared to gravel or other grass options which require costly herbicides and frequent mowing.[8]

Carbon Sequestration & Erosion Control Improvements in soil management through various techniques can ensure that the soil sequesters increase the amounts of carbon over time. By adopting agricultural or land management practices that consider soil health, the soil can become a carbon sink, enhancing the decarbonization benefit of the solar energy development.[9] Further, by planting with native and perennial grasses, deep-rooted systems prevent erosion from rainfall and wind is reduced, avoiding movement of excess nutrients such as legacy phosphorous to waterways.[10]

PV projects can support ecosystem health

By opting for native pollinators over other traditional less environmentally-positive approaches with industry standards for ground cover options, maintenance costs can be reduced by as much as 70%.

Agriculture

North American agriculture is a mainstay of the economies of rural communities, and a vital sector providing resilient domestic food production. The thoughtful integration of agriculture with solar offers opportunity to generate new business models and value-added products, as well as support the advancement of academic research in ecology, farming and other fields.

Dual use business models create a nexus and mutually beneficial relationships between technology, ecology, agriculture and local economies, including land, food, water, and built environments.[11]

The team identified multiple options for incorporating agriculture, pollinator habitat, and other ecosystem services with solar (Table 1 overleaf).

A decision support tool to better inform decisions

At the early stages of development, it is important to have clarity on the availability, benefits, drawbacks, and risks associated with the many different dual use solar options. This understanding is key for informing decision makers so that they can achieve outcomes that provide the greatest total societal value and have a positive business case. Arup and Enel are working with stakeholders in the industry to develop a decision support tool that provides this insight while also assisting with the delivery of dual use solar outcomes (Figure 7).

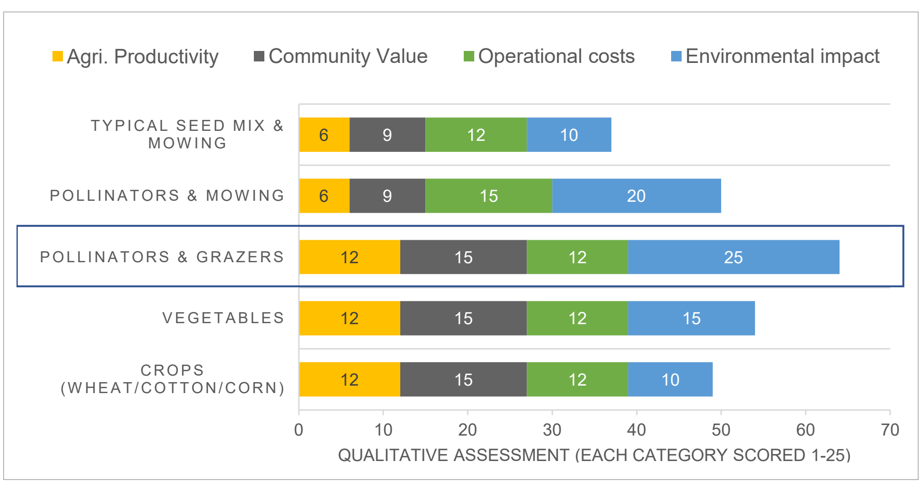


Figure 7 – Sample output from Arup Dual Use Opportunity (DUO™) Tool, outcome is based on specific outcome weightings and project details and will vary for differing projects.

Strengthen rural communities

Farming and land management in and around the PV plant, as well as associated value chain activities, can create additional opportunities for local communities.

Driving success with early decision making and engagement

The success of dual use solar is dependent on early engagement of all stakeholders in order to maximize the benefits.

Dual use typologies	Agricultural product(s)	Management practices	Ecological outcomes	Economic outcomes
Grazers & pollinators	• Beef • Lamb • Alpacas • Wool • Dairy	*Carefully managed grazing that ensures that a balanced native vegetation mix is maintained onsite that is evenly fertilized by manure.*	• Supports array of biodiversity • Significantly reduces machinery & fossil fuels use • Increase rate of pollination of local farming • Improves soil quality for future land productivity	• Low or net positive solar operating cost • Supports local supply chains • Provides additional skilled employment • Ecosystem services to farmers • Improve future land productivity
Specialist crops	• Herbs (e.g. mint) • Nuts (e.g. hazelnuts) • Berries (e.g. blackberries) • Other Fruits (e.g. olives)	*Unlike commercial farms, productivity is not primary revenue. Greater flexibility for eco-friendly practices that include co-planting of pollinators and reduced fertilizer/herbicides/ pesticides.*	• Crops can provide pollinator habitat • Crops can offset carbon emissions (e.g. hazelnuts) • Complimentary areas support biodiversity • Increase pollination for local farming • Minimize soil erosion	• Low or net positive solar operating cost • Supports local supply chains • Provides additional skilled employment • Ecosystem services to farmers
Commodity crops	• Wheat • Cotton • Corn		• Complimentary areas support biodiversity • Potential for biodiesel	
Pollinators & mowing	• Hay production • Honey	*Use of native slow growing plants to minimize need for mowing and maximize ecological benefits. Autonomous mowers to be considered.*	• Supports array of biodiversity • Increase rate of pollination of local farming • Minimize soil erosion	• Minimize operating costs • Ecosystem services to local farmers
Typical seed mix & mowing	Not applicable	*Regular mowing required to prevent fire risks to site and minimize interference with solar operations.*	• Minimize soil erosion	• Comparatively high operating costs

Table 1 - Dual Use Opportunities Sample

Differentiating between sustainable energy and renewable energy

The long-term benefits of sustainable energy for the local community and environment can be significant, but how can one know if a solar site is truly sustainable? In an industry that is inherently 'green,' it can be difficult to differentiate.

Adherence to sustainable business models and principles of circular economy serve as the foundation for moving toward sustainable solar energy. In addition, performance-based standards, such as the Envision rating system, offers project developers a transparent, third-party framework that considers the overall project impact and includes consideration of circularity and dual use.

Given the growth outlook for solar energy across North America, landowners, developers, power purchasers and other interested parties should engage early to assess and understand the dual use characteristics that will deliver, and harvest, the greatest value for the local economy, environment and society.

A Call to Action

Dual use solar offers the opportunity to improve North America's land, environment, and rural economies. Improved and traceable material sourcing offers the opportunity to source ethically, and build on the decarbonization benefits of solar by reducing eco-toxicity and embodied carbon. Transparency and smart choices by all stakeholders in the process are key. Customers can ask for sustainable energy options. Landowners can ask for dual use development proposals. Developers, designers, and contractors can find innovative new means of delivering on the ambitions of circularity and sustainability.

We need more collaboration with landowners, policy makers, farmers, ecologists, and solar specialists to achieve the full potential. Join us.

A win-win opportunity

Sustainable solar developed in an environmentally sensitive way strengthens and diversifies rural economies and the environment while providing renewable energy buyers the opportunity to better meet ESG goals.

End Notes

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External Contributors

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A Unique Conservation Solution.

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