


Exhibit 1:
August 7, 1990, 55 FR 32137, Sole Source Aquifer Designation for the
***Plymouth-Carver Aquifer*, Massachusetts, U.S. Environmental**
Protection Agency.

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(Cite as: 55 FR 32137)

NOTICES

ENVIRONMENTAL PROTECTION AGENCY

[FRL-3817-7]

Sole Source Aquifer Designation for the Plymouth-Carver Aquifer, Massachusetts

Tuesday, August 7, 1990

AGENCY: U.S. Environmental Protection Agency (EPA).

ACTION: Notice.

SUMMARY: In response to a petition from the Massachusetts Department of Environmental Protection (DEP), Division of Water Supply (DWS), the Town of Kingston, and the Plymouth County Coalition for a Better Environment, notice is hereby given that the Regional Administrator, Region I, of the U.S. Environmental Protection Agency (EPA) has determined that the Plymouth-Carver Aquifer satisfies all determination criteria for designation as a sole source aquifer, pursuant to section 1424(e) of the Safe

Drinking Water Act. The designation criteria include the following: Plymouth-Carver Aquifer is the principal source of drinking water for the residents of that area; there are no reasonably available alternative sources of sufficient supply; the boundaries of the designated area and project review area have been reviewed and approved by EPA; and if contamination were to occur, it would pose a significant public health hazard and a serious financial burden to the area's residents. As a result of this action, all federal financially assisted projects proposed for construction or modification within the Plymouth-Carver Aquifer will be subject to EPA review to reduce the risk of ground water contamination from these projects which may pose a threat to the health of persons in the aquifer's service area.

DATES: This determination shall be promulgated for purposes of judicial review two weeks after publication in the Federal Register.

ADDRESSES: The data upon which these findings are based are available to the public and may be inspected during normal business hours at the U.S. Environmental Protection Agency, Region I, J.F. Kennedy Building, Water Management Division, GWP-2113, *32138 Boston, MA 02203. The designation petition submitted may also be inspected at EPA Region I, or the Plymouth Public Library in Plymouth, or the Carver Public Library in Carver, Massachusetts.

FOR FURTHER INFORMATION CONTACT: Robert E. Adler, Ground Water Management Section, Water Management Division, EPA Region I, J.F. Kennedy Building, WGP- 2113, Boston, MA 02203, and the phone number is 617-565-3600.

SUPPLEMENTARY INFORMATION: .

I. Background

Section 1424(e) of the Safe Drinking Water Act (42) U.S.C. section 300h-3(e), Public Law 93-523, states:

If the administrator determines, on his own initiative or upon petition, that an area has an aquifer which is the sole or principal drinking water source for the area and which, if contaminated would create a significant hazard to public health, he shall publish notice of that determination in the Federal Register. After the publication of any such notice, no commitment for Federal financial assistance (through a grant, contract, loan guarantee or otherwise) may be entered into for any project which the Administrator

determines may contaminate such aquifer through a recharge zone so as to create a significant hazard to public health, but a commitment for federal financial assistance may, if authorized under another provision of law, be entered into to plan or design the project to assure that it will not so contaminate the aquifer.

On April 7, 1989, EPA received a petition from the Massachusetts DEP requesting designation of the Plymouth-Carver Aquifer as a sole source aquifer. EPA determined that the petition, after receipt and review of additional requested information, fully satisfied the Completeness Determination Checklist. A public hearing was then scheduled and held on January 10, 1990 in Plymouth, Massachusetts, in accordance with all applicable notification and procedural requirements. A four week public comment period followed the hearing.

II. Basis for Determination

Among the factors considered by the Regional Administrator as part of the detailed review and technical verification process for designating an area under section 1424(e) were: (1) Whether the aquifer is the sole or principal source (more than 50%) of drinking water for the defined aquifer service area, and that the volume of water from an alternative source is insufficient to replace the petitioned aquifer; (2) whether contamination of the aquifer would create a significant hazard to public health; and (3) whether the boundaries of the aquifer, its recharge area, the project designation area, and the project review view are appropriate. On the basis of technical information available to EPA at this time, the Regional Administrator has made the following findings in favor of designating the Plymouth-Carver Aquifer as a sole source aquifer:

1. The Plymouth-Carver Aquifer is the sole source of drinking water for nearly all of the residents within the service area.
2. There exists no reasonably available alternative drinking water source or combination of sources of sufficient quantity to supply the designated service area.
3. The petitioners, with EPA assistance, have appropriately delineated the boundaries of the designated aquifer area, the aquifer recharge area, the project review area and the aquifer's service area.

4. Although the quality of the aquifer's ground water is rated as good to excellent, it is highly vulnerable to contamination due to its geological characteristics. Because of this, contaminants can be rapidly introduced into the aquifer system from a number of sources with minimal assimilation. This may include contamination from several sources such as the following: chemical spills; highway, urban and rural runoff; septic systems; leaking storage tanks, both above and underground; road salting operations; saltwater intrusion; and landfill leachate. Since nearly all residents are dependent upon the aquifer for their drinking water, a serious contamination incident could pose a significant public health hazard and place a severe financial burden on the service area's residents.

III. Description of the Plymouth-Carver Aquifer, Designated and Project Review Area

The Plymouth-Carver Aquifer is a 199.0 square mile aquifer located in eight (8) towns in southeastern Massachusetts, primarily in Plymouth County, north of the Cape Cod Canal in Bourne and south of the Jones River in Kingston. Plymouth Bay borders the aquifer on the northeast with Cape Cod Bay bordering the eastern edge. As delineated in this petition, the Cape Cod Canal forms the southeastern border, Buzzards Bay forms the southern border, and the Weweantic River forms the southwestern border. To the west and north, the aquifer is bordered successively by the Weweantic River, Rocky Meadow Brook, Muddy Pond Brook, River Brook, wetland areas, and finally, along the northern border, the Jones River. It includes the entire area of the Towns of Plymouth, Bourne and Sandwich north of the Cape Cod Canal, most of the Towns of Carver and Wareham, substantial portions of Kinston and Plympton, and a small section of the Town of Middleborough (8 towns).

The Plymouth-Carver aquifer exhibits regional ground water flow patterns that are typical of coastal aquifers in eastern Massachusetts. Unlike upland stream-valley aquifer systems in which ground water flow is generally convergent or inward from high elevations of till and bedrock to low elevations within valleys, the flow pattern within the Plymouth-Carver aquifer is divergent, radiating outward from a topographically high area toward low lying bodies of both salt and fresh water. Ground water discharges to streams and the ocean.

The unconsolidated stratified glacial deposits which form the aquifer were deposited during the last retreat of glacial ice about 15,000 years ago. These deposits are saturated with water fed by direct infiltration of precipitation (recharge). The saturated thickness of the aquifer is the entire thickness of the aquifer from the water table to the top of bedrock. Ground water table elevations range from approximately sea level to approximately 125 feet at interior ground-water highs, with the maximum saturated thickness of more than 160 feet at some locations occurring along the axis of the underlying bedrock valley and its tributaries. Average hydraulic conductivities (ability of the aquifer material to transmit water) for stratified sand and gravel, range from 55 to 313 feet/day and average 188 feet/day. These values are consistent with values for similar deposits on nearby Cape Cod. The average rate of recharge to coarse-grained stratified drift is at least 1.15 million gallon/day/square mile (24 inches/year) and to fine-grained deposits is somewhat less.

Ground water in the aquifer system discharges to the many rivers and streams that drain the aquifer, to ponds, swamps, bogs and directly to the ocean. Average ground water discharge leaving the aquifer area as stream flow is about 140 cubic feet/second. All ponds and surface waters within the aquifer receive nearly all of their recharge from ground water and hence can be considered part of the Plymouth-Carver aquifer system. Much of the water that discharges to swamps and bogs is lost as a result of evaporation, transpiration, and consumption water use.

The Plymouth-Carver aquifer is quite vulnerable to contamination. Because of its highly permeable and transmissive character, and large size granular materials, ground water contaminants can quickly travel long distances, and affect a large area. The recharge area is characterized by moderate relief. Activities occurring in the upland areas can have direct impact on ground water quality in the rest of the aquifer. The present quality of the water from the aquifer has been characterized as good to excellent. Municipal supply wells in the aquifer area have been affected by relatively few instances of major contamination. There are, however, several instances of local contamination which have occurred at several places in the aquifer.

The designated area is defined as the surface area above the aquifer and its recharge area, which in the case of the Plymouth-Carver aquifer, comprises the project review area as well. The project review area is also the same as the designated area.

IV. Information Utilized in Determination

The information utilized in this determination includes: the petition submitted to EPA Region I by the petitioners; additional information requested from and supplied by the petitioners; written and verbal comments submitted by the public, communities in the region, state legislators; coordination with the U.S. Geological Survey and technical information obtained from them, and the technical papers and maps submitted with the petition. This information is available to the public and may be inspected at the libraries or EPA Region I office identified under the "Addresses" section previously.

V. Project Review

EPA Region I is working with the federal agencies most likely to provide financial assistance to projects in the project review area. Interagency procedures and Memoranda of Understanding have been developed through which EPA will be notified of proposed commitments by federal agencies to projects which could contaminate the Plymouth-Carver Aquifer. EPA will evaluate such projects and, where necessary, conduct an in-depth review, including soliciting public comments when appropriate. Should the Regional Administrator determine that a project may contaminate the aquifer as to create a significant hazard to public health, no commitment for federal financial assistance may be entered into. However, a commitment for federal financial assistance may, if authorized under another provision of law, be entered into for planning or designing a project to ensure that it will not contaminate the aquifer. Included in the review of any federal financially assisted project will be the coordination with state and local agencies and the project's developer. Their comments will be given full consideration and EPA's review will attempt to complement and support state and local ground water protection measures. Although the project review process cannot be delegated, EPA will rely to the maximum extent possible on any existing or future state and/or local control measures to protect the quality of ground water in Plymouth-Carver Aquifer.

VI. Summary and Discussion of Public Comments

Forty five people attended the January 10, 1990 public hearing regarding the Plymouth-Carver Sole Source Aquifer Petition. Many delivered supportive oral comments, but the Town of Plymouth expressed some concern regarding the implications of a designation on their public works projects. Forty formal comments were made in total during the hearing and the four-week comment period. Comments were received from state

legislators, local water suppliers and fire districts, local communities, a regional planning agency, environmental interests, etc. All but one of these supported the designation.

Questions were raised regarding the following:

1. The location of the northwest corner of the delineated boundary; and
2. The extent and limitations of protection provided by the federal Sole Source Aquifer Program and the need for local government to continue with taking actions to protect the aquifer.

In response to questions about delineation of the designated aquifer area, EPA explained that the aquifer is characterized by divergent ground water flow from a high ground water table elevation in the interior area of the aquifer. The area along the northwest section of the aquifer is characterized by bogs, wetlands, meandering streams, flat topography, and low ground water gradient. The boundary issue that was raised at the hearing related to the precise placement of the boundary line in specific localized areas. Following explanation of the basis for delineation, no further comments were made. The boundary, as originally proposed in the petition, is the boundary that is delineated in this designation. EPA responded to comments which expressed concern and confusion that the effectiveness of sole source aquifer designations is limited because only a small part of the development in the designated area will receive federal financial assistance. EPA recognized the limited applicability of the program and acknowledged that a comprehensive ground water protection program must include land use planning and management at the state and local levels as well. The DEP and EPA noted, however, that Massachusetts state regulations for underground storage tanks, site assignment for new solid waste landfills, and for hazardous waste facilities, give added protection by restricting these facilities when sole source aquifers are involved. Also, SSA designation often brings a new awareness locally for protecting resources.

The Town of Plymouth opposed the designation of the aquifer. In its opposition, the Town asserted that the designation will result in more government oversight and interference, will delay certain public road improvements to route 44, and will favor an ocean outfall over a land based treatment option in planning for a sewage treatment facility. EPA agreed that the designation would add another layer of review for impacts affecting the quality of ground water in the aquifer. It is noted that such aquifer reviews generally do not hinder or delay projects because the reviews conducted on large

projects are in conjunction with federal Environmental Impact Statements (EISs), environmental assessments, or state Environmental Impact Reports (EIRs). EPA routinely participates in the scoping and assessment of EISs and EIRs for major projects. This has been the case in the route 44 improvements. On smaller projects, reviews are generally less complicated, take three to six weeks, and do not cause undue delay. It is also noted that protection of public health is the principal concern of the program. Project delays that result in the protection of public health are favored over project expediency.

In addition to the concern that designation causes local project delays, the Town took the position that a sole source aquifer review is an unnecessary layer of review because local government can "protect its own." At the hearing, EPA observed that if local authorities, state and federal environmental and regulatory agencies are all carrying out their statutory and regulatory duties, the sole source aquifer review will be minimal, and in most cases will be incorporated into the existing environmental review processes.

*32140 In response to the issue that designation of a sole source aquifer would likely favor an ocean outfall option over a land based discharge option in Plymouth's sewage treatment planning, it is noted that the designation would not necessarily preclude a land based discharge. It is further noted that for land disposal to be allowed, Massachusetts ground water discharge permit regulations would probably require advanced treatment and effluent that would meet Massachusetts drinking water standards. As such, the performance standards would be determined under state regulations and scrutinized by EPA in their implementation.

The Town of Plymouth also expressed concern over the apparent lack of definitive guidelines from EPA governing the sole source aquifer program resulting in confusion and uncertainty. It is noted that EPA has clear and definitive Petitioner Guidance, Reviewer's Guidance, regulations concerning the implementation of the program at the Edwards aquifer, Region II post-designation guidance, relevant applicable state performance requirements, risk assessment capabilities, and others. Notable letters of support were received from state and local governments and representatives, water suppliers, environmental organizations and residents. Reasons given for support include: (1) The nearly total dependence of the residents on the aquifer's ground water for their drinking water supply; (2) the fact that there are no reasonably available

alternative sources of water, and that proper boundaries have been delineated; (3) growth and development in the Plymouth-Carver region threaten the continued purity of the resource; and (4) the Plymouth-Carver Aquifer's designation as a sole source aquifer would heighten public awareness of the vulnerability of the resource and would encourage further protection efforts.

VII. Findings

Given the information before me, all criteria for designating the Plymouth- Carver aquifer as a sole source aquifer have been met, and the region's aquifer is a resource that fully deserves efforts to protect it.

Dated: July 31, 1990.

Julie Belaga,

Regional Administrator.

[FR Doc. 90-18457 Filed 8-6-90; 8:45 am]

BILLING CODE 6560-50-M

55 FR 32137-01, 1990 WL 329590 (F.R.)

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Last updated on August 30, 2022

Exhibit 2:

May, 2021, *Comment Letter on MEPA #13940 Environmental Notification Form for Three AD Makepeace-Borrogo LGMSI in Wareham*, prepared by Partnership for Policy Integrity.



Secretary Kathleen A. Theoharides
Executive Office of Energy and Environmental Affairs
Attn: MEPA Office
100 Cambridge Street, Suite 900
Boston, MA 02114
Via email to MEPA@mass.gov

Re: Expanded Environmental Notification Form, March 15, 2021 and May 11, 2021 Supplement
ADM TMUD Wareham Solar Projects
EEA No. 13940-ADM Tihonet Mixed Use Development
Wareham, Plymouth, Carver, Massachusetts

Dear Secretary Theoharides,

The Partnership for Policy Integrity (PFPI) submits the following comments on the Expanded Environmental Notification Form (“EENF”) EEA # 13940 to the Massachusetts Environmental Policy (“MEPA”) Unit. PFPI’s work focuses on forests and climate, and our involvement in state policy matters has up to this point largely been confined to biomass energy. However, we are very concerned at how the state’s policy on large-scale solar energy appears to be promoting projects that result in net damage to Massachusetts’ forests, and accordingly are submitting these comments on particular aspects of the Wareham solar projects.

General comments on the state’s solar policy

First, this project, and the others going in, represent not a success of the state’s solar energy policy, but a failure. It is shocking to see that the state’s renewable energy policy is actually incentivizing forest clearing for solar. Climate change mitigation is not just about reducing fossil fuel emissions. Climate modeling is crystal-clear that we need to not only reduce emissions, but actually sequester CO₂ that has *already* been emitted. Restoring and expanding forests is the only means under our control to achieve this at scale. Accordingly, anything that undermines forest carbon uptake is actively undermining climate mitigation. The state should not have a policy that pits solar against forests. Policies should offer incentives for preserving and expanding forests, not destroying them.

Satellite imagery from Global Forest Watch shows that forest loss in the vicinity of the project is particularly high. Figure 1 shows forest loss just since 2000¹; it doesn’t even include the large amount of conversion to cranberry bogs and other uses from before 2000. In fact, pulling back, this area appears to have one of the highest rates of forest loss since 2000 in the entire state of Massachusetts.

¹ Data from Global Forest Watch at <https://bit.ly/3ukdyc0>

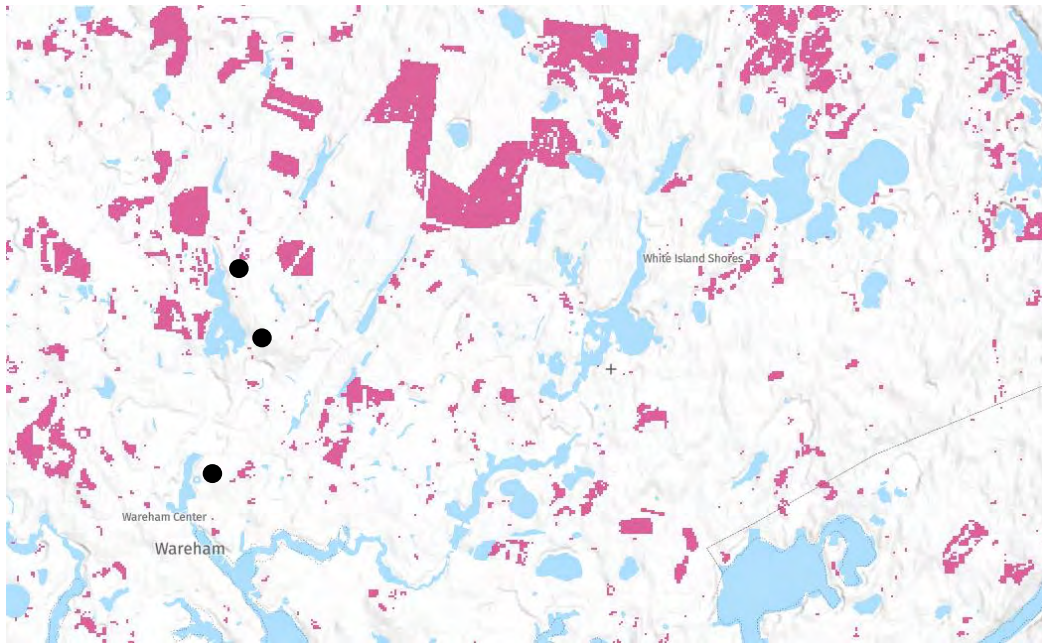


Figure 1. Global Forest Watch overview of forest loss in the area of the project. The three proposed solar fields are marked with black dots.

Regarding this specific project, it is tone-deaf for the EENF to claim (page 11) that *“Furthermore, the Master Plan’s Natural and Cultural Resources Goal 1 is to, ‘Coordinate and strategically implement several ongoing efforts to increase climate resilience in Wareham.’ While the Project will not contribute directly to climate resilience specifically in Wareham, it will advance the Commonwealth’s renewable energy initiatives, which broadly address the issues surrounding climate change.”*

We would argue that any project that causes more forest loss in Wareham is actually undermining the town’s climate resilience.

General comments on the project

These projects are extraordinarily damaging

Using Google Earth to view other solar projects installed in the same area as the proposal makes it evident how damaging these projects are. Removal of forest and land preparation scrapes the soil down to essentially white sand, and even beyond this, further sand mining is occurring. This essentially resets the ecosystem to where it was right after the glaciers retreated. Transpiration from vegetation cools and moistens the air, but the sand pit is a glaring, radiating zone without any ability to affect or modify its microclimate. The subsoil is sterile sand with few available nutrients, meaning nothing much will grow here again in any human timeframe, even after the solar panels are removed. This may be within the owner’s rights – but why is it being subsidized with Massachusetts clean energy subsidies? Approval of the project and receipt of the subsidies should at a minimum be made contingent on the ability to fully restore the site to forest. In few years, these projects are going to be seen as dinosaurs and be viewed with shame for the forest destruction they caused. Assuming a sane climate policy prevails, forest protection and restoration will be prioritized, and solar will be built in places that are already sacrifice zones, such a parking lots, road medians, and perhaps the cranberry bogs of Wareham.



Figure 2. A recent solar and sand mining project in the vicinity of the proposed project (at 41.800214°, -70.703461°)

Comments on the analysis for the proposal

The proposal contains questionable assumptions and analyses in at least two respects – consideration of mitigation for the loss of forests, and consideration of net GHG impacts of the project.

Mitigation of habitat loss

The 2014 certificate on the ENF states, “NHESP indicates that a long term net benefit can be developed through a) permanent protection of appropriate habitat in the vicinity of previously designated conservation areas, and b) providing funding for long-term habitat management to benefit the affected species.”

We wonder if the program would use similar language today. There is no “net” benefit given the accelerating forest loss in the region, as shown in Figure 1.

At page 5 of the March 2021 EENF, it states, “Although portions of the 150 Tihonet Road PV+ES Project lie within identified but unmapped pine barrens habitat, the Proponent is coordinating with NHESP and will undertake appropriate mitigation in the form of conservation lands and habitat funding.”

Even if these minimal set-asides are actually happening, this does not constitute “mitigation” given that the entire pine barrens ecosystem is being obliterated where the solar panels are installed. Setting aside other land for conservation is nice, but there is a net loss of ecosystem that is occurring. There is no “mitigation.”

Other impacts

The loss of vegetation also changes the hydrology of the site. The proponent is developing stormwater retention basins, the planning for which needs to take into account changes in rainfall amount and intensity now underway with climate change. Has this occurred? Does the modeling actually recognize non-stationarity of rainfall?

The ponds already have issues with dissolved oxygen and phosphorous pollution, which is evident with satellite photos that show extensive algae growth. Also, it appears that there is potentially some planting activity planned for the area under the solar panels. We wonder if the project will use herbicides to reduce growth of the meadow? If so, has the potential for water contamination been evaluated, given the sandy soils and the proximity to ponds?

We also note that wetland resources in this rare pine barrens ecosystem are being disturbed. This area of eastern MA has extremely fragile ecosystems. It seems a real failure of state policy, both in terms of MEPA review and in terms of solar incentives, that this project is moving forward and seemingly headed for state approval and even financial support.

GHG analysis

Failure of the state to provide guidance

The 2014 certificate discusses developing a protocol for evaluating GHG impacts, but apparently this has not been done. Why not? There has been plenty of time. There should have been a protocol for the proponents to follow, instead of being left to make it up as they go along. Why is the state so lax on these matters?

Failure to include ecosystem carbon loss

In calculating the GHG “benefit” of the project, the proponent simply ignores the carbon emissions from removing the forest from the site. Why do they assume this is legitimate? It is not, because this is stored carbon. They appear to claim it would only be emitted to the atmosphere if it were burned (page 2 of memo), but in fact even if the trees were converted into long-lived wood products, a significant portion of the wood would be lost right away during processing.

The basic IPCC protocol for assessing emissions impacts of forest clearing treats felling trees as an instantaneous emission of stored carbon, though more refined approaches are possible when data are available. The appropriate protocol to require here appears to be the one for “Other Land”²:

Tier 1

*A Tier 1 method follows the approach in Equation 2.16 in Chapter 2 where the amount of above-ground biomass that is removed is estimated by multiplying the area (e.g., forest area) converted annually to Other Land by the average carbon content of biomass in the land prior to conversion (B_{BEFORE}). In this case, B_{AFTER} in Equation 2.16 is set to zero by default. **The default assumption for the Tier 1 calculation is that all carbon in biomass (less harvested wood products removed from the area) is released to the atmosphere immediately (i.e., in the first year after conversion) through decay processes either on- or off-site.***

Tier 2

² https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_09_Ch9_Other_Land.pdf

A Tier 2 method can be developed and used if country-specific data on carbon stocks before conversion to Other Land (i.e., B_{BEFORE} in Equation 2.16) are obtainable. B_{AFTER} remains at zero. In addition, under Tier 2, carbon losses can be apportioned to specific conversion processes, such as burning or harvesting. This allows for more accurate estimation of non-CO₂ greenhouse gas emissions. A portion of biomass removed is sometimes used as wood products or as fuel wood. Chapter 2, Section 2.4 provides the basic method for estimating non-CO₂ greenhouse gas emissions from biomass burning. Chapter 12 provides guidance for estimation techniques for carbon stored in harvested wood products.

Tier 3

A Tier 3 method requires more detailed data/information than the Tier 2 approach, e.g.,:

- Geo-referenced disaggregated areas converted annually are used for each land use converted to Other Land;
 - Carbon densities are based on locally specific information and; and
 - Biomass stock values are based on inventories and/or the model estimations.
- Where data are available, Tier 3 methods may be used to track the dynamic behaviour of carbon stocks and greenhouse gas emissions following conversion. **Where the land remains in a vegetation-free state (due to severe degradation), there will generally be a continuing decline in carbon stocks.** If this is not the case, countries should consider whether the land should be classified under another land use, as indicated in Chapter 3.

In the case of this project, where stumps and roots will be removed, the loss of biomass carbon is especially notable. The loss of soil carbon is also extreme. According to the data the proponents themselves cite (from EPA), soil carbon can constitute more than 50 - 60% of ecosystem carbon. The total removal of topsoil and the layers of subsoil that are most likely to store soil organic carbon in dissolved forms also needs to be taken into consideration. The state should require the proponents to find data that accurately reflect the aboveground and belowground carbon loss, including from soils, and do the calculation properly.

Failure to include timing of GHG emissions

The proponent draws attention to the future gain of carbon on the site, stating that the calculations are “likely conservative” because they do not include the carbon that will be sequestered in the “meadow” growing beneath the solar panels (to be planted?) and the future carbon sequestration in the forest that will replace the solar panels when the project is decommissioned. These hypothetical impacts are in the future, while the liquidation of site carbon is happening now, just when it is most urgent to reduce emissions. Carbon loss happening in the near term with certainty needs to be valued more highly than future potential carbon gain. Further, it appears that the proponent is actually misrepresenting the developer’s intentions when they say the area will be reforested, because the developer is on video³ as saying that after the “fad” of solar passes, the “junk” will be hauled away and the site will be turned into a housing development.

Sequestration analysis is incorrect

The proponents’ assessment of carbon emissions from the project is confined to estimates of future forest carbon sequestration that will be foregone. They analyze this using two approaches. The first approach uses data they say they obtained from Northeast Survey Consultants, but they do not say what the data are, or how they were obtained, though they do refer to diameter at breast height (DBH)

³ <https://www.youtube.com/watch?v=nh7fnq2y3Sg>

measurements “where applicable.” It is not clear what this means. It is also not clear how the tree volume estimates were made or how they relate to the DBH. The report further makes an error in converting the dry weight to green weight of 72.5%, citing an unpublished online document⁴ with no citations which states, “Taking all species in the table into account, the average tree is 72.5% dry matter and 27.5% moisture.” This is not correct for trees in New England, where moisture content of freshly harvested wood is around 50% and sometimes more.

Given this failure and the proponents’ evident unfamiliarity with protocols for ecosystem carbon assessment, we have no confidence in the approach to calculating increased DBH and volume through time, which uses a “simplified, linear growth rate formula.” They do cite a reference for this approach, but it is not clear if their analysis of forest biomass takes into account the fact that trees with bigger circumference tend to also be taller, meaning their overall volume is greater. In fact, the regression curve that proponents provide for volume/weight (cubic meters) looks very similar to a standard curve of the relationship between diameter and area of a cross-section of a tree (square meters), which if the trunk is circular in cross-section would follow the relationship of “pi-r-squared.” We graphed up that simple relationship (in blue) and overlaid it on the on the proponents’ graph (Figure 3):

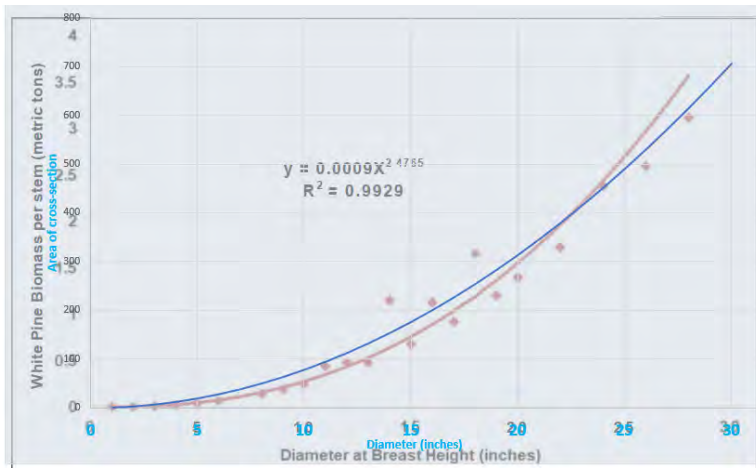


Figure 3. The graph of the relationship between diameter and area (square meters) overlaid on the proponents’ graph of diameter and volume (cubic meters) translated in some unknown way to weight of biomass.

It appears that the proponents’ analysis of biomass per stem does not correctly reflect the overall increase in volume, because it traces a relationship of DBH to stem cross-sectional area, rather than full tree volume. Further, a stem analysis does not really tell much about forest biomass as a whole, unless there is a detailed count of stems per acre, and the analysis includes the volume of stumps and roots. Even with that information, the analysis of carbon *stocks* is incomplete, because it does not include soil carbon. For an analysis of future sequestration (carbon sinks), however, soil carbon may be difficult to quantify.

For a more credible approach, at a minimum the proponents could use the USFS Forest Inventory and Analysis data and tools that the Forest Service makes available for estimating forest carbon stocks and sinks. Additionally, research suggests carbon sequestration by larger, older trees has in some cases been

⁴ https://www.unm.edu/~jbrink/365/Documents/Calculating_tree_carbon.pdf

underestimated, for instance see Stephenson et al 2014⁵ and most recently Leverett et al 2021,⁶ with Figure 1 from that paper reproduced below. While growth patterns from individual trees can not be directly extrapolated to whole stands, the data suggest that the *apparent* “slowing” of growth by older trees is often not reflected in their volume, which continues to increase.

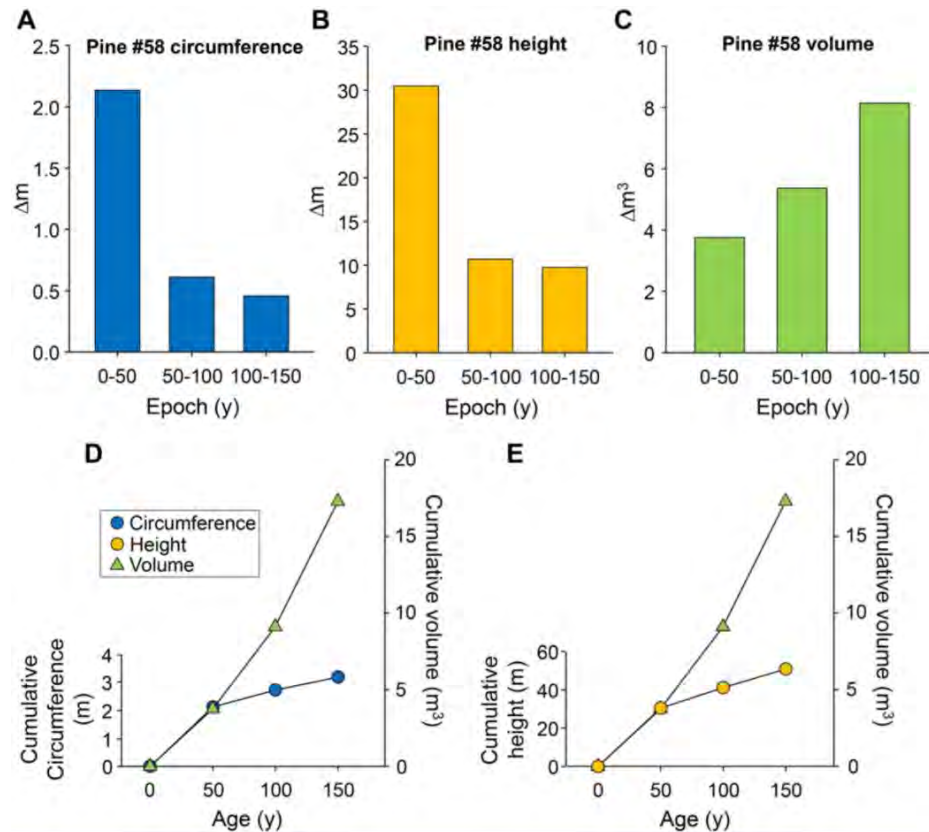


Figure 4, which is Figure 1 from Leverett et al, 2021. *Changes in circumference, height and volume of a stand-grown individual eastern white pine (Pine #58) in three 50-y intervals. Upper panels (A) Change in circumference during 0–50, 50–100, and 100–150 years. (B) Change in height between 0–50, 50–100, and 100–150 years. (C) Change in above-ground tree volume (trunk plus limbs) between 0–50, 50–100, and 100–150 years. Lower panels (D) Cumulative circumference at 50, 100, and 150 years compared to cumulative above-ground volume. (E) Cumulative height at 50, 100, and 150 years compared to cumulative above-ground volume. On each lower panel initial slopes were matched to reflect the rapid change in circumference and height during the first 50-years interval. Note that volume is a proxy for above-ground carbon. Values for circumference, height and volume of Pine #58 were determined by a combination of direct measurement and chronosequence and described in the text and in Supplement.*

⁵ Stephenson, N. L., et al. (2014). "Rate of tree carbon accumulation increases continuously with tree size." *Nature* 507(7490): 90-93. <https://www.nature.com/articles/nature12914#Sec14>. Supplementary information at <https://www.nature.com/articles/nature12914#Sec14>

⁶ Leverett, R. T., et al. (2021). "Older Eastern White Pine Trees and Stands Accumulate Carbon for Many Decades and Maximize Cumulative Carbon." *Frontiers in Forests and Global Change* 4(40). <https://www.frontiersin.org/articles/10.3389/ffgc.2021.620450/full>

The second approach employed by the proponents to estimate foregone sequestration relies on an EPA estimate of forest carbon stocks that includes soil carbon, deadwood, etc. However, the proponents incorrectly apportion sequestration based on stocks, assuming that because living biomass constitutes 31% of the ecosystem carbon, then it must be responsible for the same proportion of active carbon sequestration. If only this were true! If mineral soils added new carbon to stocks at the same rate as living biomass, maybe we wouldn't have a climate crisis (though we'd be up to our eyeballs in soil). In fact among the several problems with this analysis, the proponents have underestimated the amount of ecosystem carbon uptake for which living biomass is responsible, so have underestimated the total ecosystem C sink.

Assumption of fossil fuel displacement is not valid

The entire GHG benefit of the project is based on the assumption that it will displace fossil fuels. The proponents make several statements to this effect. However, for there to be a net reduction in GHG emissions, there does need to be actual, verifiable substitution. Climate warming is a function of the total amount of CO₂ loading, not the GHG intensity of generation. Therefore if solar and other relatively emission-free technology comes online, but the total amount of fossil fuel burning stays the same or increases, there will be no decrease in the amount of CO₂ emitted per year. Yes, it seems likely that fossil fueled electricity generation decreases as solar and wind generation come online and become cheaper, but the other thing that happens is that electricity use increases as consumers become aware that more "green" energy is available, and as electricity becomes cheaper. As electrification increases, for instance of vehicles, overall use will rise, keeping pressure on fossil generators to continue operating. Substitution can only occur if the total amount of electricity generation from fossil sources is capped⁷ - otherwise there is simply additional generation, and no net reduction in emissions. As there is no requirement for fossil generation to be taken offline as new solar generation comes online, there can be no assumption that substitution is occurring – as attractive as this concept appears.

Valuing forests solely as "carbon sinks"

Overall, the very concept embodied in the EENF, that forests are valued in this context solely for their ability to sequester carbon is, frankly, insane. Yes, it is probably possible to calculate a GHG "benefit" to building the solar field and replacing forests, making dubious assumptions as the proponent does. In that case, why not clear all the forests in Wareham? Isn't that the logical outcome of such calculations? Perhaps the state should provide incentives to remove *all* the forest in eastern MA and replace it with solar – then we could claim even more GHG "reductions."

The obvious absurdity of that suggestion indicates that there is some scale at which this policy of allowing forest removal for solar no longer makes sense. To us, it seems obvious that this point has already been reached. Forest loss occurring for any reason is hugely counterproductive for ecosystem values and climate alike; clearing forests for solar, specifically, when there are so many alternative places it could be built, is repugnant.

⁷ Leturcq, P. (2020). "GHG displacement factors of harvested wood products: the myth of substitution." Scientific Reports 10(1): 20752. <https://doi.org/10.1038/s41598-020-77527-8>

Decommissioning should include reforestation

The proponent states that funds are set aside for decommissioning. In fact, given the current rapid rate of forest loss in the region now, we suspect that in the future, the highest use of the site will be as forest. Accordingly, the decommissioning cost should include reforestation as a value to society. There is precedent for this – for instance, the landowner has currently been benefitting from Chapter 61, which is a program that reduces taxes because of the public benefit of keeping land in forests. Making approval of these projects and receipt of publicly funded renewable energy subsidies contingent on future mitigation back to the natural state is completely reasonable. At a minimum, state officials should require real mitigation, which returns the land to its natural forested state, as a condition for approval. If this can not be assured, the project should not be approved. Ideally, the state should change its policies and stop approving any so-called “green” energy projects that rely on clearcutting, and in this case obliterating, the natural ecosystem. In the case of this particular project, it seems likely this area will functionally be a waste land, and that forest regeneration will be paltry, if it occurs at all, due to sandy soils that will be rendered even more nutrient-poor with removal of topsoil and sand mining.

Thank you for the opportunity to comment.

Mary S. Booth, PhD
Director, PFPI

A handwritten signature in black ink that reads "Mary S Booth". The signature is written in a cursive, flowing style.

Exhibit 3:
January 2021, *Leaching via Weak Spots in Photovoltaic Modules*, by
Nover et al.

Leaching via Weak Spots in Photovoltaic Modules

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Abstract: This study identifies unstable and soluble layers in commercial photovoltaic modules during 1.5 year long-term leaching. Our experiments cover modules from all major photovoltaic technologies containing solar cells from crystalline silicon (c-Si), amorphous silicon (a-Si), cadmium telluride (CdTe), and copper indium gallium diselenide (CIGS). These technologies cover more than 99.9% of the world market. We cut out module pieces of $5 \times 5 \text{ cm}^2$ in size from these modules and leached them in water-based solutions with pH 4, pH 7, and pH 11, in order to simulate different environmental conditions. Unstable layers open penetration paths for water-based solutions; finally, the leaching results in delamination. In CdTe containing module pieces, the CdTe itself and the back contact are unstable and highly soluble. In CIGS containing module pieces, all of the module layers are more or less soluble. In the case of c-Si module pieces, the cells' aluminum back contact is unstable. Module pieces from a-Si technology also show a soluble back contact. Long-term leaching leads to delamination in all kinds of module pieces; delamination depends strongly on the pH value of the solutions. For low pH-values, the time dependent leaching is well described by an exponential saturation behavior and a leaching time constant. The time constant depends on the pH, as well as on accelerating conditions such as increased temperature and/or agitation. Our long-term experiments clearly demonstrate that it is possible to leach out all, or at least a large amount, of the (toxic) elements from the photovoltaic modules. It is therefore not sufficient to carry out experiments just over 24 h and to conclude on the stability and environmental impact of photovoltaic modules.

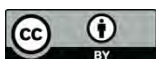
Keywords: leaching; long term; photovoltaic modules; delamination; solubility



Citation: Nover, J.; Zapf-Gottwick, R.; Feifel, C.; Koch, M.; Werner, J.H. Leaching via Weak Spots in Photovoltaic Modules. *Energies* **2021**, *14*, 692. <https://doi.org/10.3390/en14030692>

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1. Introduction

Photovoltaic (PV) modules are not a niche product anymore. The market started with an installed capacity of 20 MW in the early 1990s and increased up to 635 GW of total installed PV modules worldwide at the end of 2019 [1]. By assuming an average lifetime of 30 years, we have to deal with an increasing amount of waste from PV modules of up to 1.7 million tonnes until 2030 [2].

In principle, photovoltaics are a green technology; however, some PV modules contain toxic elements such as lead in the solder ribbons and metalization pastes, or even worse, such as in CdTe technology, the toxic elements Cd and Te in the photoactive layer itself. Many modules using copper indium gallium diselenide (CIGS) also contain cadmium in the so-called CdS buffer layer of the CIGS cells. This situation is mainly possible because PV modules are still excluded from the EU Directive on the restriction of hazardous substances (ROHS 2) in electrical and electronic equipment. This exclusion will remain until the next review of the RoHS 2, which is planned for 2021 [3]. For all other electric and electronic equipment (EEE) on the EU market, the tolerated maximum concentrations by weight in homogeneous materials for lead (Pb) and cadmium (Cd) are 0.1% and 0.01%, respectively. Clearly, in the case of the compounds CdS or CdTe, with 50% of the mass being Cd,

the RoHS is not obeyed. However, also the technology of modules with crystalline Si cells has a problem with RoHS, although it could easily be overcome by using cell connectors without lead (usually, the solder contains about 40% lead) in the solder. The tiny amount of Pb in the metallization pastes could be kept below the RoHS limits. In 2019, the amount of lead-free metallization pastes in the case of silicon (Si) solar cells was only 30% [4]. At the same time, the world market share of lead-containing solder for cell connectors was over 90% [4].

Most probably, photovoltaic modules, which contain toxic substances, are safe for the users and the environment, at least as long as the modules are not damaged. Nevertheless, what happens if modules are damaged? What happens at the end of their use? Are they “donated” or “exported” like old cars, other old electronic equipment, and waste to countries outside the EU? In the worst case, finally, wherever it may be, the modules are crushed and/or discarded in landfills. What could happen with the toxic elements? In fact, it is no longer a question if these substances are released into the environment: several studies proved they do and that the release depends on the pH-value of the leaching solvents, as well as on the redox conditions [5–10]. A literature review can be found in [11].

Despite of all these studies [5–11], several questions are open: How are the toxic substances released? What are the weak spots in the modules? Does leaching only occur in the case of delaminated modules, i.e., in modules, that have lost the front glass? In this case, in particular for thin film modules, it would be understandable that the toxic substances are leached from, for example, the CdTe layers, which are no longer protected by the front glass. Does it work the other way around: Are the thin layers leached from the edges of the module (pieces) leading, finally, to delamination? Clearly, after delamination, the leaching would then be accelerated even more, because the leaching solution is now able to attack the thin layers not only from the edges, but also from the surface. Are there any potentially accelerating parameters, like agitation or temperature, regarding the leaching?

The present contribution gives answers to most of these questions via a long-term study. In contrast to previous work, our leaching tests are not only conducted over 24 h as requested by standard leaching tests [12–15], but for more than 1.5 year; some of our results are even taken after almost two years. Furthermore, we analyze not only eluted amounts of toxic substances like cadmium (Cd) and lead (Pb), but also other elements present in the module layers such as zinc (Zn), tellurium (Te), indium (In), gallium (Ga), selenium (Se), aluminum (Al), molybdenum (Mo), and copper (Cu), to identify soluble and, therefore, weak layers in PV modules. Parts of the experimental details were published earlier in German [16]; some results about the leaching of Cd, Te, and Pb up to day 360 were published earlier by us [10]. We find, that, finally, the modules delaminate because of the leaching from the edges of the module pieces. In all kinds of modules, at least one of the layers of the different cell types represents a weak path for the leaching. In the case of CdTe module pieces, the CdTe layer itself and the Mo contact are soluble. In the case of CIGS module pieces, the Zn front contact, the Mo back contact, and the Cd-containing buffer layer are susceptible to strong leaching. For crystalline silicon module pieces, the Al back contact is a weak spot; for amorphous silicon (a-Si) module pieces, also the back contact (Ni) and the intermediate layer containing Zn are identified as weak spots.

Section 2 of the present contribution describes the sample preparation and the leaching conditions and shows how we determine the total amount of elements within each type of our investigated solar modules. Section 3 presents our leaching results. We measured for more than 1.5 years, not only at room temperature, but also at increased temperature, as well as under accelerated leaching conditions. The leaching time constant depends on the module type, as well as on the leaching conditions. Section 4 identifies the weak spots for each particular module type. Section 5, finally, concludes that the amount of leached out elements after 1.5 years in some cases exceeds the value after one day by more than two orders of magnitude. Thus, leaching experiments, which are just carried out over one day, are valuable. However, statements about the stability and environmental noxiousness of photovoltaic layers are highly questionable when based on such short-term measurements.

2. Materials and Methods

2.1. Sample Preparation and Experimental Conditions

For cutting the module pieces with well-defined sizes and edges, we applied water jet cutting to get samples from the four major commercial PV technologies: crystalline silicon (c-Si), amorphous silicon (a-Si), cadmium telluride (CdTe), and copper indium gallium diselenide (CIGS). The module pieces are cut in a way that all module pieces contained at least one solder ribbon, but no parts of the frame, module boxes, or cables. The sample size of the module pieces for the leaching experiments was $5 \times 5 \text{ cm}^2$.

The leaching experiments were carried out under three different conditions, in order to identify potential accelerating conditions:

- Room temperature $T_{RT} = 25 \text{ }^\circ\text{C}$, no agitation;
- Room temperature $T_{RT} = 25 \text{ }^\circ\text{C}$, with agitation (orbital shaking with rotational speed $n = 100 \text{ min}^{-1}$);
- Increased temperature $T_{IT} = 40 \text{ }^\circ\text{C}$, with agitation (orbital shaking with rotational speed $n = 100 \text{ min}^{-1}$).

For all experiments, we used high-density polyethylene (HDPE) bottles supplied with the leaching solution with a 1000 mL volume and two pieces from the very same module; see also [10]. The samples were not fixed in the bottles, and the bottles were lightproof. From earlier experiments (not presented here), we know that light accelerates leaching. However, light leads also to the production of alga, in particular for the long leaching times we are using. Alga production changes the experimental conditions and makes the leaching experiments less reproducible. Therefore, for the experiments presented here, we decided to use lightproof bottles. In order to increase the significance and validity of our experiments even more, each experiment was conducted in triplicate (this means three bottles, each one filled with two samples) for every condition. The leaching data, i.e., the concentration of a particular element in the solutions, are given as the mean value of the probes taken from the three bottles.

The leaching solutions with three different pHs covered the pH range of different environmental conditions that might occur in rain, groundwater, or waste disposal sites; their exact chemical composition and pH are shown in Table 1. All leaching solutions were based on deionized (DI) water. Over the whole 1.5 years of the experiments, the pH and the oxidation/reduction-potential E_H remained almost constant. Data for E_H , following DIN38404-6, stemmed from measurements with a platinum electrode against a silver/silver chloride reference (Ag/AgCl). The concentration of potassium chloride $c_{KCl} = 3 \text{ mol/L}$ was $T = 25 \text{ }^\circ\text{C}$; we converted the data to a potential against a standard hydrogen electrode [17].

Throughout the leaching experiments, starting after 0.5 days, we periodically took 15 mL samples from the leaching solutions in the bottles and analyzed them for the leached out elements. After taking the probe, we poured in again fresh solution of 15 mL to keep the 1000 mL volume. All data were corrected for the amount of elements that were taken out from the solution due to sampling.

Table 1. Composition of leaching solutions with pH-values of 3, 7, and 11 used in the experiments and the measured reduction potential E_H ; the same conditions as in [10]. (Copyright (2017) The Japan Society of Applied Physics, reproduced with permission).

pH	E_H (V)	Chemical Composition
3	0.62	15.4 g/L $\text{C}_6\text{H}_8\text{O}_7$, 2.8 g/L Na_2HPO_4 , DI water
7	0.56	3.7 g/L KH_2PO_4 , 5 g/L Na_2HPO_4 , DI water
11	0.33	0.04 g/L NaOH, DI water

2.2. Heavy Metal Analysis and Determination of Initial Metal Content in Module Pieces

We characterized the samples that were taken from the leaching solutions with inductively coupled plasma mass spectrometry (ICP-MS) and give the data for the leached elements according to ISO 17294-2 [18]. This method is only able to measure dissolved substances; it cannot detect precipitations in the solution. Therefore, the elements in the precipitates were not counted as leached.

Here, we always give the amount of leached out elements as a percentage with respect to the total amount of elements that were in the original module pieces. Therefore, we had to measure the total mass of those elements in the module pieces before the experiment. For that purpose, similar module pieces as those for the experiments were milled to a powder. Then, the powder was digested by adding acid and oxidizing agents and, finally, using microwave irradiation. After that, the digested samples underwent the ICP-MS analysis, similar to our earlier experiment [10]. For each PV technology, and for all the elements analyzed, Table 2 shows their mass M_{total} that was contained in the original reference module pieces.

Table 2. Elemental mass M_{total} in the 5×5 cm² module pieces for crystalline silicon (c-Si), amorphous silicon (a-Si), cadmium telluride (CdTe), and copper indium gallium diselenide (CIGS). The data represent mean values and the standard deviation from three measurements.

Element	c-Si (mg)	a-Si (mg)	CdTe (mg)	CIGS (mg)
Zn		0.9 ± 0.4		16.1 ± 3.1
Cd			13.9 ± 0.9	0.2 ± 0.002
Te			15.6 ± 1.1	
In				14.1 ± 4.3
Ga				0.7 ± 0.1
Se				6.7 ± 1.3
Al	167 ± 40	196 ± 27	289 ± 63	280 ± 190
Mo			12.7 ± 1.7	5.0 ± 0.2
Cu	254 ± 15	130 ± 14	80 ± 11	146 ± 5.7
Ni		1.0 ± 0.1		
Pb	16.7 ± 0.8		2.4 ± 0.3	

2.3. Mass Balancing at the End of the Leaching Experiments

During the leaching experiments, the total mass:

$$M_{total} = M_{diss} + M_{MP} + M_{FR} \quad (1)$$

of a particular element is the sum of the following masses: the amount M_{diss} dissolved in the solution, the remaining mass M_{MP} within the module pieces, and the mass M_{FR} that precipitated in the bottles of the solution. Clearly, at the end of the leaching experiment, the total mass, determined by Equation (1) should equal the masses in Table 1. We measured the mass M_{FR} in the following way: First, the module pieces were removed from the bottles, and then, the solution was filtered using vacuum filtration with a cellulose nitrate membrane filter with a pore size of 0.45 µm. The mass M_{MP} was measured in the same way as the total mass of the elements in one module piece, as described previously. To measure the mass of the filter residue M_{FR} , we digested the filter residue together with the filter by applying a microwave enhanced oxidative digestion. Again, ICP-MS measured these samples, and the measurement of the cellulose nitrate membrane filter itself (blank value) ran in parallel. Subtracting the blank values for the filter, we calculated the amount of each element in the filter residue.

3. Results

3.1. Delamination of Module Pieces

One focus during long-term leaching in water-based solutions lies in the occurrence of delamination. In order to simulate field conditions, in a first series of experiments, we did not use any accelerating leaching parameters for the module pieces for analyzing the delamination (Figure 1a). Delamination, in this study, is defined as a separation between all kinds of module layers, not only between the encapsulation layer, often ethylene vinyl acetate (EVA) foil, and the glass. The delamination was determined by visual examination.

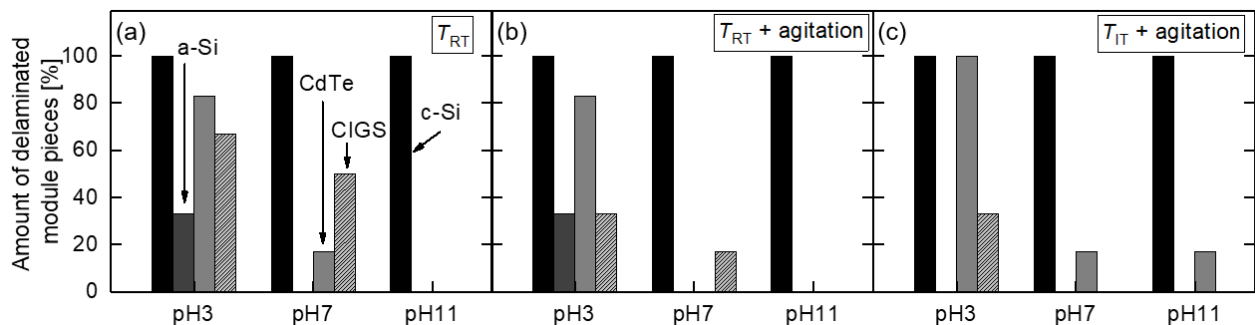


Figure 1. Amount of delaminated module pieces from crystalline silicon (c-Si), amorphous silicon (a-Si), cadmium telluride (CdTe), and copper indium gallium diselenide (CIGS) depending on the pH value of the water-based solution after 1.5 years for the three different experimental conditions: (a) $T_{RT} = 25^\circ\text{C}$, no agitation, (b) $T_{RT} = 25^\circ\text{C}$, with agitation, and (c) $T_{IT} = 40^\circ\text{C}$, with agitation.

After 1.5 years of leaching, we observed delamination in all kinds of PV module pieces: c-Si, a-Si, CdTe, and CIGS. The probability of delamination depends on the pH value of the solutions and the experimental conditions. In the case of c-Si module pieces, we always observed 100% delamination, independent of the pH-value, temperature, and agitation: in all aqueous solutions and for all module pieces, delamination occurred. However, in this case, delamination occurred via the EVA layer, and the type differed from the delamination type of thin film module pieces (via thin layers), as discussed later. Delamination of a-Si module pieces only happened in aqueous solutions with pH 3, and only 30% of the module pieces were affected. The agitation (Figure 1b) and also the temperature (Figure 1c) had no accelerating effect on the delamination. In fact, during the leaching experiments with $T_{IT} = 40^\circ\text{C}$ plus agitation, no delamination of a-Si module pieces was found. The highest amount of delamination in the case of CdTe module pieces occurred in acidic water-based solutions. For this type of module, the increased temperature weakly affected the delamination, as shown in Figure 1c. At room temperature, no delaminated CdTe module pieces were observed in the solutions with pH 11, whereas in neutral solutions, only 17% of the module pieces showed delamination. The pH dependence held also for the CIGS module pieces. In pH 3 solutions, the highest amount of delamination occurred with 67% of the module pieces. In pH 7 solutions, the amount of delaminated module pieces was still 50%. In alkaline solutions with pH 11, no delamination was observed with agitation or with increased temperature.

We classified all these delaminations into three different types: (i) Total separation: Here, the front side is clearly separated from the rear side. This delamination occurs in case of CdTe and a-Si module pieces. Figure 2a shows a scheme of this delamination type. (ii) Fractional separation: Here, only parts of the rear or front side are separated. The major part of the module compound is still intact. This type of delamination takes place for CIGS module pieces and for c-Si module pieces when leached in solutions with pH 11. The scheme is shown in Figure 2b. (iii) Blistering: Figure 2c shows this third type of delamination. Blistering occurs between either the front glass and the EVA foil, or between the EVA foil and the solar cell, but there is no complete separation. This type only occurs in c-Si module pieces.

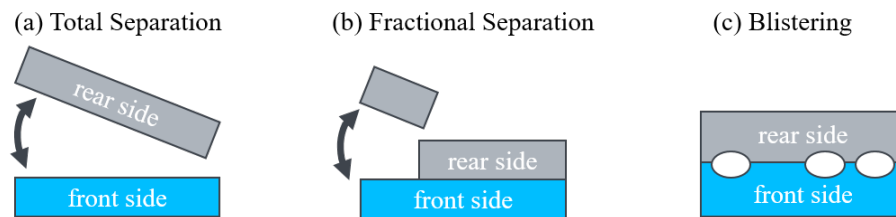


Figure 2. Different types of delamination during the leaching process: (a) Total separation (observed for CdTe and a-Si module pieces). The front side is completely separated from the rear side. (b) Fractional separation (observed for CIGS and c-Si module pieces). Only small parts of the rear side are separated; the major part of the module structure is still intact. (c) Blistering (only observed for c-Si module pieces). Bubble formation emerges locally on the front side of c-Si module pieces, either between glass and EVA or between EVA and solar cell depending on the pH. In this case, no separation occurs between the front and the rear side.

Total separation: Figure 3a–d shows photographs of the front and the rear side of a $5 \times 5 \text{ cm}^2$ CdTe module piece before and after 1.5 years of leaching. Before leaching the CdTe module piece, the integrated series connection of the cells is visible (see the horizontal lines) on the front side (Figure 3a) and also on the rear side (Figure 3b). On the rear side, one sees also the solder ribbon. Only the rear side glass of the module piece shows cracks caused by the water jet cutting. The breakage pattern of this glass indicates that heat-strengthened glass is used as the rear side glass. Figure 3c,d shows the front and the rear side of a CdTe module piece after the leaching process of 1.5 years in solutions with pH 3. Apart from a few parts, the module material disappeared completely. The solder ribbon is still attached to the rear side glass by an insulating tape. After this long-term leaching, the front and the rear side glasses are no longer connected to each other, but totally separated. For a-Si module pieces, the same type of delamination is observed.

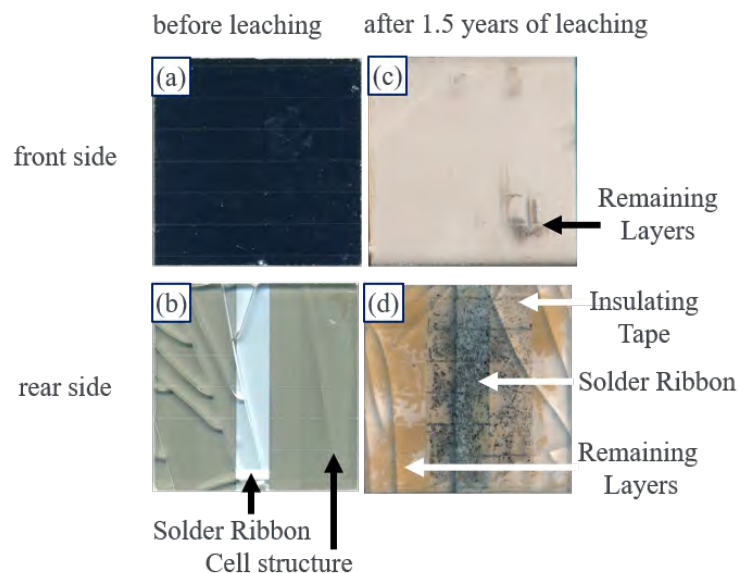


Figure 3. Photographs of (a) the front and (b) the rear side of a $5 \times 5 \text{ cm}^2$ CdTe module piece before leaching. On the rear side, the solder ribbon and the interconnection of cells are visible. (c) Front side of the module piece after leaching over 1.5 years in solutions with pH 3. Apart from a few visible remaining parts, the module material disappeared. (d) Rear side of the module piece after the leaching. The solder ribbon with the insulating tape is visible and also some parts of remaining layers. After 1.5 years of leaching, the front and the rear side glasses are no longer attached to each other; total separation occurs.

Fractional separation: Figure 4a–d shows photographs of the front and the rear side of a $5 \times 5 \text{ cm}^2$ CIGS module piece before and after 1.5 years of leaching: parts of the rear side are separated. Both glasses, the front and the rear side glass, show cracks due to the water jet cutting. Figure 4c shows a photograph of the front side after 1.5 years of leaching in solutions with pH 3. From the front side, a few transparent spots around the edges are visible. From a more detailed look at the back side of the module piece (Figure 4d), it becomes clear that at the transparent spots, parts of the rear side glass are missing, together with the back contact and the active module layers. Therefore, only the transparent front glass remains.

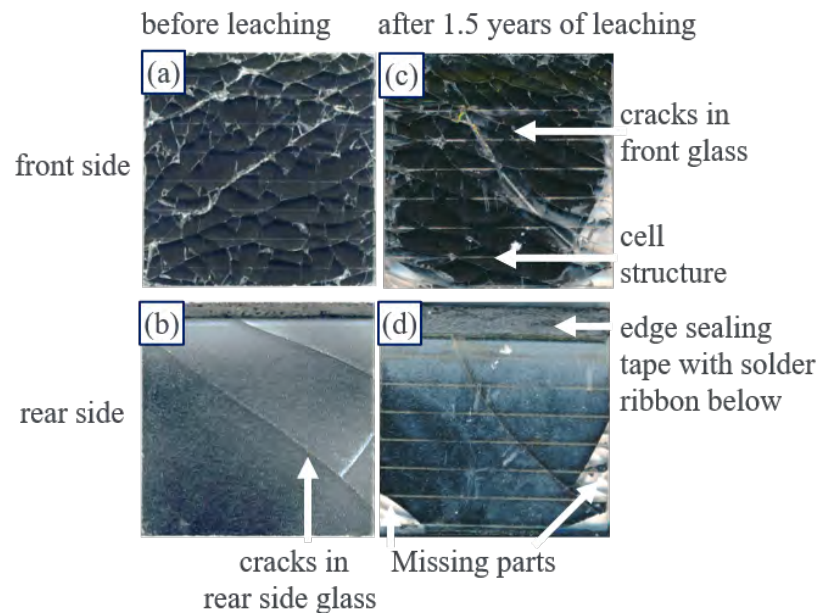


Figure 4. Photographs of (a) the front and (b) the rear side of a $5 \times 5 \text{ cm}^2$ CIGS module piece before leaching. On the rear side, the edge sealing tape with the solder ribbon below is visible. In the front glass, as well as in the rear side glass, cracks are recognizable; they stem from the water jet cutting. (c) Front side after leaching for 1.5 years in pH 3 solution. (d) Rear side after leaching. Parts of the rear glass are missing, together with the back contact and the active layers. Only the transparent front glass remains.

Blistering: Figure 5a shows a photograph of a c-Si module piece of $5 \times 5 \text{ cm}^2$ in size after 1.5 years of leaching in pH 3 solution. In this case, local bubble formation takes place between the solar cell and the EVA foil, especially around the solder ribbon, but no total separation is observed. In solutions with pH 11, delamination between the EVA foil and the front glass appears across extended areas (Figure 5b). A few parts of the glass are separated, and the exposed EVA foil with the solar cell below remains. Due to delamination, the textured structure of the front glass becomes visible. The breakage pattern of the glass matches the pattern known for tempered glass. The rear side of the c-Si module pieces (white backsheets) shows no changes caused by leaching. Only for this PV technology, the occurrence of delamination, i.e., blistering, does not depend on the pH value of the leaching solution. Module pieces leached in pH 7 solutions also show blistering. Blistering takes place at both locations: between the solar cell and the EVA foil, as well as between the EVA foil and the front glass.

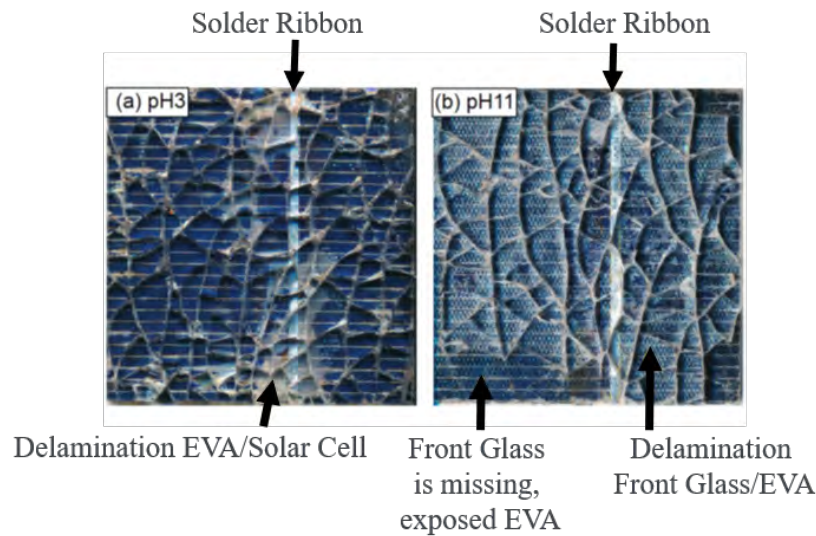


Figure 5. Photographs of c-Si module pieces with $5 \times 5 \text{ cm}^2$ after 1.5 years of leaching in solutions with (a) pH 3 and (b) pH 11. In solutions with pH 3, a local bubble formation occurs between the solar cell and the EVA foil, preferably around the solder ribbon. In solutions with pH 11, a delamination between the EVA foil and the front glass appears across extended areas. A few parts of the glass are separated, and the exposed EVA foil with the solar cell below remains.

3.2. Leaching Results

The previous figures, as well as our previous experiments on milled module pieces [8] give the proof for severe leaching for all module technologies. In the following, we present detailed results on the elements that were leached out from module pieces of $5 \times 5 \text{ cm}^2$ in size. In a first publication [10], we presented preliminary leaching data for Cd, Te, and Pb only and until Day 360, i.e., about one year. In contrast, here, we extend our study to 1.5 years and include many more other elements. This gives us the chance to identify possible weak spots and the leaching paths in the modules. In detail, we measure the amount of the following elements in our water-based solutions of Table 1 with different pH-values: Zn, Te, In, Ga, Se, Al, Mo, Cu, Cd, and Pb. The non-toxic element Si, which is contained in the modules' cells from crystalline, as well as from amorphous silicon, is not measured, simply because the module glass itself also contains high amounts of Si. Our measurement conducted by ICP-MS cannot distinguish between Si from the cells and from the glass of the modules.

3.2.1. CdTe Module Pieces

Figure 6a shows the common structure of a CdTe module including the front glass and front contact (usually tin oxide (SnO_2)), the buffer layer cadmium sulfide (CdS), the photoactive layer CdTe, the Mo back contact, the encapsulant EVA, and finally, the rear side glass. The typical thickness of each layer is also given [19–21]. CdTe modules are mostly fabricated in a superstrate configuration: the production process starts with the front glass, on which the transparent front contact SnO_2 is deposited. We used commercial CdTe-modules for the preparation of the module pieces and measured the amount of eluted elements with the above discussed ICP-MS method. Therefore, we are not able to distinguish between the Cd from the CdS buffer layer and the Cd from the photoactive CdTe film.

Figure 6b–d shows the time-dependent leaching of the elements Cd, Te, and Mo in water-based solutions with pH 3, pH 7, and pH 11; see also [10] for the leaching results of Cd and Te until Day 360. These results stemmed from experiments at $T_{RT} = 25^\circ\text{C}$ without agitation. In all solutions, the amount of leached elements increases with time, but with different leaching rates for different pHs of the solutions. At the early beginning of leaching, Mo from the back contact leaches out with the highest amount, followed by Cd.

Tellurium leaches the least. Thus, already from this observation, it becomes clear that the Mo layer is a weak spot in the case of the CdTe module. After approximately 300 days of leaching, the concentration of Te increases dramatically and approaches the eluted amount of Cd and Mo. Around this time of leaching, delaminations are observed. After 1.5 years, the concentrations of eluted Cd and Mo related to the total amount in the module piece in acidic solutions (pH 3) reach $c_{Cd} \approx 92\%$ and $c_{Mo} \approx 88\%$. The amount of eluted Te is $c_{Te} \approx 54\%$.

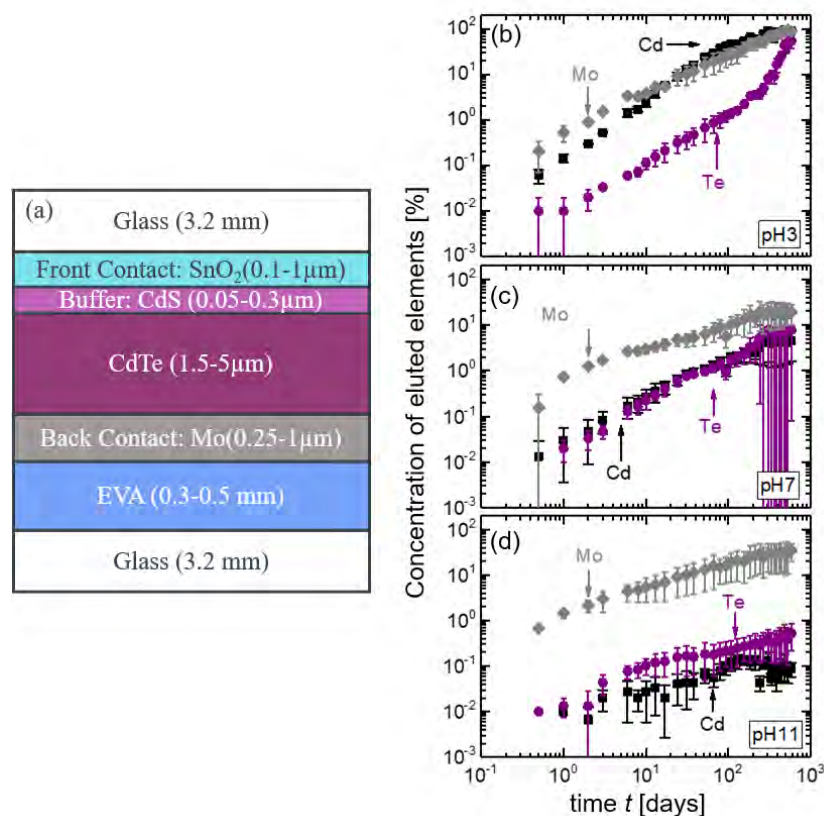


Figure 6. (a) Schematic structure of a typical CdTe module (not drawn to scale) and (b) time-dependent leaching results of the elements Cd, Te, and Mo from CdTe module pieces in acidic aqueous solutions with pH 3 and (c) in solutions with pH 7 and (d) pH 11.

Figure 6c shows the leaching in water-based solutions with pH 7. Here, the concentrations of eluted Cd, Mo, and Te, finally, after 1.5 years, reach $c_{Cd} \approx 4.5\%$, $c_{Mo} \approx 19\%$, and $c_{Te} \approx 7.8\%$, respectively. In this case, the leaching of Cd and Te shows the same time-dependent leaching behavior. The large standard deviations for Te appearing after approximately 300 days of leaching are due to the delamination of one module piece out of three experimental runs. Clearly, after delamination of this particular module piece, substantially higher amounts are leached out, because the leaching solution is able to directly attack the CdTe layers from the surface. Therefore, we observe substantially higher amounts of eluted Te and slightly higher amounts of Cd for this one out of the three experimental runs. The leaching of Mo is highest from the beginning to the end and comparable to the leaching amounts of Cd and Te.

Figure 6d presents the leaching data for pH 11. Here, at the end of the experiment, the amount of eluted Mo is still high with $c_{Mo} \approx 34\%$. The measured concentration of Te is below 1% after 1.5 years, and the amount of leached Cd is the lowest. In solutions with pH 11, the time-dependent leaching rates of Cd and Te are much lower compared to the leaching rates in solutions with pH 7 and pH 3. For all conditions, the leaching rate of Mo is always higher than the one of Cd and Te. This indicates again that, in the case of CdTe modules, the Mo back contact is a weak spot.

The leaching results in Figure 6b–d clearly demonstrate an enormous difference between the leaching concentrations after one day and after the 1.5 years. For example, the Cd-elution in pH 3 at the end of the experiment reaches almost 100%, whereas it is only about 1 % after one day. For pH 3 and pH 7, the eluted concentrations increase approximately linearly with time: a one order of magnitude increase (on the log-scale) of the time leads to a one order of magnitude higher concentration (on the log scale) of the concentration. For pH 11, the data approach a square root dependence with time: it needs a two orders of magnitude increase on the time scale for a one order of magnitude increase on the concentration scale.

Figure 7 shows the ratio $R_{Cd:Te}$ of dissolved Cd to dissolved Te from leaching CdTe module pieces in solutions with pH 3, pH 7, and pH 11. For leaching solutions with pH 3, the value of $R_{Cd:Te}$ is not constant over the leaching time. At the beginning of leaching, $R_{Cd:Te}$ is highest with 35:1, but with time, it approaches $R_{Cd:Te} \approx 1$. For neutral solutions with pH 7, $R_{Cd:Te} \approx 1$ and is almost constant over time. The same behavior applies for leaching in alkaline solutions, but with $R_{Cd:Te} \approx 0.1$. This means that more Te is dissolved in the solutions.

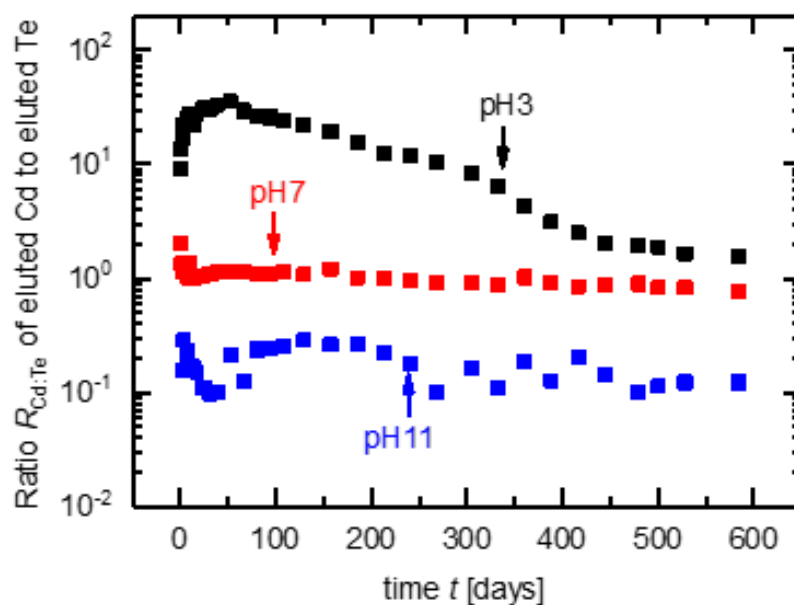


Figure 7. Ratio $R_{Cd:Te}$ of dissolved Cd to dissolved Te from leaching CdTe module pieces in solutions with pH 3, pH 7, and pH 11.

3.2.2. CIGS Module Pieces

Figure 8a shows a schematic cross-section through a CIGS module, composed of the front glass with EVA, the front contact (usually consisting of aluminum-doped zinc oxide, ZnO:Al), a buffer layer of CdS, the absorber layer Cu(In, Ga)Se₂, and a thin interfacial layer of MoSe₂ between the substrate glass and the CIGS. The MoSe₂ is formed by a reaction between the Mo and the Se atmosphere during the deposition of the Cu, In, and Ga [22]. CIGS modules are built in a substrate configuration. The fabrication starts with the deposition (sputtering or evaporation) of Mo on the rear glass. Then, the CIGS is deposited, mostly by co-sputtering or thermal evaporation of the constituent elements, Cu, In, and Ga in a Se atmosphere.

Figure 8b shows the leaching data for Zn, Cd, Mo, Cu, Ga, and In in pH 3 solutions. At the beginning of leaching, Zn from the front contact shows the highest amount with $c_{Zn} \approx 1\%$ already after one day; finally, we observe $c_{Zn} \approx 62\%$ after 1.5 years. Furthermore, already after one day, certain amounts of Mo from the back contact and In from the absorber layer are measurable in the solutions. Other elements, like Cd, Cu, and Ga, are detected later on. The leaching rates of each element differ in absolute values, but show a similar

time dependence. The leaching of the Mo from the CIGS module pieces differs from the data for Mo from CdTe module pieces (see Figure 6b). The Mo from CdTe module pieces seems to be more soluble, in particular for acidic solutions. The difference probably results from the formation of MoSe_2 at the back side of the CIGS films.

Figure 8c shows the leaching of Zn, Cd, Mo, Cu, Ga, and Se in pH 7 solutions. Indium is not detected in the solution with pH 7. The leaching of Zn for this pH is lower than that for pH 3, and so is the concentration after 1.5 years. In solutions with pH 11, we only find Mo, Ga, and Se with low concentrations in the solutions, as shown in Figure 8d. The leached Mo is lowest for pH 11 compared to the data from solutions with pH 3 and pH 7. In the case of CIGS module pieces, comparable to CdTe, the Mo back contact is a weak spot, but also the front contact Zn and the buffer layer Cd.

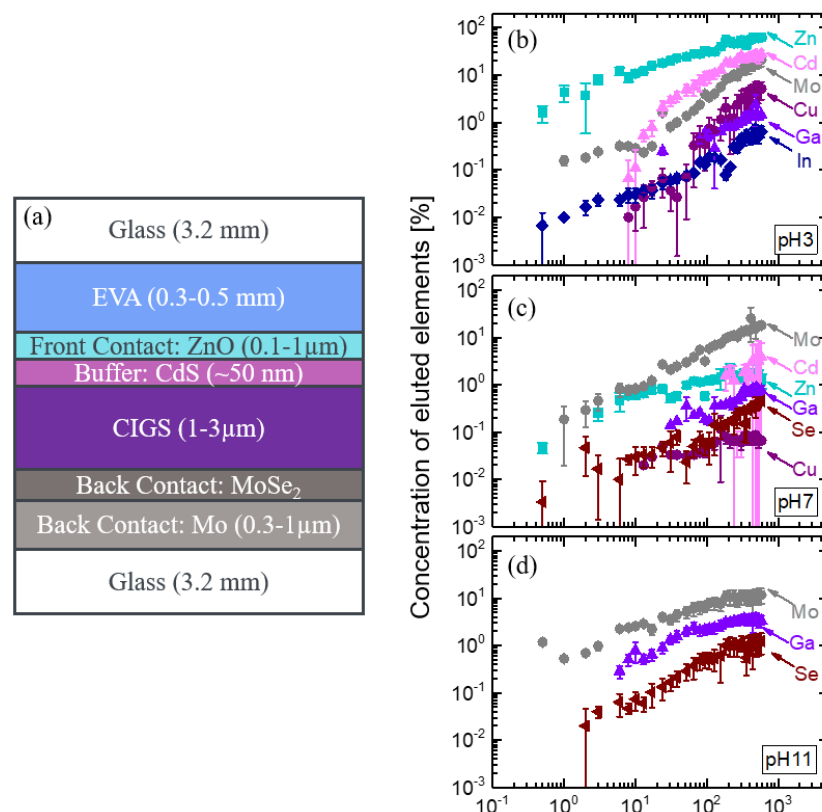


Figure 8. (a) Schematic structure of a typical CIGS module (not drawn to scale) and (b) time-dependent leaching results of the elements Zn, Cd, Mo, Cu, Ga, and In from CIGS module pieces in acidic aqueous solutions with pH 3 and (c) in solutions with pH 7 and (d) pH 11. In leaching solutions with pH 11, the concentrations of the elements Cd, Zn, Cu, and In are below the detection limit.

3.2.3. c-Si Module Pieces

Figure 9a shows a schematic cross-section through a classic c-Si module, consisting of a front glass with EVA, a silver front contact grid with contact fingers and busbars, and the silicon solar cell with a screen printed aluminum back contact and screen printed Ag contact pads (not drawn in the scheme). In contrast to thin film modules, instead of a rear glass, most c-Si modules have a backsheet and a second EVA sheet at the rear side. Figure 9b,c shows the leaching data for Al and Pb for pH 3 and pH 11 (see also [10] for the leaching results of Pb until Day 360). In the case of pH 7, the concentrations of Al and Pb are below the detection limit, which is 500 $\mu\text{g/L}$ for Al and 20 $\mu\text{g/L}$ for Pb. The eluted Pb stems either from the solder ribbon, which is not shown in the schematic cross-section, or from the screen printed metallization. For pH 3, the amount of leached Pb remains constant and below 0.1% until Day 241. After this time, the concentration increases dramatically up to $c_{\text{Pb}} \approx 3.7\%$ after 1.5 years. The concentration of Al reaches $c_{\text{Al}} \approx 27\%$ after 1.5 years in

the acidic solution. In contrast, for the alkaline solution with pH 11, the concentrations of Al and Pb are significantly lower, as shown in Figure 9c. In both cases, the leaching rates of Al are orders of magnitude higher than the ones for Pb. Thus, in the case of c-Si module pieces, the Al contact, which is screen printed and fired into the back side, makes up the weak spot and opens the path for leaching.

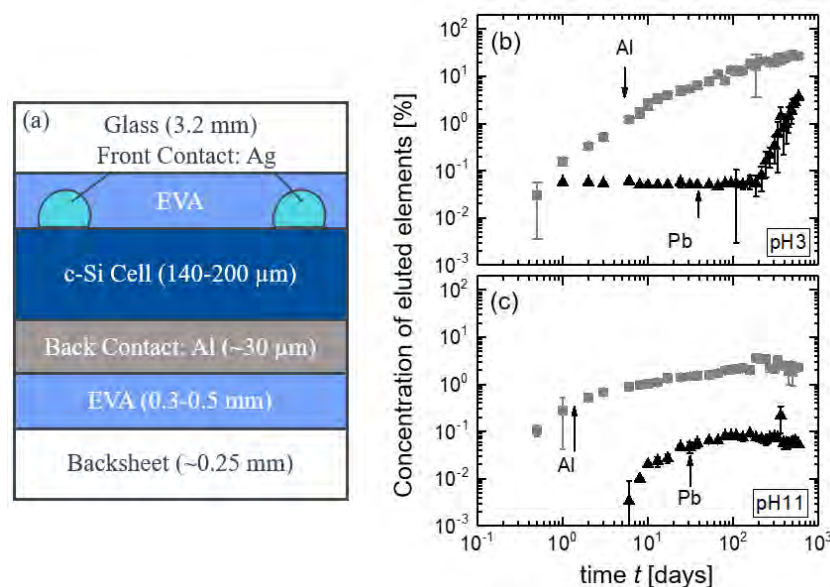


Figure 9. (a) Schematic structure of a typical c-Si module (not drawn to scale) and (b) time-dependent leaching results of Al and Pb from c-Si module pieces in acidic aqueous solutions with pH 3 and (c) in solutions with pH 11. In leaching solutions with pH 7, the concentrations of Al and Pb are below the detection limit.

3.2.4. a-Si Module Pieces

The common structure of an a-Si module is shown in Figure 10a. Amorphous silicon modules typically consist of a front glass with the front contact layer (SnO_2 is mostly used), the photoactive p-i-n layer from a-Si, followed by an intermediate layer consisting of ZnO and Ag, the back contact with a combination of Ni and Cu, and the encapsulant with the rear glass [23]. Similar to the production of CdTe modules, a-Si modules are built in a superstrate configuration, starting with the deposition of the front contact directly on the front glass. Figure 10b,c shows the concentrations of eluted Zn, Cu, and Ni in the solutions with pH 3 and pH 7. Unfortunately, we do not have any data about Ni before Day 388 of leaching. In leaching solutions with pH 11, the concentrations of Zn, Cu, and Ni are below the detection limits. For the other pH-values, we are able to present data: Zn, which stems from the intermediate layer, shows strong leaching with concentrations up to $c_{\text{Zn}} \approx 90\%$ after 1.5 years of leaching in the acidic pH 3 solution. The concentration of eluted Ni lies in the same range, whereas the concentration of Cu is $c_{\text{Cu}} \approx 7.5\%$. In aqueous solutions with pH 7, the elements Zn, Ni, and Cu leach only in minor amounts. The elements Zn, Cu, and Ni are leached out linearly with time, but with different rates depending on the element itself, as well as on the pH of the solution. In all cases, the leaching of the Zn is highest, and therefore, we identify the ZnO layer as a weak spot in a-Si module pieces.

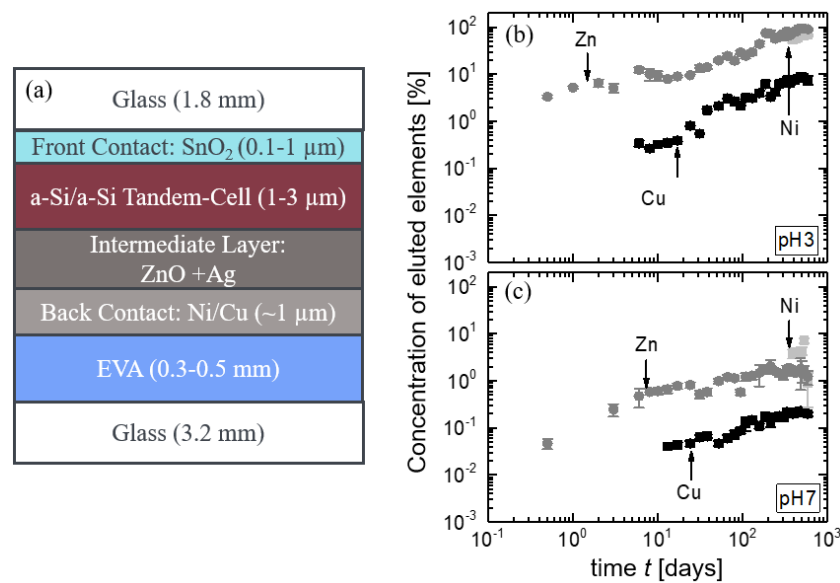


Figure 10. (a) Schematic structure of a typical a-Si module (not drawn to scale) and (b) time-dependent leaching results of Zn, Cu, and Ni from a-Si module pieces in acidic aqueous solutions with pH 3 and (c) in solutions with pH 7. In leaching solutions with pH 11, the concentrations of Zn, Cu, and Ni are not measurable according to the detection limit.

3.3. Accelerating Leaching Parameters for Cd from CdTe Module Pieces

All of the experiments considered so far were performed without any acceleration, for example, by elevated temperatures or stirring/agitation. Figure 11a,b compares the data for Cd, leached out from CdTe module pieces, for the three different pH-values and with/without agitation. Apart from the tests at $T_{RT} = 25\text{ }^{\circ}\text{C}$, we also used additional agitation and solutions at an elevated temperature $T_{IT} = 40\text{ }^{\circ}\text{C}$. All test series ran in parallel. Figure 11a shows the results after $t = 1$ day and Figure 11b after $t = 416$ days. The comparison of the two figures again underlines the dramatic difference in the leaching results after one day and after more than a year. Therefore, standard leaching experiments, which are only carried out over one day, are more or less meaningless, when one aims at judging the toxicity of CdTe modules. Furthermore, after just one day (see Figure 11a), additional agitation and/or elevated temperatures only slightly increase the amount of eluted Cd, even if for pH 3 solutions. In contrast, in particular for pH 7, increasing the temperature from $T_{RT} = 25\text{ }^{\circ}\text{C}$ to $T_{RI} = 40\text{ }^{\circ}\text{C}$ results in five times stronger leaching. Leaching in pH 11 solution triples the leaching of Cd for the same temperature increase. In contrast, in the case of agitation, we are not able to detect any Cd in the alkaline solutions after one day. In the case of pH 3, for all experimental conditions, after $t = 416$ days, the amount of eluted Cd in acidic solutions reaches almost 100%. In the case of the neutral pH 7 solutions, the final data all lie in the same range of $2\% < c_{Cd} < 4\%$. After 416 days, the eluted Cd reaches saturated values. Therefore, as shown in Figure 11b, there is almost no or only minor differences between the data with and without additional accelerating parameters.

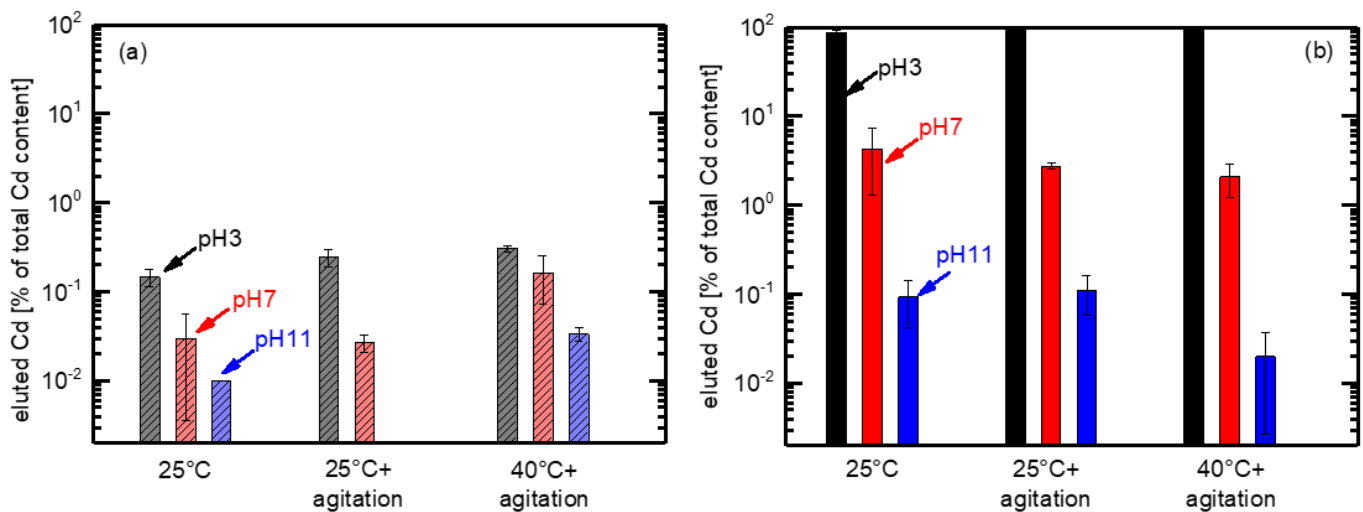


Figure 11. Dramatic difference between the leaching data after one day and more than a year of Cd out of CdTe module pieces. (a) Amount of eluted Cd from CdTe module pieces after $t = 1$ day in solutions of pH 3, 7, and 11 and different leaching conditions: with/without agitation and increased temperature $T_{IT} = 40^\circ\text{C}$ plus agitation. For all conditions, after one day, the Cd concentration ranges below 1%. (b) Amount of eluted Cd from CdTe module pieces after $t = 416$ days. For pH 3, almost 100% of the Cd is leached out. For pH 7, still several percent are leached out. This finding raises the question of the meaningfulness of judging the toxicity of CdTe containing modules with tests that are carried out for one day only.

3.4. Analysis of Time Dependence

To get a better understanding of how the different leaching conditions affect the time-dependent leaching, we fit the measured concentration $C(t)$ at the time t to an exponential model according to:

$$C(t) = C_{max}(1 - e^{-\frac{t}{\tau}}), \quad (2)$$

where C_{max} is the maximum, final concentration dissolved in the solution and τ is the leaching time constant. The leaching time constant represents the time for the concentration to reach 63% of its final value as a measure of leaching velocity. For times $t \ll \tau$, the Taylor expansion of Equation (2) yields a linear behavior according to:

$$C(t) = C_{max} \frac{t}{\tau}. \quad (3)$$

Indeed, in almost all of our experiments, if not disturbed by delamination effects, we see the linear time dependence predicted by Equation (3) and the saturation predicted by Equation (2). Equation (3) is the direct consequence of the number of atoms (Cd) that are leached per unit time, being directly proportional to the number of atoms that are still available for etching. Such an approach always leads to an exponential function such as Equation (2). However, not only delamination (which is expected to accelerate the leaching), but also other effects such as the formation of surface layers (see our work [24]), diffusion limitations, and/or the formation of precipitates could result in deviations from a behavior following Equations (2) and (3). For a diffusion limited leaching on a thin layer, one would observe a square root dependence, as discussed in [24]. This might be the case for some of the data here, in particular for pH 11.

Most of experimental data, in particular for pH 3 and pH 7, show an excellent agreement with the linear behavior, predicted by Equation (3) for time $t \ll \tau$, as well as for the saturation behavior, Equation (2). As an example, Figure 12a–c shows the time-dependent leaching of Cd from CdTe module pieces in solutions with pH 3 for the three different leaching conditions. The data are excellently fit with coefficients of determination $R^2 \geq 0.96$. Figure 12d–f shows the leaching data of Cd in solutions with pH 7. The dotted lines

represent the calculated fit according to Equation (2). The dashed lines show the calculated maximum Cd concentration C_{max} in the solutions; the time constants τ are also given. Modifications to the leaching conditions lead to accelerated leaching with a shorter time constant τ : For example, increasing the temperature to $T_{IT} = 40^\circ\text{C}$, as shown in Figure 12c, leads to a time constant that is only a third of the value at $T_{RT} = 25^\circ\text{C}$. In contrast to the time constant, the C_{max} -value is almost independent of the leaching conditions in pH 3 solution; it holds $C_{max} \approx 100\%$. Figure 12d shows the leaching data for pH 7 at $T_{RT} = 25^\circ\text{C}$ without agitation; we find $\tau = 210$ days. After this time $t = \tau$, a value of 63% of the maximum Cd concentration is reached, which is estimated to be $C_{max} = 4.8\%$. Modified experiments slightly decrease the maximum concentration, which we explain by the large standard deviations at the end of leaching, caused by the delamination of module pieces. Additional agitation decreases the time constant to $\tau = 80$ days (Figure 12e); increased temperature yields $\tau = 20$ days (Figure 12f), i.e., four-times faster leaching.

The excellent fits of our leaching data for pH 3 and pH 7 to Equations (2) and (3) show also that in this case, the leaching is not limited by any diffusion processes, which might take place inside or on the surface of the CdTe layers (this statement holds also for the experiments on all other cell technologies). This behavior is in contrast to our results on the leaching of milled module pieces, which were reported in a separate publication [24]. There, the model for the small spherical CdTe particles, with sizes below one millimeter, predicts a power law, with leaching data following a dependence on time t according to $t^{0.43}$. Indeed, in [24] we observed this behavior for the small particles also experimentally. Due to the different size and geometry of the samples, the leaching from the flat plates of module pieces as presented here, at least for pH 3 and pH 7, follows a different time dependence, which, for short times compared to the leaching time constant, is $t^{1.0}$, as, for example, shown in Figure 6b,c.

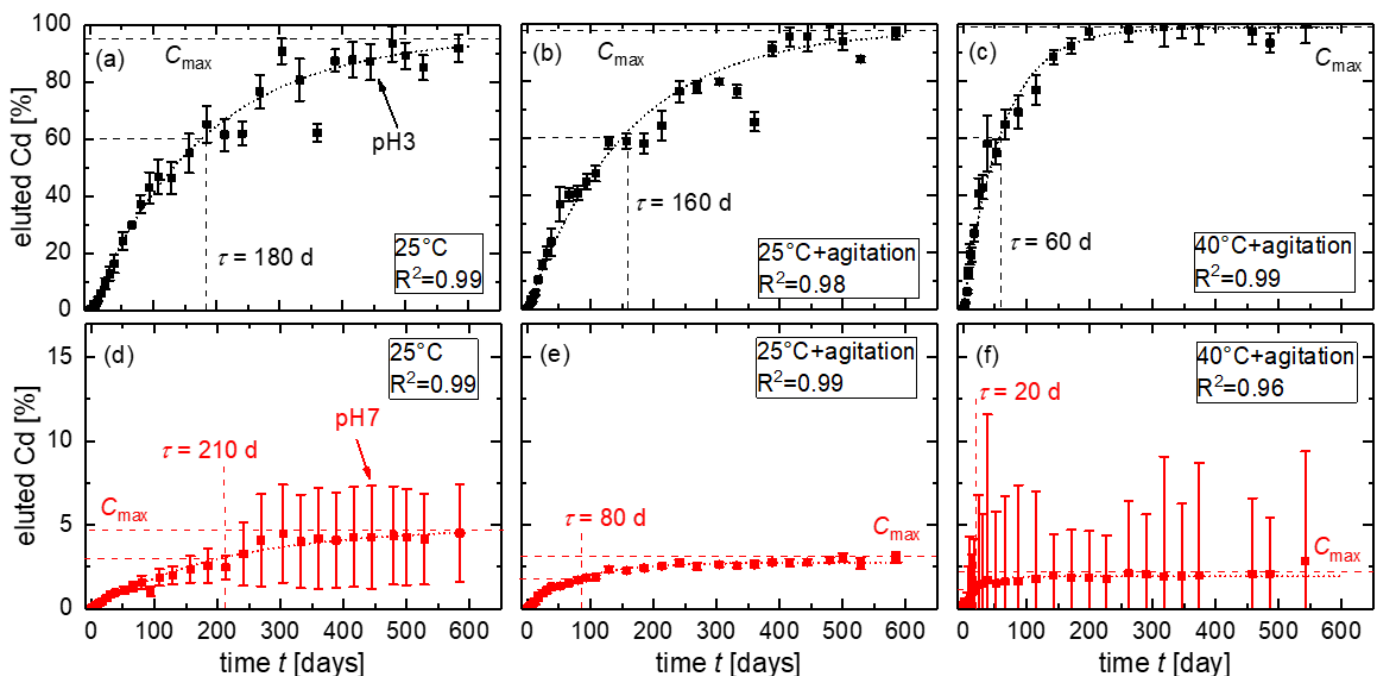


Figure 12. Leaching of Cd from CdTe module pieces in solutions with pH 3 at (a) $T_{RT} = 25^\circ\text{C}$, (b) at $T_{RT} = 25^\circ\text{C}$ with agitation, and (c) at $T_{IT} = 40^\circ\text{C}$ with agitation. Eluted Cd in solutions with pH 7 at (d) $T_{RT} = 25^\circ\text{C}$, (e) at $T_{RT} = 25^\circ\text{C}$ with agitation, and (f) at $T_{IT} = 40^\circ\text{C}$ with agitation. The dotted lines represent the calculated fit according to Equation (2) with high coefficients of determination R^2 . The dashed lines show the calculated maximum concentration C_{max} in the solutions.

Figure 13a shows the leaching time constant τ for pH 3 and pH 7: A higher temperature results in faster leaching. In our study, $T_{IT} = 40^\circ\text{C}$ is used, which is a common temperature PV modules reach when exposed to sunlight; on hot summer days, the temperatures are

even higher. In solutions with pH 7, the change in the leaching time constant due to varied conditions is even stronger. In contrast to a different τ , Figure 13b shows that the maximum concentration C_{max} of eluted Cd remains nearly constant and independent of modifications to the leaching conditions. However, the value C_{max} highly depends on the pH of the leaching solution: it holds $C_{max} \approx 100\%$ for pH 3 and $C_{max} \leq 4.8\%$ for pH 7. The lower C_{max} for pH 7 is explained by the formation of cadmium hydroxide in neutral solutions. This compound is not soluble and therefore not detected by our measurement method ICP-MS.

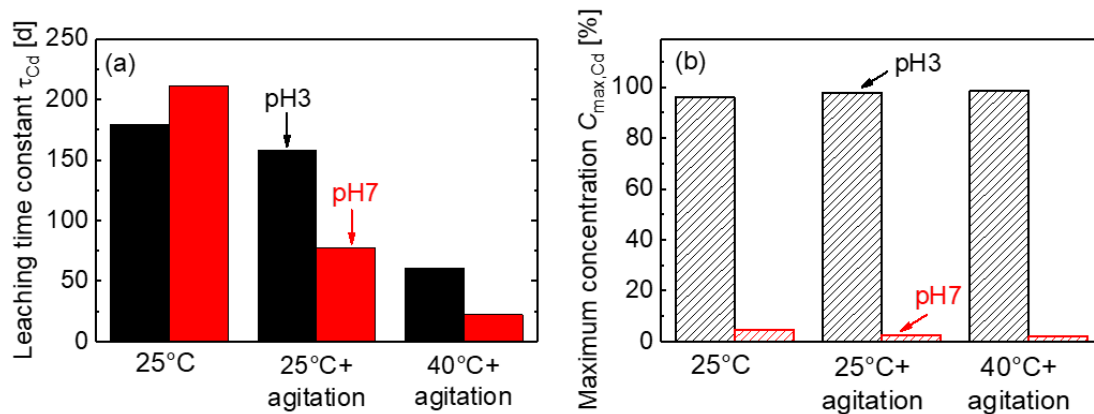


Figure 13. Calculated fit parameters for the leaching of Cd from CdTe module pieces under different conditions. (a) Leaching time constant τ_{Cd} for solutions with pH 3 and pH 7. (b) Maximum concentration C_{max} for the same conditions as in (a).

3.5. Mass Balance for CdTe Module Pieces

Figure 14 shows the distribution of the mass fractions for the elements Cd, Te, and Mo from CdTe module pieces leached for 700 days at $T_{RT} = 25^\circ\text{C}$ without agitation: the dissolved amount in the solution M_{diss} , the remaining mass in the module piece M_{MP} after the leaching process, and the mass of the filter residue M_{FR} with particles bigger than 0.45 mm. There are strong differences between the leaching behavior for pH 3 and pH 11:

pH 3: Almost all Cd, Te, and Mo from the module pieces is found in the mass M_{diss} of dissolved elements. In particular, for Cd, almost nothing remains in the module piece (mass M_{MP}) or is found in the mass M_{FR} of precipitates.

pH 11: Almost all Cd and Te still remain in the module pieces and are represented by the mass M_{MP} . Only in the case of Mo, a part of the Mo is measured in the solution as M_{diss} .

Mass loss for Te and Mo: The sum of the masses in the solution, filter, and module pieces measured after the leaching should reach 100% of the value before the leaching. However, for Te and Mo, the sum of the measured values after leaching is below 100%. The relatively small amount of missing mass is termed M_{Rest} in Figure 14. We explain the difference by the milling process for the determination of the remaining mass M_{MP} in the module piece. For a few samples, the milling process did not completely crush the encapsulation. The Mo back contact has a strong adhesion to the encapsulant. Therefore, it seems possible that not all Mo material was digested. There might also be a material loss during the filtration process, either when drying the filter afterwards, or due to particles remaining in the HDPE bottles despite carefully repeated rinsing.

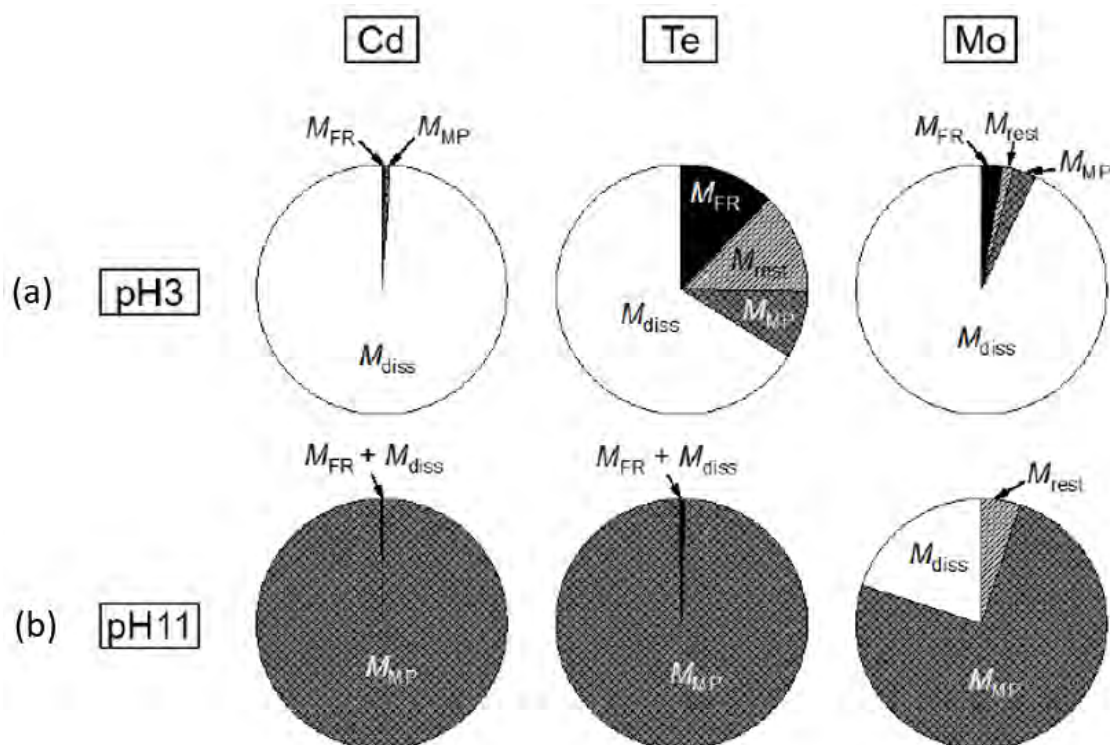


Figure 14. Mass balance of the CdTe module piece after 700 days in leaching solutions with (a) pH 3 and (b) pH 11 at $T_{RT} = 25^{\circ}\text{C}$ without agitation. In solutions with pH 3, the largest fraction of Cd, Te, and Mo is dissolved and found as M_{diss} ; only a small fraction M_{MP} remains in the module pieces. No Cd-particles (mass M_{FR}) are measured within the filter residue, whereas for Te and Mo, a small part is found in the residue. In solutions with pH 11, the major part of the elements Cd and Te remains in the module piece and is not leached out. Molybdenum is also measured in the solution.

4. Discussion

The combination of leaching experiments and the observation of delamination yields the following major insight: In the case of thin film modules (CdTe, CIGS, and a-Si), the delamination is the consequence of the high solubility of one or more thin layers of the modules' cells. They form a path for the attack of the water-based solutions. In contrast, in the case of modules containing cells from crystalline silicon, the cell's Al back contact is highly soluble, but not responsible for delamination. Instead, blistering occurs: delamination of c-Si modules is not visible on the back side, but on the front side, either between the front glass and EVA or between the EVA and the Si cell, depending on the pH of the leaching solution. Delamination between the front EVA and solar cell preferentially occurs around the solder ribbon on the front side of the cell and is therefore correlated with the leaching of Pb out of the solder ribbon. The backsheets on the rear side of the c-Si module piece shows no changes after the leaching. Unfortunately, the backsheet is not transparent; therefore, we do not have information about the condition of the solder ribbon on the back side and how the leaching of the Al back contact affects the leaching of the solder ribbon on the back. In solutions with pH 3, a local delamination takes place between the solar cell and the EVA foil, whereas in pH 11 solutions, the delamination occurs between front glass and EVA. In pH 7 solutions, we observe both kinds of delamination. The solution probably attacks the coupling agent. Therefore, in this case, we assume adhesion problems to be the main reason for blistering.

In the case of CdTe module pieces, the photoactive CdTe, as well as the Mo back contact are highly soluble in acidic, aqueous solutions with pH 3. The severe leaching correlates with the frequent total separation, i.e., delamination of the module pieces. For this type of module and under acidic conditions, frequently, the front side is clearly separated from the rear. As a consequence, this delamination enhances the leaching, especially of Te, which is

observed in all leaching solutions, independent of pH. For short times, leaching for Cd, Te, and Mo increases linearly with time, but at different rates; the rates depend on the pH. The ratio $R_{Cd:Te}$ of eluted Cd to eluted Te Cd:Te also depends on the pH. This behavior is in accordance with the Pourbaix (potential-pH) diagram for CdTe in aqueous solutions showing the possible species of Cd and Te depending on the pH and the redox potential E_H [9]. In solutions with pH 3, the Te species have a lower solubility compared to the Cd species, which are present as Cd^{2+} ions. The solubility of predominant species of Cd and Te for pH 7 is the same, which explains the ratio $R_{Cd:Te} = 1$. In solutions with pH 11, probably, Te species form with a solubility that exceeds that of Cd. This assumption explains the estimated $R_{Cd:Te} \approx 0.1$. It is notable that only in solutions with pH 3, the ratio $R_{Cd:Te}$ is strongly time dependent, whereas it is almost constant for solutions with pH 7 and pH 11.

Increasing the temperature results in accelerated leaching of Cd from CdTe module pieces. The same behavior was earlier reported by Collins and Anctil [25] for the leaching of Cd from CIGS modules and Pb from c-Si modules, by increasing the leaching temperature to $T = 50$ °C. All of our leaching data for Cd are well described by Equation (2) and the C_{max} -value for Cd, which decreases with increasing pH. This finding is in accordance with the data reported by Ramos-Ruiz [5] on leaching of Cd and Te out of CdTe modules in solutions with different pH values under simulated landfill conditions. This pH-dependent leaching is understood on the basis of known leaching patterns, not only for Cd, but for all measured elements in this study.

In contrast to CdTe modules, with total delamination, for CIGS module pieces, fractional separation occurs in solutions with pH 3, as well as with pH 7: only parts of the rear side are separated. Our leaching experiments point out all CIGS module layers to be more or less soluble in aqueous solutions. The highest solubility is found for Zn from the front contact in pH 3 solutions, and at this location, we observe the fractional separation. With the Zn eluted, there is no longer a stable bond between the front glass/EVA and the rear side consisting of the photoactive layers (CdS, CIGS) and the back contact on top of the rear glass.

The leaching concentrations of Cd out of CIGS module pieces are lower than from CdTe module pieces. This lower leaching of Cd indicates that CdS in the CIGS cells is more stable against the solutions than CdTe. The Mo back contact of CIGS module pieces also seems to be more stable than the Mo back contact of CdTe module pieces. Between these two module types, the amounts of leached Mo differ especially in solutions with pH 3 and pH 11: in these solutions, Mo from CIGS shows lower leaching than Mo from CdTe module pieces. This difference probably arises from the formation of the $MoSe_2$ layer during the deposition of the CIGS layer in module fabrication. Theelen et al. [26] proposed that $MoSe_2$ prevents the formation of molybdenum oxide, MoO_x , which is the main reason for the degradation of Mo when it comes in contact with water or moisture. Modules from CdTe do not contain a protecting $MoSe_2$ layer. Therefore, during leaching, MoO_x is probably formed. The formation of MoO_x results in a large volume expansion [26]. This could explain the observed delaminations for CdTe module pieces.

Amorphous silicon module pieces show also highly time-dependent leaching, in particular the front layer of ZnO in combination with the Ni/Cu back contact. After 1.5 years of leaching, the elements Zn and Ni reach almost 100% in solutions with pH 3. The time-dependent leaching behavior of Zn from a-Si module pieces is similar to the leaching behavior of Zn from CIGS module pieces in both solutions of pH 3 and pH 7. The leaching rates are also comparable. Therefore, in the case of a-Si modules, ZnO is a weak spot. This finding is in line with the experiments of Pern et al. [27]: These authors studied the stability of various transparent conducting oxides (TCO), including ZnO. In their experiments, ZnO showed the highest degradation rates (of all studied TCOs) when it comes in contact with moisture.

5. Conclusions

Our leaching experiments on PV modules pieces from CdTe, CIGS, c-Si, and a-Si in water-based solutions with pH 3, pH 7, and pH 11 simulate different environmental conditions. Due to the wide span of pH-values, it seems also possible to predict from our experiments the behavior for other pH-values. During the leaching over 1.5 years, we observe different types of delamination. In the case of thin film modules (CdTe, CIGS, a-Si), the thin film layers themselves or the contact materials (e.g., Mo, ZnO) are the weak spots. Finally, their leaching leads to delamination. In contrast, in the case of modules with c-Si, the Al back contact shows the strongest leaching. However, this leaching is not responsible for the delamination. Instead, problems with the EVA causes blistering, which leads to the delamination of the module pieces with c-Si.

The time-dependent leaching is well described by an exponential saturation behavior with a leaching time constant, at least for low pH-values. The leaching time constant differs from element-to-element and changes under agitation and/or a temperature increase. For times small compared to this time constant, the amount of leached out elements increases linearly with time. It is therefore understandable that, roughly speaking, the concentrations of many leached out elements after 500 days are also more than two orders of magnitude higher than after one day. However, we observe also ratios of the concentrations after one 500 days and after one day that are higher or lower than two orders of magnitude: Higher values are obtained, when delamination occurs during leaching. Lower values are obtained when, for example, the ratio of eluted to precipitating elements changes during the experiment.

In the case of Cd leaching from CdTe module pieces, increased temperature leads to substantially accelerated leaching. In contrast, the maximal concentration of leached Cd only depends on the pH of the solution. A mass balance method shows that Cd, which is not measured in the solutions as dissolved, remains in the module pieces themselves and is not, as expected, leached out and then precipitated in the solutions.

In any case and under all experimental conditions, it is possible to either leach out all or a substantial amount of most elements from the module pieces. Clearly, in the case of our module pieces, leaching starts from the unprotected edges of the pieces of $5 \times 5 \text{ cm}^2$ in size, cut out from large area modules. During the manufacturing of commercial modules, they are provided with an edge sealing, which should prevent any leaching under normal operating conditions of the (undamaged) modules. However, if the edge sealing of the modules is not carefully done, or if it is damaged, or even worse, if the (front) module glass is broken, leaching is unavoidable. Rain water with pH values always below pH 7 will suffice to leach out the (toxic) elements. Even worse, if modules are cracked, crushed, or even milled and end up in landfills, the module constituents will also be leached out. Therefore, if toxic materials are not completely avoided in photovoltaic modules, it is of utmost importance to (i) replace damaged modules as fast as possible and to (ii) recollect and recycle them completely. In all other cases, in view of the huge amount of installed PV modules, most of them still containing Pb (mostly in the solder of the cell connectors) and/or Cd, they may impose a severe danger to the environment.

Compared to other, earlier studies, our experiments were carried out over more than a year. As one of the key results, we found huge differences between the amount of elements found in the solutions after one day and more than a year. In our opinion, tests for just one day are inappropriate to judge module technologies, in particular if conclusions and political decisions on the toxicity and environmental issues of photovoltaic module technologies are based on such short-term measurements.

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Exhibit 4:
August 2018, *EPA Confirms GenX Chemicals Used in Solar Panels*,
published by the Carolina Journal.

EPA confirms GenX-related compounds used in solar panels

DAN WAY

AUGUST 27, 2018

FAYETTEVILLE — Although top national environmental regulators confirmed GenX and related chemical compounds are used to produce solar panel components, they say their research does not prioritize what risks that might pose to the environment and human health.

Peter Grevatt, national director of the Environmental Protection Agency's Office of Ground Water and Drinking Water in Washington, D.C., recently told *Carolina Journal* the GenX solar concern "is one that's in a much broader set of challenges."

GenX is known to be used in making Teflon film that coats many solar panels. The chemical falls under the larger umbrella of compounds classified as PFAS chemicals.

"There's literally so many thousands of these compounds, and we don't have methods to measure most of them. So we are getting up on the research, and trying to figure out ways of identifying what's out there," Andy Gillespie, associate director for ecology at EPA's National Exposure Research Laboratory in Research Triangle Park, told *CJ*.

Kristina Beasley said that lack of knowledge underscores her concerns. She is among opponents of an expansion plan for the industrial-scale Wilkinson Solar Plant in the Terra Ceia community of Beaufort County. Their opposition is believed to be the first in the state to raise the issue of potential GenX contamination in an N.C. Utility Commission regulatory hearing.

“I definitely think that it is an issue, and further research, I think, should be done,” Beasley said. She said the public doesn’t appreciate concerns about toxic chemicals, fluids, and substances leaking into the soil and groundwater as solar installations age and deteriorate, or suffer damage from windstorms or other disasters.

As *C7* pointed out more than three years ago, North Carolina doesn’t have rules for decommissioning solar facilities or a disposal plan for spent panels. Critics worry about potential pollution. Residents consistently have raised fears in town halls and solar plant permit hearings about contamination from compromised solar panels.

But community activists are not the only ones weighing in. Donald van der Vaart, former secretary of the N.C. Department of Environmental Quality, who holds a doctorate in chemical engineering, sees reason for concern given North Carolina’s more than 7,500 solar installations.

“North Carolina’s solar power capacity is now the second highest in the nation. EPA researchers recognize that solar panels may be a source of GenX compounds,” said van der Vaart, a senior fellow at the John Locke Foundation. “I would expect Duke Energy and the Public Utilities Commission would want to see test results to protect them from future liability.”

“One line of research that we are doing is looking at material management, end-of-life management, but we’re not yet at the point where we’re doing it product by product,” Gillespie said when asked whether the EPA has concerns about GenX leaching from solar panels.

“Lots of things go to landfills, or go to incinerators, or other things. We’re trying to understand the aggregate risk. We just haven’t gotten to the stage of doing it by many of the thousand different products that these chemicals can be used in,” he said.

“It’s a fair question to ask” about potential environmental and human health impacts from GenX and other PFAS chemicals in solar panels, said U.S. Rep. Richard Hudson, R-8th Congressional District.

“Obviously I’m aware of the concern, and that’s why I’ve been pushing to get the EPA to quickly get us as much science as possible so that we can determine how much of a concern we have,” Hudson said. “There’s not enough science, clearly.”

Solar enthusiasts contend there is no threat from GenX or related chemicals, while critics fret the wealthy renewable energy industry and its host of lobbyists influence regulators and lawmakers to disregard potential GenX connections to solar panels.

“We’ve got to go where the science is,” Hudson said. “If it’s dangerous then we need to treat it. Prevention, and remediating the problem.”

Hudson, Grevatt, and Gillespie were among EPA, N.C. Department of Environmental Quality, federal, state, and local government officials in Fayetteville on Aug. 14 for an all-day listening session Hudson facilitated. The event was designed to update residents on regulators’ efforts to investigate and combat GenX in the groundwater, soil, and air surrounding the Chemours chemical plant here, and to hear their feedback.

“GenX, I know, has been a significant concern for folks in the state of North Carolina,” Grevatt said, “but we’re really focused right now most of all on understanding potential threats to human health, and making sure that communities have the tools they need to address those concerns.”

The EPA plans to issue a toxicity assessment outlining a first-of-its-kind health-risk profile for GenX and PFAS compounds next month. It’s scheduled to release a national management plan by the end of 2018.

The EPA is collaborating with states, academic researchers, industry scientists, and other federal agencies to develop methods and tools for states and local communities to find GenX and other PFAS compounds in the environment.

“Those tools are going to be equally applicable to [assessing solar electric plants] as they will be about looking for GenX in other parts of the environment,” Grevatt said. They won’t be tailored to each specific threat.

Linda Culpepper, interim director of DEQ's Division of Water Resources, was a panelist at the Fayetteville event. Asked later if she was hearing concerns about GenX in solar panels, she responded: "Just what you're seeing probably. The same thing in research that people are looking at — as these products degrade over time are there any kind of chemicals coming from that?"

CF asked DEQ for a response to concerns about GenX solar panel contamination. The agency's response is [here](#).

Exhibit 5:

Excel file, PFAS testing results for drinking water wells (community and non-community) in Wareham, downloaded by Save the Pine Barrens from the Massachusetts EEA Data Portal November 13, 2022.

PWS ID	PWS Name	Town	Class	Contaminant Group	Chemical Name	Collected Date	Result	UOM	Result Qualifier	Result Description	Reporting Limit	Location ID	Location Name	Raw or Finished	Method	Maximum Contaminant Level	Lab Reported Detection Limit	Required Detection Limit
4310000	WAREHAM FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	07/05/2022	ND	NG/L			2 NG/L	10036	MAPLE SPRINGS PLANT	F	EPA 537.1	20	0.5000 NG/L	2.0000
4310003	ONSET FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	01/27/2022	ND	NG/L			2.1000 NG/L	10405	WELL #7	F	EPA 537.1	20	2.1000 NG/L	2.0000
4310000	WAREHAM FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	07/19/2021	ND	NG/L			2 NG/L	10031	SEAWOOD SPRINGS	F	EPA 537.1	20	Not Recorded	2.0000
4310003	ONSET FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	09/14/2021	2.84	NG/L			1.8100 NG/L	10400	WELLS #3,#4 (01.G,02G)	F	EPA 537.1	20	0.5880 NG/L	2.0000
4310003	ONSET FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	01/27/2022	ND	NG/L			2 NG/L	10402	WELL #6	F	EPA 537.1	20	2.0000 NG/L	2.0000
4310000	WAREHAM FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	04/21/2021	ND	NG/L			2 NG/L	10035	MAPLE SPRINGS PLANT -	F	EPA 537.1	20	Not Recorded	2.0000
4310003	ONSET FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	09/14/2021	ND	NG/L			1.8600 NG/L	10401	WELL #5	F	EPA 537.1	20	0.6130 NG/L	2.0000
4310003	ONSET FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	01/27/2022	ND	NG/L			2.2000 NG/L	10401	WELL #5	F	EPA 537.1	20	2.2000 NG/L	2.0000
4310000	WAREHAM FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	07/19/2021	ND	NG/L			2 NG/L	10035	MAPLE SPRINGS PLANT -	F	EPA 537.1	20	Not Recorded	2.0000
4310000	WAREHAM FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	01/03/2022	ND	NG/L			2 NG/L	10034	SEAWOOD SPRINGS PLAN F	F	EPA 537.1	20	0.5000 NG/L	2.0000
4310003	ONSET FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	09/14/2021	ND	NG/L			1.8800 NG/L	10402	WELL #6	F	EPA 537.1	20	0.6210 NG/L	2.0000
4310003	ONSET FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	09/26/2022	9.8	NG/L			1.8000 NG/L	RW-02G	WELL 3 RAW	R	EPA 537.1	20	1.8000 NG/L	2.0000
4310000	WAREHAM FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	04/21/2021	ND	NG/L			2 NG/L	RW-03G	MAPLE SPRINGS WELL 3 F R	R	EPA 537.1	20	Not Recorded	2.0000
4310003	ONSET FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	01/18/2022	ND	NG/L			1.8000 NG/L	RW-01G	WELL 4 RAW	R	EPA 537.1	20	0.5950 NG/L	2.0000
4310003	ONSET FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	09/26/2022	3.3	NG/L			1.8000 NG/L	10400	WELLS #3,#4 (01.G,02G)	F	EPA 537.1	20	1.8000 NG/L	2.0000
4310000	WAREHAM FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	10/17/2021	ND	NG/L			1.7000 NG/L	10035	MAPLE SPRINGS PLANT -	F	EPA 537.1	20	Not Recorded	2.0000
4310000	WAREHAM FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	04/21/2021	ND	NG/L			2 NG/L	10034	SEAWOOD SPRINGS PLAN F	F	EPA 537.1	20	0.4000 NG/L	2.0000
4310000	WAREHAM FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	04/21/2021	ND	NG/L			2 NG/L	RW-07G	SEAWOOD SPRINGS WELL R	R	EPA 537.1	20	0.4000 NG/L	2.0000
4310000	WAREHAM FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	04/21/2021	ND	NG/L			2 NG/L	RW-02G	MAPLE SPRING WELL 2 R/R	R	EPA 537.1	20	Not Recorded	2.0000
4310003	ONSET FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	04/27/2022	ND	NG/L			2.1000 NG/L	10401	WELL #5	F	EPA 537.1	20	2.1000 NG/L	2.0000
4310003	ONSET FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	04/27/2022	ND	NG/L			2.2000 NG/L	10402	WELL #6	F	EPA 537.1	20	2.2000 NG/L	2.0000
4310000	WAREHAM FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	04/04/2022	ND	NG/L			2 NG/L	10036	MAPLE SPRINGS PLANT	F	EPA 537.1	20	0.5000 NG/L	2.0000
4310003	ONSET FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	04/27/2022	ND	NG/L			2.1000 NG/L	10405	WELL #7	F	EPA 537.1	20	2.1000 NG/L	2.0000
4310000	WAREHAM FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	04/21/2021	ND	NG/L			2 NG/L	RW-04G	MAPLE SPRINGS WELL 4 F R	R	EPA 537.1	20	Not Recorded	2.0000
4310003	ONSET FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	09/14/2021	ND	NG/L			1.7800 NG/L	10405	WELL #7	F	EPA 537.1	20	0.5890 NG/L	2.0000
4310000	WAREHAM FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	04/21/2021	ND	NG/L			2 NG/L	RW-08G	SOUTH LINE WELL 8 RAW R	R	EPA 537.1	20	Not Recorded	2.0000
4310000	WAREHAM FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	10/18/2021	ND	NG/L			1.7000 NG/L	10034	SEAWOOD SPRINGS PLAN F	F	EPA 537.1	20	Not Recorded	2.0000
4310000	WAREHAM FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	04/21/2021	ND	NG/L			2 NG/L	RW-06G	SEAWOOD SPRINGS WELL R	R	EPA 537.1	20	Not Recorded	2.0000
4310000	WAREHAM FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	07/19/2021	ND	NG/L			2 NG/L	10034	SEAWOOD SPRINGS PLAN F	F	EPA 537.1	20	Not Recorded	2.0000
4310000	WAREHAM FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	04/21/2021	ND	NG/L			2 NG/L	RW-01G	MAPLE SPRINGS WELL 1 F R	R	EPA 537.1	20	Not Recorded	2.0000
4310003	ONSET FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	09/26/2022	ND	NG/L			1.9000 NG/L	RW-01G	WELL 4 RAW	R	EPA 537.1	20	1.9000 NG/L	2.0000
4310003	ONSET FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	01/18/2022	10.6	NG/L			1.8500 NG/L	RW-02G	WELL 3 RAW	R	EPA 537.1	20	0.6110 NG/L	2.0000
4310003	ONSET FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	07/26/2022	25.9	NG/L			1.8000 NG/L	10400	WELLS #3,#4 (01.G,02G)	F	EPA 537.1	20	1.8000 NG/L	2.0000
4310000	WAREHAM FIRE DISTRICT	WAREHAM	COM	PFAS	PFAS6	01/03/2022	ND	NG/L			2 NG/L	10035	MAPLE SPRINGS PLANT -	F	EPA 537.1	20	0.5000 NG/L	2.0000

Exhibit 6:
September 2021, *PFAS and other compounds in solar panels, wiring,*
***and coatings*, published by Saving Greene.**



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PFAS and other compounds in solar panels, wiring, and coatings

Renewable energy should offer more than promises that it is good for the environment. The solar industry promotes photovoltaic (PV) technology in the most wholesome terms: generating clean, free power from the sun. This benevolent assessment potentially omits environmental impacts during the manufacturing, operational lifetime, and disposal of solar panels and battery storage systems. Host towns need proof, not simply promises, when evaluating how solar projects may affect their residents and environment, both now and in the future.

Introduction

In July 2021, the Town of Avon, New York adopted Local Law 3 of 2021. This precedent-setting amendment to the local solar law prohibits using solar panels that “utilize or contain any amount of GenX chemicals or polyfluoroalkyl (PFAS) substances.”¹ This position aligns with state and federal laws protecting our water supply. For the long-term safety of Coxsackie residents, Hecate Energy (Hecate) and its successors should agree to a Certificate condition that prior to construction, Hecate will provide documentation verifying that the solar panels and associated electrical equipment used to construct the Greene County Solar Facility (the Facility) do not contain per- and polyfluoroalkyl substances (PFAS), including PFOA, PFOS, and GenX chemicals.

¹ <https://www.avon-ny.org/PDFs--Town%20Clerk/ll3-2021.pdf>

We would like to believe that Hecate’s commitment to our town’s public health and safety, as well as their desire to avoid potential future liability, would encourage them to give these comments careful consideration. Hecate must rely on manufacturers’ data, which may not be fully transparent for solar panels and lithium-ion batteries, especially when they are manufactured outside of the United States – in this case often in China.

This Certificate condition would help safeguard our soil, surface waters, and ground-water from potential contamination. While such protection would help protect Sleepy Hollow’s water supply, it provides important safeguards for all residents living in the vicinity of the Facility. Hecate and the Town of Coxsackie should perform pre- and post-installation soil and water testing, with annual monitoring. In addition, the installer should fund an escrow account for the Town to hire an independent, certified third-party laboratory for soil and water testing.

PFAS and related compounds

According to the National Institute of Environmental Health Sciences, perfluoroalkyl and polyfluoroalkyl substances (PFAS) are toxic, persistent, and bioaccumulative.² These synthetic fluorochemicals were first developed in the 1930s and have strong carbon-flourine bonds that make the structure repel both oil and water.³ The Green Science Policy Institute details that these manmade chemicals are widely used in building materials such as paints, cleaning products, non-stick coatings, sealants, tapes, wire coverings, glass, solar panels, and batteries.⁴ PFAS is commonly found in foam used to extinguish electrical fires.⁵

These “forever chemicals” have been linked to cancer and other health issues. Certain PFAS do not break down easily, causing them to remain indefinitely in the soil and water. Their potential hazard and persistence in the environment may pose a cumulative danger to public health. PFAS comprise a group of compounds, including PFOA, PFOS and GenX chemicals. The United States Environmental Protection Agency (EPA) has

² <https://www.niehs.nih.gov/health/topics/agents/pfc/index.cfm>

³ <https://www.nature.com/articles/d41586-019-00441-1>

⁴ <https://greensciencepolicy.org/docs/pfas-building-materials-2021.pdf>

⁵ <https://www.gao.gov/assets/gao-21-421.pdf>

identified that the potentially toxic and carcinogenic nature of many of these chemicals demands careful evaluation.^{6, 7}

The disposal of PFAS-containing materials is problematic, as evidenced by the recent cleanup and lawsuits filed against Noralite Hazardous Waste Facility in Cohoes, New York.⁸ In July 2021, the village of Hoosick Falls reached a \$65 million settlement with Saint-Gobain, Honeywell International, 3M, and DuPont for PFOA contamination of their groundwater that affected at least 544 private wells.⁹ Unfortunately the water remains contaminated, and the plant that used PFOA chemicals has been declared a Superfund site.

PFAS legislation in New York State

In 2016, the NYS Department of Environmental Conservation (DEC) issued a regulatory impact statement to 6 NYCRR Part 597 adding PFOA and PFOS as hazardous substances. This ruling was adopted by the DEC in March 2017.¹⁰ In July 2020, NYS passed S.8817 and A.4739-C, which ban the use of PFAS in food packaging.¹¹ And in August 2020, the NYS Department of Public Health (DPH) voted to set the maximum contaminant levels (MCLs) at 10 parts per trillion (10 ppt) for both PFOA and PFOS in our drinking water supply.¹² NYS legislation permits the DPH to require that public water systems are tested for the contaminants and ensure that elevated levels are addressed.¹³

⁶ <https://www.epa.gov/pfas/basic-information-pfas>

⁷ <https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/risk-management-and-polyfluoroalkyl-substances-pfas>

⁸ <https://www.wamc.org/capital-region-news/2020-06-25/cohoes-residents-file-intent-to-sue-norlite-over-burning-firefighting-foam>

⁹ <https://pfasproject.com/hoosick-falls-new-york/>

¹⁰ <https://www.dec.ny.gov/regulations/104968.html>

¹¹ <https://www.nysenate.gov/legislation/bills/2019/s8817>

¹² https://www.health.ny.gov/environmental/water/drinking/docs/water_supplier_fact_sheet_new_mcls.pdf

¹³ <https://news.bloomberglaw.com/environment-and-energy/new-york-moves-on-some-of-strictest-pfas-drinking-water-limits>

PFAS legislation in other states

North Carolina is among the top three states for solar development. By February 2018, residents and the state were questioning the presence of PFAS in solar panels.¹⁴ *The North Carolina State Journal* reported that EPA physical scientist Dr. Mark J. Strynar provided 39 records from the SciFinder database used by the EPA to identify applications of PFAS with solar panels.¹⁵ In August 2018, *The Carolina Journal* reported that the EPA confirmed that PFAS are used in solar panel production.¹⁶ While studies may not be conclusive, the lack of definitive conclusions and transparency raises concerns.

In December 2020, Marc Fitch of the Yankee Institute reported that the Connecticut Department for Health was concerned about PFAS in solar panels.¹⁷ “We’ve asked the question, have received some information, and have also received some push-back when we ask those questions about whether these panels contain PFAS and different PFAS chemicals.” It is the lack of answers and documentation that is troubling and raises questions of the long term impact of solar panels and battery storage on our soils and drinking water.

PFAS Federal legislation

Federal regulations surrounding PFAS are being adopted rapidly, and further restrictions at the national level are expected. US Representative Debbie Dingell (D-MI-12) sponsored Bill H.R.2467, PFAS Action Act of 2021, to “establish requirements and incentives to limit the use of perfluoroalkyl and polyfluoroalkyl substances, commonly referred to as PFAS, and remediate PFAS in the environment.”¹⁸ The Bill passed the House July 21, 2021 and is awaiting a vote in the Senate.¹⁹ The Executive Office of the President and other advocacy groups such as Consumer Reports support passage of the

¹⁴ <https://nsjonline.com/article/2018/02/solar-panels-could-be-a-source-of-genx-and-other-perflourinated-contaminants/>

¹⁵ https://nsjonline.com/wp-content/uploads/2018/02/perfluoro-and-solar-panels-Reference_02_15_2018_120238-002.pdf

¹⁶ <https://www.carolinajournal.com/news-article/epa-confirms-genx-related-compounds-used-in-solar-panels/>

¹⁷ <https://yankeeinstitute.org/2020/12/03/departement-of-public-health-concerned-about-pfas-in-solar-panels-near-drinking-water/>

¹⁸ <https://debbiedingell.house.gov/news/documentsingle.aspx?DocumentID=2975>

¹⁹ <https://www.congress.gov/bill/117th-congress/house-bill/2467>

Bill.^{20,21} Additionally, the Environmental Protection Agency (EPA) proposes reporting and record-keeping requirements for PFAS under the Toxic Substances Control Act (TSCA).²²

The August 3, 2021, *National Law Review* included an article by John Gardella of CMBG3 Law in Boston. He concludes that while the US Senate vote has not been determined, that “the pressure is on the EPA to take regulatory action well beyond just drinking water, and companies absolutely must begin preparing now for regulatory actions that will have significant financial impacts down the road.”²³

PFAS in solar panel and battery manufacturing

Despite industry and a few academic assurances to the contrary, broad research consistently indicates that PFAS chemicals are used in solar panel and battery manufacturing and installation. PFAS is found in the coatings on electrical wires, backing panels, tapes, and adhesives.

Of particular concern is the use of PFAS in anti-reflective coatings (ARC) and anti-soil coatings (ASC) that are used to increase solar panel productivity. Material and Data Safety Sheets detail the contents of products manufactured in the United States. However, at this time, China is the major supplier of polysilicon²⁴ solar panels and batteries.²⁵ Accountability and transparency for materials and products made outside of the United States is questionable. In June 2021, the Biden administration banned import and use of certain solar energy materials and products from China due to the country’s use of forced labor and genocide at polysilicon mines.²⁶

Two types of solar panel coatings are commonly used: anti-reflective coatings (ARC) and anti-soil coatings (ASC)

²⁰ <https://www.whitehouse.gov/wp-content/uploads/2021/07/HR2467.SAP-Final.docx.pdf?source=email>

²¹ https://advocacy.consumerreports.org/press_release/house-votes-to-approve-the-pfas-action-act-hr-2467/

²² <https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/risk-management-and-polyfluoroalkyl-substances-pfas>

²³ <https://www.natlawreview.com/article/congress-presses-forward-pfas-measures>

²⁴ <https://www.solarpowerworldonline.com/2021/05/no-avoiding-it-now-soon-the-top-4-polysilicon-manufacturers-will-be-based-in-china/>

²⁵ <https://www.forbes.com/sites/rpapier/2019/08/04/why-china-is-dominating-lithium-ion-battery-production/?sh=770793d23786>

²⁶ <https://www.ecowatch.com/china-solar-panels-ban-biden-2654961710.html>

Anti-Reflective Coating (ARC)

A bare silicon glass surface may have a reflection index of more than 30%.²⁷ Anti-reflective coatings (ARC) are used to increase solar panel productivity by adding a dielectric coating on the glass surface. This coating textures the glass surface, which results in specific bands of wave lengths to be trapped inside the panel where they can generate additional electricity by coming in contact with the photovoltaic cells.

In their Application Appendix 15-A: Glare Analysis, Hecate Energy states that the panels they expect to use will have an anti-reflective coating, presumably to increase efficiency.

Anti-Soil Coating (ASC)

Dust and dirt can foul the panel surface and hinder the conversion of light to electricity. To maintain steady performance, the panel's surface must be cleaned regularly. Current manual or robotic cleaning methods are expensive and inefficient.

The hydrophobic qualities of ASCs create a non-stick surface that promotes water shedding, resulting in "self-cleaning" solar panels. This coating is applied to the front facing glass surface at the time of manufacture. The water-repelling surface promotes water cohesions, allowing the water droplets to form fully with minimal surface contact. This enhances water droplet shedding and in the process removes dust and dirt from the surface of the panel. ASCs help decrease maintenance costs while increasing the electricity generated. It can be reapplied in the field with products such as 3M AS Liquid 600.²⁸

ASC is typically manufactured with either silicon dioxide (SiO₂) or titanium dioxide (TiO₂) nanoparticles combined with long chains of fluoropolymers. While SiO₂ may be inexpensive it is less durable to environmental elements. TiO₂ appears to be more stable and is reported to be more frequently used for solar panel ASC.

There are increasing concerns about the negative impact of TiO₂ on the environment and human health. In December 2020, California announced the review of titanium dioxide nanoparticle classification under their Safe Water Act Proposition 65.²⁹

Gohar Dar's book *TiO₂ Nanoparticles*, published in February 2020, includes a chapter on "Toxicity of TiO₂ Nanoparticle". This research indicates that lung tumors are found in

²⁷ <https://www.pveducation.org/pvcdrom/design-of-silicon-cells/anti-reflection-coatings>

²⁸ https://www.coatingsworld.com/issues/2012-10/view_paint-amp-coatings-manufacturer-news/3m-rolls-out-pv-anti-soiling-coating/

²⁹ <https://www.paintsquare.com/news/?fuseaction=view&id=23184>

mice that have had long term exposure to TiO₂.³⁰ Chapter 2: “Applications in Nanobiotechnology and Nanomedicine” research indicates safety concerns regarding TiO₂ nanoparticles on aquatic species.³¹

While the potential for titanium dioxide nanoparticles to contaminate our soils is not conclusive, the possibility warrants further investigation. The evidence appears to be mounting, and the developer should carry the burden of proof.

Research papers call for caution and further study of ARC and ACS on solar panels. Natatajan Shanmugam’s May 2020 study “Anti-Reflective Coating Materials: A Holistic Review from PV Perspective,”³² published in *Energies*, provides a 98-page comprehensive report. On page 67 the author states: “The implementation of ARCs on the solar cell would suppress the reflection, and in turn, enhances the PCE, [power conversion efficiency] but their durability with continuous exposure to the environment and performance degradation characteristics are some novel areas where research is required.”

ARC and ASC resist some stresses, but not others:

[T]he coatings may resist the harsh environmental stresses such as damp heat and humidity freeze, but they are susceptible to damage under UV exposure. XPS analysis revealed a clear reduction in fluorine in the composition of the coating after exposure to UV and outdoor testing.³³

Kenan Isbilir’s 2019 thesis at Loughborough University studies the “performance and durability of anti-reflective and anti-soiling coatings on solar cover glass”³⁴ His thesis investigated the durability of commercially available two types of single layer (ARC1 and ARC2) and one multilayer anti-reflective (MAR) commercially available coatings, as well as ASCs. After testing several coatings, he concludes that:

The durability of these coatings against UV light and abrasion resistance would need to be improved if they are to be applied to PV cover glass.

In 2020, Gizelle C. Oehler found that certain ASC break down in as little as two weeks:

³⁰ <https://onlinelibrary.wiley.com/doi/abs/10.1002/9783527825431.ch2>

³¹ <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3720578/>

³² https://www.researchgate.net/publication/341556138_Anti-Reflective_Coating_Materials_A_Holistic_Review_from_PV_Perspective

³³ https://www.researchgate.net/publication/329506058_Testing_of_an_Anti-Soiling_Coating_for_PV_Module_Cover_Glass

³⁴ https://repository.lboro.ac.uk/articles/thesis/The_performance_and_durability_of_anti-reflective_and_anti-soiling_coatings_on_solar_cover_glass/8132048/1

Surprisingly, the coatings began to degrade quickly, and the effect was clear after only two weeks of exposure. Degradation resulted in decreasing water contact angle and increasing roll-off angles. As observed by Bhaduri et al., the degradation was much faster than anticipated because the outdoor environment combines the stresses tested in the laboratory [31]. Degradation was caused by a number of mechanisms including solvent release, fluorine loss, thinning of the coating, and increasing surface macro-roughness.³⁵

The location or accumulated amounts of the degraded chemicals is not discussed in these studies. It is logical to assume that the chemicals sloughing off with the rainwater are deposited into the underlying soil, groundwater and aquifers. The cumulative effect of tens of thousands of solar panels for 35 or more years would most likely permanently contaminate the site's groundwater, soil, and stormwater runoff. If coatings are reapplied during the projects lifetime then additional concerns are raised. How is the ground protected during reapplication? How often is the coating reapplied to the panels on site? Improper disposal of broken and decommissioned solar panels may permanently contaminate landfills and any nearby aquifers. If regulations continue to become more restrictive, how will the panels be disposed of, and is the decommissioning fund adequate?

Millions upon millions of solar panels will be used and disposed of within New York State during the next two decades. Periodic upgrades and damage or defects will need to be addressed long before the end of the project's life.³⁶ Developers should carry the burden of proof that their materials and products do not contain PFAS. Towns and taxpayers should trust but verify all materials provided by the developers. The people cannot afford the risk that solar panels and storage batteries may contaminate our drinking water and soil, either upon installation, during use, or during disposal. It seems doubtful that developers' required liability coverage would be sufficient for a large-scale PFAS cleanup project.

In June 2021, Niagara County adopted an Extended Producer Responsibility (EPR) law to protect their landfills from being overburdened by the disposal of solar panel waste. The law requires "producers of solar panels sold in the county to finance and manage their safe reuse and recycling when decommissioned."³⁷ Phone calls to Greene and Columbia county landfills have not provided confirmation that they will accept large quantities of solar panels, either today or in the future. One company suggested contacting We Recycle Solar, which is located in Arizona. State and federal laws for PFAS are

³⁵ https://repository.lboro.ac.uk/articles/journal_contribution/Testing_the_durability_of_anti-soiling_coatings_for_solar_cover_glass_by_outdoor_exposure_in_Denmark/11558853

³⁶ <https://hbr.org/2021/06/the-dark-side-of-solar-power>

³⁷ <https://www.productstewardship.us/news/571089/Niagara-County-Passes-Nations-2nd-Solar-Panel-Producer-Responsibility-Law.htm>

likely to become more numerous and stringent. The town and county should consider the possibility of PFAS contamination from solar panels deposited in our local landfills and require developers to prove that their installations will not include products containing PFAS.

Industry Response

Manufacturers of ARC and ASC may understand the environmental concerns and toxicity risks of their products. A few companies are beginning to provide non-toxic coatings. One company's solution is a proprietary nanoparticle coating that is an environmentally friendly.

WattGlass has addressed and overcome many of the issues typical of other antireflective coatings (ARCs): things such as toxicity, shelf life, and durability. WattGlass is happy to offer a non-toxic, water based, long shelf-life solution to existing ARC technologies that is easily implemented as a drop in replacement.³⁸

Solar ARC surpasses the performance of conventional coatings and is resistant to particulate soiling while remaining non-hazardous and 100% water-based. Typically, these coatings result in tradeoffs between performance and functionality and utilize hazardous materials such as solvents, acids, and fluorocarbons. Not with WattGlass.

If Watt Glass feels it is important to stress their environmentally friendly non-fluorocarbon solution again and again, it raises the obvious question: what are the other companies using, and how might their products harm our soil, water, and public health?

What's next

On August 19, 2021, OxyChem announced that it was closing its Niagara Falls plant, the site of America's first major environmental disaster, Love Canal. In 1988, NYS Department of Health Commissioner David Axelrod called the Love Canal incident a "national symbol of failure to exercise a sense of concern for future generations."³⁹

Solar energy resources are marketed as an environmentally-friendly way to generate electricity. However, research indicates that solar panels, coatings, wire coverings, tapes, adhesives and batteries contain PFAS that may permanently harm our soils and poison our drinking water.

³⁸ <https://www.wattglass.com/technology>

³⁹ <https://www.nytimes.com/1988/08/05/nyregion/after-10-years-the-trauma-of-love-canal-continues.html>

An October 2020 Bloomberg Law article provides insight into upcoming PFAS regulations in relation to the Development of renewable energy in New York State.

Overall, along with the CLCPA, the new Siting Law and the expected PFAS regulations fundamentally change long-standing environmental paradigms in New York State. The flurry of regulations expected from Albany in the next few years will usher in a new era of environmental regulation quite different from today. Those well prepared for the transition will be positioned to prosper from it, while those who are not will fall behind or find their business plans or goals outdated or not fully achievable.⁴⁰

Conclusions

Renewable energy developers are responsible to their investors. Not the town. Not the neighbors. And not the environment. Solar projects are held by individual LLCs whose only asset may be an aging infrastructure built on leased ground. At time of decommissioning – or evidence of contaminants – it is unlikely that there will be a deep-pocketed corporation to bring the site into compliance with current or future EPA and DEC standards.

The July 2021 ruling on the Fieldwood Energy, LLC bankruptcy case sets precedent that previous oil well owners, and the insurance companies that issue them bonds, are responsible for the cleanup cost of wells.⁴¹ Insurance company trends with oil and gas may become the standards for the renewable energy sector, making it difficult and costly to insure solar power plants.

Prior to construction, Hecate Energy should be held responsible to neighboring residents and Coxsackie's municipal government by providing documentation that the solar panels, coatings, and electrical infrastructure specified for the project do not contain PFAS or other toxic chemicals. Attempting to remedy a “forever chemical” such as PFAS contamination over more than a thousand acres of solar coverage would likely be impossible.

While there are a few alternative options that may be safer, these products are more expensive and are manufactured in smaller quantities. Utility-scale solar power plants require hundreds of thousands, if not millions, of photovoltaic panels at the time of installation. The ability to manufacture and deliver this quantity is limited to the very largest

⁴⁰ <https://news.bloomberglaw.com/environment-and-energy/impact-of-new-yorks-renewable-energy-permitting-program-pfas-regulation>

⁴¹ <https://www.bondexchange.com/oil-industry-woes-lead-to-massive-changes-in-the-insurance-industry/>

suppliers, most of them based in China, where Material Data and Safety Sheets are limited and if provided the information is questionable.

Reputable solar panel manufacturing companies that freely provide Material Data and Safety Sheets may be limited. Solar developers that provide toxicity guarantees on their panels being free of dangerous chemicals may be even fewer. While the level of toxicity of ARC and ASC may lack clarity, the coatings' exposure to the elements and where the sloughed-off chemicals will be deposited is not. The chemicals are likely to enter the soil and groundwater.

When reviewing this Application, the Siting Board must not rely on good intentions. As has been noted throughout this proceeding, multiple solar projects will be constructed in the watershed of Sleepy Hollow Lake. Measures should be taken to determine that panels, electrical infrastructure, and wiring for these projects is PFAS-free.

What we are discussing here is a matter of public health and safety, we encourage the Board to require developers to provide specification sheets, and to describe preventive measures, testing policies, and Material and Data Safety Sheets in order to protect Coxsackie public health and to protect the town from future liability. Preventative measures – not after-the-fact remediation – are the answer to avoiding PFAS contamination of soil, stormwater runoff, drinking water, and aquifers surrounding the project.

Exhibit 7:

2022, Zoning By-Law Amendments: Article 5 Section 590 Solar Energy Generation Facilities, Article 3 Section, 320 Use Table, and Article 16 Definitions, prepared by the Town of Wareham.

Town Meeting Warrant Article

Warrant Article:

Identifier: (to be determined by office) Article # _____

Title:

Zoning By-Law Amendments:

Article 5 Section 590 Solar Energy Generation Facilities, Article 3 Section 320 Use Table, and Article 16 Definitions

Warrant Article:

To see if Town Meeting will delete Article 5 Section 590 of the Wareham Zoning By-Laws in its entirety and to replace it with the version of the Article 5 Section 590 Solar Energy Generation Facilities bylaw as presented and to make revisions as presented to Article 3 Section 320 Use Table and Article 16 Definitions of the Wareham Zoning By-Laws as necessary and related to Article 5 Section 590 or to take any action relative thereto.

Motion:

I move that Town Meeting vote to delete Article 5, Section 590 of the Wareham Zoning By-Laws in its entirety and to replace it with the version of Article 5 Section 590 Solar Energy Generation Facilities bylaw as presented and to make revisions as presented to Articles 3 Section 320 Use Table and Article 16 Definitions of the Wareham Zoning By-Laws as necessary and related to Article 5 Section 590.

Explanation:

Revisions to Section 590 and other supporting bylaw sections of the Wareham Zoning By-Law have been made by the Solar Bylaw Study Committee after careful consideration and significant community input.

The Committee, comprised of seven Wareham citizens of diverse backgrounds, has aimed to balance the rights of landowners to use their land to develop solar energy systems while being committed to protecting the health, safety and welfare of our diverse communities including but not limited to the environmental justice and elderly populations and to preserve the natural environment.

The goal is to encourage the responsible use of solar energy generation facilities, encourage construction and operation of Large-Scale Ground-Mounted Solar Photovoltaic Installations in previously disturbed areas to minimize adverse ecological impacts, to provide standards for the placement, design, construction, monitoring and modification of large-scale ground-mounted solar energy facilities that address public safety, minimize impacts such that no person is deprived of the freedom from excessive or unnecessary glare or noise, scenic, natural and historic resources of the Town and provide adequate financial assurance for decommissioning.

Revisions to Section 590 of the Wareham Zoning By-Law encourages the use of solar energy systems and protects solar access consistent with Massachusetts General Laws Chapter 40A Section 3 and Section 9B (Solar Access) and Green Communities Act M.G.L. Chapter 25A Section 10. This section of the Wareham Zoning By-Law is consistent with Wareham's 2020 Master Plan (page 76) and 2017-2024 Open Space and Recreation plan (pages 88-90) as they recognize the need to protect water and wildlife habitat resources while providing opportunities to increase resiliency from the effects of climate change with green infrastructure and conservation of forests and farmland..

Revisions to Section 590 incorporate the MA state model by-law and Department of Energy Resources SMART program guidance (225 CMR 20.00 September 22, 2021) that strongly discourages siting such projects in areas of important habitat. They strongly discourage locations that result in significant loss of natural resources and encourage rooftop siting, as well as locations in industrial and commercial districts, on farms where appropriate and on vacant, previously disturbed land. Section 590 of the Wareham Zoning By-Law recognizes that significant tree cutting is problematic because of the important water management, cooling, and climate benefits trees provide.

Submitted by: Solar By-Law Study Committee; Nancy McHale Chair

Date: March 9, 2022; revised March 24, 2022

Reference Information:

Article Inserted by Board of Selectmen at the request of: Solar By-Law Study Committee

590 Solar Energy Generation Facilities

591. Purpose

The purpose of section 590 of the Wareham Zoning By-Law is to encourage the responsible use of solar energy generation facilities, encourage construction and operation of Large-Scale Ground-Mounted Solar Photovoltaic Installations in previously disturbed areas to minimize ecological impacts, to provide standards for the placement, design, construction, monitoring, modification and removal of large-scale ground-mounted solar energy facilities that address public safety, minimize impacts on environmental justice communities such that no person is deprived of the freedom from excessive or unnecessary glare or noise, scenic, natural and historic resources of the Town and provide adequate financial assurance for decommissioning.

Section 590 of the Wareham Zoning By-Law aims to balance the rights of landowners to use their land to develop solar energy systems while protecting the health, safety, and welfare of the public by protecting the Plymouth/Carver sole source aquifer upon which all residents rely for drinking water, the abundant small streams that feed the watersheds and estuaries leading to Buzzards Bay.

Section 590 of the Wareham Zoning By-Law encourages the use of solar energy systems and protects solar access consistent with Massachusetts General Laws Chapter 40A Section 3 and Section 9B (Solar Access) and Green Communities Act M.G.L. Chapter 25A Section 10. This section of the Wareham Zoning By-Law is consistent with Wareham's 2020 Master Plan and 2017-2024 Open Space and Recreation plan as they recognize the need to protect water and wildlife habitat resources while providing opportunities to increase resiliency from the effects of climate change with green infrastructure and conservation of forests and farmland.

Section 590 of the Wareham Zoning By-Law seeks to satisfy the MA state guidance that strongly discourages siting such projects in forested areas such as the globally rare Pine Barrens.

Section 590 of the Wareham Zoning By-Law strongly discourages locations that result in significant loss of ecosystem values and natural resources, including farm and forest land, and encourages rooftop siting, as well as locations in industrial and commercial districts, or on vacant, previously disturbed land.

Section 590 of the Wareham Zoning By-Law recognizes that significant tree cutting is problematic because of the important water management, cooling, and climate benefits trees provide. According to Tufts.edu, forests pull about one-third of all human-caused carbon dioxide emissions from the atmosphere each year. Researchers have calculated that ending deforestation and allowing mature forests to keep growing could enable forests to take up twice as much carbon.¹

592. Applicability

All Large-Scale Ground-Mounted Solar Photovoltaic Installations proposed to be constructed after the effective date of Section 590 of the Wareham Zoning By-Law will be subject to Site Plan Review in accordance with Article 15 of this Zoning By-Law and the additional standards of this section.

Section 590 of the Wareham Zoning By-Law also pertains to physical modifications that materially alter the type, configuration, or size of these installations or related equipment that occur after the effect date.

The provisions set forth in section 590 of the Wareham Zoning By-Law shall take precedence over all other sections when considering applications related to the construction, operation, and/or repair of Large-Scale Ground-Mounted Solar Photovoltaic Installations unless there is a

¹ <https://now.tufts.edu/articles/curb-climate-change-easy-way-don-t-cut-down-big-trees#:~:text=Forests%20pull%20about%20one%2Dthird,up%20twice%20as%20much%20carbon.>

conflict within provisions of Section 590, the MORE RESTRICTIVE section shall take precedence.

592.1 Compliance with Laws, Ordinances and Regulations

The construction and operation of all Large-Scale Ground-Mounted Solar Photovoltaic Installations shall be consistent with all applicable local, state and federal requirements, including but not limited to all applicable safety, construction, electrical, and communications requirements.

All Large-Scale Ground-Mounted Solar Photovoltaic Installations must meet all the Land Use and Siting Criteria, per 225 CMR 20.05(5)(e).

592.2 Special Permit Granting Authority (SPGA)

The Planning Board shall be the Special Permit Granting Authority for **Large-Scale** Ground-Mounted Solar Photovoltaic Installations requiring a Special Permit under this by-law.

592.3 Site Plan Review Authority

The Planning Board shall be the Site Plan Review Authority for **Large-Scale Ground-Mounted Solar Photovoltaic Installations** under this by-law.

593. Application for Site Plan Review

Application for Site Plan Review with Special Permit shall require the filing of a Site Plan Review with Special Permit application and site plan in accordance with Article 15 of the Wareham Zoning By-Law.

No Large-Scale Ground-Mounted Solar Photovoltaic Installations shall be approved or constructed until evidence has been given to the permit granting authority that the utility company that operates the electrical grid where the installation is to be located has been informed of the large ground-mounted solar energy facilities owner or operator's intent to install an interconnected customer-owned generator.

Off-grid systems shall be exempt from this requirement.

Such plans shall contain the following specific information for an application to be considered complete:

593.1 Landscape plan including sizes, types and numbers of plantings and details. Existing vegetation and other unique land features shall be preserved where feasible.

593.2 Proposed changes to the landscape of the **project area** grading, vegetation clearing and planting, exterior lighting, screening vegetation or structures.

593.3 Plans of the Large-Scale Ground-Mounted Solar Photovoltaic Installation signed by a Professional Engineer licensed to practice in the Commonwealth of Massachusetts showing the proposed layout of the system and any potential shading from nearby structures.

593.4 Certification from a professional engineer that the construction of the Large-Scale Ground-Mounted Solar Photovoltaic Installation meets the Performance Standards set forth 225 CMR 20.05(5)(e)6.

593.5 A stormwater management plan detailing the existing environmental and hydrological conditions of the project area, proposed alterations of the **project area** and all proposed components of the drainage system and any measures for the detention, retention, or infiltration of water, for the protection of water quality and protection from flooding. Specific attention shall be paid to the potential for negative effects on streams and wetlands such as silting from runoff.

- 593.6 A description of the Solar Photovoltaic Installation and the technical, economic and other reasons for the proposed location and design shall be prepared and signed by a registered professional engineer.
- 593.7 Confirmation prepared and signed by a registered professional engineer that the Solar Photovoltaic Installation complies with all applicable Federal and State standards.
- 593.8 One or three line electrical diagram detailing the Solar Photovoltaic Installation, associated components, and electrical interconnection methods, with all National Electrical Code compliant disconnects and over current devices.
- 593.9 Documentation of the major system components to be used, including the photovoltaic panels, mounting system, inverters, on-site accessory battery storage, and any other associated equipment.
- 593.10 Documentation of the sound generated by equipment used in the production of electrical energy, including any proprietary documentation.
- 593.11 An operation and maintenance plan (see also section 596 on decommissioning). Such plan should include:
1. Regular (not less than annual) inspection of the property, the visual screening, the fencing, and all other equipment installed as part of the project. The inspection shall identify all repairs and maintenance required to maintain the fencing, noise buffering and visual screening. A plan and timeline for effecting the maintenance must be submitted to the SPGA.
 2. Regular (windblown, litter, etc) trash and debris removal from the site.
 3. A description of property and landscape maintenance plan, including all required vegetative plantings and screening.
 4. The operations and management plan must include active maintenance of the vegetation for the duration of the project. Use of herbicides and pesticides shall be prohibited for the maintenance of the project site except where necessary in dual use agriculture in accordance with the Pesticide Control Act. Landscape Requirements should include all requirements listed in Article 10 of the Zoning Bylaw.
- 593.12 An assessment of the impact on the environment formatted in a before / after method so that it is easy to measure and understand the changes that the proposed Solar Photovoltaic Installation will have on the property and the property abutters. Such reports will be conducted by a party mutually agreed upon by the Planning Board and the prospective developer.
- 593.13 An evaluation of the impact on the wildlife, habitat, and endangered species to determine potential harm to wildlife and habitat by the proposed Solar Photovoltaic Installation. The evaluation will be conducted by a party mutually agreed upon by the SPGA and the prospective developer.
- 593.14 Line of Sight study to determine visual impact from all directions. All panels and equipment associated with the Solar Photovoltaic Installation should be invisible to any residential home in Wareham, as well as from any public or private road. The Study will be conducted by a party mutually agreed upon by the SPGA and the prospective developer
- 593.15 All applicants must provide a historical and cultural heritage evaluation on the potential impact of the Solar Photovoltaic Installation. The evaluation(s) will be conducted by a party mutually agreed upon by the SPGA and the prospective developer
- 593.16 An alternative use analysis that addresses other siting options with various environmental impacts. Financial impacts are not sufficient reason for approval of project with significant environmental impact

594. Siting

No Solar Photovoltaic Installation shall be constructed, installed or modified without first obtaining a building permit.

594.1 Prohibited Siting

Solar Photovoltaic Generation Units sited on the following types of parcels are not allowed:

1. Permanently protected open space, categorized under Article 97 of the Massachusetts Constitution,
2. A Wetland Resource Area, not including Buffers, unless authorized by the regulatory body, such as an Order of Conditions issued by the local Conservation Commission; or
3. State Historic Register properties
4. Land that is Priority Habitat, Core Habitat, Estimated Habitat, and/or Critical Natural Landscape or where at least 50 percent of the parcel's area is designated as Priority Habitat, Core Habitat, and/or Critical Natural Landscape
5. Large-Scale Ground-Mounted Solar Photovoltaic Installations sized greater than 5,000kW DC.

594.2 As-of-Right Siting

The following types of solar facilities are allowed anywhere or as noted:

1. Small-Scale Ground-Mounted Solar Photovoltaic Installations (less than 250 kW DC) are permitted as-of-right in all districts when connected behind the meter.
2. Roof-mounted or building-mounted solar energy facilities are permitted as-of-right in all districts when connected behind the meter.

594.3 Restricted Siting

Large-Scale Ground-Mounted Solar Photovoltaic Installations sized between 250kw and 5,000kW are allowed, subject Site Plan Special Permit, in the R-130, R-60, CG, CS, IND, CR districts or as noted:

1. Ground-mounted solar energy facilities sited on a Brownfield,
2. Ground-mounted solar energy facilities sited on Eligible landfills,
3. Ground-mounted solar energy facilities sited on sand and/or gravel pits,
4. Canopy mounted solar energy facilities,
5. Public Utility solar energy facilities,
6. Ground-mounted solar energy facilities within a farm or existing agricultural land,
7. Ground-mounted solar energy facilities sited on land that has been previously disturbed.

595. Design Standards.

Unless otherwise expressly provided by Section 590 of the Wareham Zoning By-Law requirements of the underlying zoning district shall apply, except and in addition, the following design standards which shall apply.

595.1 Large-Scale Ground-Mounted Solar Photovoltaic Installations shall meet the following standards:

1. No such installation shall be segmented or broken into separate ownerships so as to avoid the prohibitions of the by-law.

2. Meet the requirements and standards for industrial uses found in Article 7: Design Standards and Guidelines of this Zoning By-Law.
3. The distance shall be 75 feet from the residential property line which may be increased to reduce or eliminate visibility and noise at the discretion of the SPGA.
4. Required separation in commercial and industrial districts, the distance shall be 25 feet which may be increased to reduce visibility and noise at the discretion of the SPGA
5. The front, side, and rear yard depth shall be in accordance with Article 6 of the Wareham Zoning By-Law; provided, however, that where the lot abuts or is across the street from a Residential Neighborhood, the front yard setback for all structures including fencing and vegetated buffer shall not be less than 75 feet, and may be more, as determined at the sole discretion of the SPGA, depending on visibility of the facility because of the density of vegetation and/or topography.
6. Earthen berms and landscape plantings will be required according to Article 10: Landscaping, of this Zoning By-Law.
7. Significant regrading of the site is prohibited. Any and all soil removal must be approved and consistent with Article III, Earth Removal Regulations of the Town By-Law.
 - No removal of all field soils;
 - Existing leveled field areas left as is without disturbance;
 - Where soils need to be leveled and smoothed, such as filling potholes or leveling, this shall be done with minimal overall impact with all displaced soils returned to the areas affected.
8. Landscaping:
 - No removal of all field soils,
 - All vegetative screening will be designed with plants that include a diversity of native species, including deciduous and evergreen plants.
 - A mix of native species including evergreen and deciduous trees, as well as native bushes and plants to be used as ground cover sufficient to maintain soil integrity and minimize soil erosion must be established and maintained for the life of the project.
 - Appropriate use of geotextile fabrics,
 - The SPGA will consider the quality of the landscape plan and the methods used to provide a visual buffer and noise barrier between the PV array and the residences around it.
9. Ballasts, screw-type, or post driven pilings and other acceptable minimal soil impact methods that do not require footings or other permanent penetration of soils for mounting are required, unless the need for such can be demonstrated; the use of chemically treated timbers to mount solar panels is prohibited.
10. Any soil penetrations that may be required for providing system foundations necessary for additional structural loading or for providing system trenching necessary for electrical routing shall be done with minimal soils disturbance, with any displaced soils to be temporary and recovered and returned after penetration and trenching work is completed;
11. No concrete or asphalt in the mounting area other than ballasts, poles for mounting solar panels, or other code required surfaces, such as transformer or electric gear pads;

12. Address existing soil and water resource concerns that may be impacted to ensure the installation does not disturb an existing soil and water conservation plan or to avoid creating a negative impact to soil and water conservation best management practices, such as stimulating erosion or water run-off conditions;
13. All large-scale ground-mounted solar energy facilities shall be required to be fenced only if necessary for public safety. Any fencing used shall be permeable to allow small wildlife to pass through, and designed to blend into the surrounding landscape.
14. All appurtenant structures, including but not limited to, equipment shelters, storage facilities, transformers, and substations, shall be architecturally compatible with each other and shall be screened from the view of public rights-of-ways and persons not on the parcel, in all residential districts.
15. Battery storage systems may be included in a project only when accessory to the PV array collection system utilized for solar power generated as part of the approved project. Hazards associated with the battery storage will be identified and addressed in the system's operation and management plan as a requirement for the Special Permit. The items to address in the operation and management plan shall include; noise, fire, and hazardous material management.
16. Access roads and driveways shall be designed to limit visibility into the site with minimum disturbance necessary to gain appropriate access to and around the arrays. Setbacks shall not be disturbed by access roads, except where allowed by the permit granting authority for access to the site.
17. Lighting of solar energy facilities shall be consistent with state and federal law. Lighting of appurtenant structures shall be limited to that required for safety and operational purposes, and shall be reasonably shielded from abutting properties. Lighting of the solar photovoltaic installation shall be directed downward and shall incorporate full cut-off fixtures to reduce light pollution. Lighting shall be Night Sky program compliant.
18. There shall be no signs, except announcement signs, no trespassing signs or any signs required to warn of danger. A sign is required that identifies the owner and operator with an emergency telephone number where the owner and operator can be reached on a twenty-four hour basis.
19. All utility connections shall be underground except to the extent that underground utilities are not feasible in the reasonable determination of the board review.
20. Inverters and transformers shall be sited so as to minimize sound impact to residences. Noise levels at the nearest residential receptors will be determined for all equipment in combination, and must be at background levels for the district in which the receptors are located, and if not, will require mitigation that must be approved as conditions of the Special Permit issued by the SPGA.
21. Solar photovoltaic panels should be positioned so as not to cast glare to abutting uses by providing screening methods. Setbacks shall provide for adequate screening of noise and glare from abutting uses and structures. Techniques such as dense natural vegetated plantings of native plants, earthen berms and/or increased setbacks will be required, depending upon site specific conditions. Setbacks shall not be disturbed by access roads, except where allowed by the permit granting authority for access to the site. Setbacks shall not be used for any purpose other than natural vegetation or other screening required by the reviewing board. Setbacks from property lines shall be as provided above for the type of large ground-mounted solar energy facilities.
22. The Solar Photovoltaic Installation owner, operator or their successors shall provide a copy of the project summary, electrical schematic, and site plan to the applicable fire

chief. Upon request the Solar Photovoltaic Installation owner, operator or their successors shall cooperate with local emergency services in developing an emergency response plan. All means of shutting down the large ground-mounted solar energy facilities shall be clearly marked. The owner or operator shall identify a responsible person for public inquiries throughout the life of the installation.

23. The Solar Photovoltaic Installation owner, operator or their successors shall maintain the facility in good condition. Maintenance shall include, but not be limited to, painting, structural repairs, and integrity of security measures and planting and maintaining healthy native plants for vegetative visual screening.
24. Site access shall be maintained to a level acceptable to the applicable fire chief and Emergency Medical Services. The Solar Photovoltaic Installation owner, operator or their successors shall be responsible for the cost of maintaining the large ground-mounted solar energy facilities and any access road(s), unless accepted as a public way.

596. Abandonment or Decommissioning

The Solar Photovoltaic Installation owner, operator or their successors in interest shall remove any ground-mounted solar energy facility which has reached the end of its useful life or has been abandoned. The owner or operator shall physically remove the installation no more than 150 days after the date of discontinued operations. The owner or operator shall notify the permit granting authority by certified mail 60 days prior to the proposed date of discontinued operations and plans for removal.

596.1 Decommissioning shall consist of but not limited to:

1. Physical removal of all below-grade foundations, mounting structures, supports, solar energy structures, equipment, security barriers and transmission lines from the site.
2. Disposal of all solid and hazardous waste in accordance with local, state, and federal waste disposal regulations.
3. Stabilization and re-vegetation of the site as necessary to minimize erosion. The SPGA may allow the Solar Photovoltaic Installation owner, operator or their successors to leave landscaping or designated below-grade foundations in order to minimize erosion and disruption to vegetation.

596.2 Abandonment: Absent notice of a proposed date of decommissioning or written notice of extenuating circumstances, the Solar Photovoltaic Installation shall be considered abandoned when it fails to operate for more than one year without the written consent of the permit granting authority. If the Solar Photovoltaic Installation owner, operator or their successors fail to remove the installation in accordance with the requirements of this section within 150 days of abandonment or the proposed date of decommissioning, the Town may enter the property and physically remove the installation.

596.3 Proponents of Solar Photovoltaic Installations shall provide a form of surety, either through escrow account, bond or otherwise, to cover the cost of removal in the event the Town must remove the installation and remediate the landscape, in an amount and form determined to be reasonable by the Town, equivalent to 200 percent of the cost of removal and compliance with the additional requirements set forth herein.

The amount of the cost of removal and reconditioning shall not be reduced by any expected or estimated amounts to be recovered through the re-sale or recycling of materials. Such surety will not be required for municipal- or state-owned facilities.

The Proponent shall submit a fully inclusive estimate of the costs associated with removal and reconditioning, prepared by a qualified engineer. The submission shall include a mechanism for calculating and adjusting the increased value of the surety removal costs

due to inflation and a regular review (not less than every five-years) and adjustment of the estimate shall be conducted. In no case will the surety be reduced.

597. Criteria for Special Permit Review and Approval

- 597.1 A Special Permit may be granted under this section if the SPGA finds that each of the design review standards set forth above have been met and that the location of the ground-mounted solar energy facilities is suitable and that the size and design are the minimum necessary for that purpose.
- 597.2 The SPGA shall also impose, in addition to any applicable conditions specified in this section, such conditions as it finds reasonably appropriate to safeguard the neighborhood, public or otherwise serve the purposes of this section, including, but not limited to: screening, lighting, noise, fences, modification of the exterior appearance of the structures, limitation upon size, method of access or traffic features, parking, removal upon cessation of use or other requirements. Such conditions shall be imposed in writing and the applicant may be required to post bond or other surety for compliance with said conditions in an amount satisfactory to the SPGA.
- 597.3 The Special Permit shall lapse if substantial use or construction has not commenced within two years of the date of issuance, except for good cause shown (including but not limited to appeals of the grant of the site plan or litigation enjoining the construction under the permit), and provided further that such construction, once begun, shall be actively and continuously pursued to completion within a reasonable time.

Article 16 Revisions to Definitions

As-of-Right Siting: As-of-Right Siting shall mean that development may proceed without the need for a special permit, variance, amendment, waiver, or other discretionary approval. As-of-right development requires a building permit and may be subject to site plan review to determine conformance with local zoning ordinances or bylaws. Projects cannot be prohibited, but can be reasonably regulated where necessary to protect public health, safety or welfare by the Inspector of Buildings, the Select Board, or the Planning Board.

Battery Energy Storage Management System: An electronic system that protects energy storage systems from operating outside their safe operating parameters and disconnects electrical power to the energy storage system or places it in a safe condition if potentially hazardous temperatures or other conditions are detected.

Battery Energy Storage System: A battery energy storage system (BESS) is an electrochemical device that charges (or collects energy) from the electrical grid or an electricity generating facility, such as but not limited to a Large-Scale Ground-Mounted Solar Photovoltaic Installation, and then discharges that energy at a later time to provide electricity or other grid services when needed.

Environmental Justice Communities: A neighborhood is defined as an Environmental Justice population if one or more of the following four criteria are true: 1) the annual median household income is not more than 65 per cent of the statewide annual median household income; 2) minorities comprise 40 per cent or more of the population; 3) 25 per cent or more of households lack English language proficiency; or 4) minorities comprise 25 per cent or more of the population and the annual median household income of the municipality in which the neighborhood is located does not exceed 150 per cent of the statewide annual median household income.

Large-Scale Ground-Mounted Solar Photovoltaic Installation / Large-Scale Ground Mounted Solar Energy Systems: A solar photovoltaic system that is structurally mounted on the ground and has a minimum nameplate capacity of 250 kW DC.

On-Site Solar Photovoltaic Installation: A solar photovoltaic installation that is constructed at a location where other uses of the underlying property occur. This would include Dual-Use installations as defined in the Massachusetts SMART program.

Off-Grid System: A solar photovoltaic installation where all energy generated on the installation site is consumed on that site and does not send any energy into the electrical grid for distribution.

Permanently protected open space: Areas shown on the BioMap2 image layer of the MassGIS database, further described at <https://www.mass.gov/service-details/biomap2-conserving-biodiversity-in-a-changing-world>

Pine Barrens: Consist of outwash from the last glacial maximum, which left thick glacial deposits of sand and gravel, providing the geologic foundation for a rare pine barren ecosystem. This forest and its fire-dependent pitch pine, the endangered Plymouth red-bellied turtles and other globally rare plant communities on top of deep deposits of glacially-deposited sands which filter and protect the Plymouth/Carver Sole Source Aquifer.

Previously Developed Areas or Previously Disturbed Areas including agricultural land: Land is disturbed if it has been the subject of human activity that has changed the land's surface, being changes that remain clear and observable

Includes the built environment such as impermeable surfaces like large rooftops, parking lots, as well as land that was subject to earth removal and land in active agricultural use.

Does not include wetlands, bogs or associated forested upland.

Priority Habitat, Core Habitat, Estimated Habitat, and/or Critical Natural Landscape: Areas shown on the BioMap2 image layer of the MassGIS database, further described at <https://www.mass.gov/service-details/biomap2-conserving-biodiversity-in-a-changing-world>

Project Area: The land under the Solar Photovoltaic including all areas within any fencing, all components of the system including all supporting structures, buffers, setbacks, access ways, vegetative screening, and any other land disturbed during installation.

Rated Nameplate Capacity: The maximum rated output of electric power production of the solar photovoltaic system in Direct Current (DC).

Residential neighborhoods: shall consist of at least 3 [three] occupied houses with at least one common lot line and a common street for access

Small-Scale Ground-Mounted Solar Photovoltaic Installation: A solar photovoltaic system that is structurally mounted on the ground and has a minimum nameplate capacity of under 250 kW DC and less than one acre in size.

Solar Energy: Radiant energy received from the sun that can be collected in the form of heat or light by a solar energy system.

Solar Energy System: A device or structural design feature, a substantial purpose of which is to provide daylight for interior lighting or provide for the collection, storage, and distribution of solar energy for space heating or cooling, electricity generation, or water heating.

Solar Photovoltaic Array: An arrangement of solar photovoltaic panels.

Solar Photovoltaic Generation Units: An arrangement of solar photovoltaic panels.

Solar Photovoltaic Installation: A solar energy system that converts solar energy directly into electricity through an arrangement of solar photovoltaic panels.

Solar Photovoltaic Installation Site Plan [or Special Permit] Review: A review by the site plan reviewing authority [or special permit granting authority] to determine conformance with the town's zoning bylaws.

State Historic Register: the Inventory of Historic and Archeological Assets, maintained by the Massachusetts State Historic Preservation Office

Wetland Resource Area: those resources identified in 310 CMR 10.00 et seq.

Article 3 – Revisions to Use Table

PRINCIPAL USE	R130	R60	R43	R30	MR30	WV1	WV2	OV1	OV2	CS	CG	CP	CNF	MAR	INS	IND
Large ground-mounted solar energy	SPR	SPR	N	N	N	N	N	N	N	N	SPZ	SPZ	N	N	N	N

Change the Row For: “Large ground-mounted solar energy to read: “Large-Scale Ground-Mounted Solar Photovoltaic Installations”

And in the 'CG' and 'CP' columns change the 'SPZ' to 'SPP' allowed by Special Permit from the Planning Board

And in the 'IND', and 'CS' columns change the “N” to ‘SPP’ allowed by Special Permit from the Planning Board

**Exhibit 8,
2022, *Special Town Meeting Article S15, Large-Scale
Ground-Mounted, Solar Photovoltaic Installations*, prepared by the
Wareham Solar Study Committee.**

Special Town Meeting Article S15

Large-Scale Ground-Mounted Solar Photovoltaic Installations

Proposed Solar Zoning By-Law Article 5 Section 590

The Wareham Solar By-Law Study Committee has rewritten Section 590 of the Zoning By-Laws to create a path for responsible development of solar projects that balances the rights of landowners while protecting health, safety, and welfare of the public.

- Limits the size of any Large-Scale Ground-Mounted Solar Photovoltaic Installation to **not greater than** 5.0MW DC. At this size, it balances solar with other competing land uses and recognizes the significant contribution that Wareham has already committed to solar development. 19 projects built; 4 not built but permitted; and potentially 6 more in the pipeline! These 29 projects **are not affected** by the revised bylaw **or** any proposed moratorium.
- **Prohibits development** of Large-Scale Ground-Mounted Solar Photovoltaic Installations **in sensitive environmental areas** such as Wetland Resource Areas, Permanently Protected Open Spaces, State Historic Register properties, land where at least 50% of the parcel's area is designated as Priority Habitat, Core Habitat, and/or Critical Natural Landscape as demonstrated in the [BioMap2](#) – thus protecting our sole source aquifer, our globally rare Pine Barrens, Sand Plains and unique local habitat.
- **Limits** grading and earth removal as part of a solar development project (Section 595.7).
- **Requires** Large-Scale Ground-Mounted Solar Photovoltaic Installations to use **non-toxic materials for poles** to mount panels. No chemically treated timber poles!
- **Provides limits** to where Large-Scale Ground-Mounted Solar Photovoltaic Installation can be sited **and encourages development on land that is already disturbed** like Brownfields, eligible landfills, sand and/or gravel pits, and over parking lots as canopies.
- **Provides flexibility** to site Large-Scale Ground-Mounted Solar Photovoltaic Installations on existing suitable agricultural land to help farmers protect their land for future generations.
- **Promotes responsible solar development by providing clear design standards**
- **Protects Town with increased guaranteed funding and a strict decommissioning plan** to cover the costs of removal of solar panels and materials from the site once it is taken offline.
- **Protects the unique nature of Wareham's neighborhoods** by requiring greater setbacks from residential property lines, and requires permanent landscaping with native species in all developments.

Support responsible solar development that protects public safety, the environment, and quality of life in Wareham



Please
Vote YES
Article S15

S15 Solar Zoning By-Law Explanation:

Revisions to Section 590 and other supporting by-law sections of the Wareham Zoning By-Law have been made by the Solar By-Law Study Committee after months of study, careful consideration, and significant community input. The Committee, comprised of seven Wareham citizens of diverse backgrounds, has aimed to balance the rights of landowners to use their land to develop solar energy systems while being committed to protecting the health, safety and welfare of our diverse communities.

The goal was to encourage the responsible development of new solar energy generation facilities in our community by limiting their overall size to no larger than 5.0MW DC which currently requires around 12-14 acres of land. This balances solar with other competing land uses and recognizes the significant contribution that Wareham has already made to solar development with 19 projects built; 4 not built but permitted; potentially 6 more in the pipeline. These 29 projects will not be affected by the revised by-law or any proposed moratorium.

It encourages construction and operation of Large-Scale Ground-Mounted Solar Photovoltaic Installations in previously disturbed areas to minimize adverse ecological impacts. This by-law provides clear standards for the placement, design, construction, monitoring and modification of large-scale ground-mounted solar energy facilities that address public safety, minimizes impacts on environmental justice communities such that no person is deprived of the freedom from excessive or unnecessary glare or noise, scenic, natural and historic resources of the Town and also provides adequate financial assurance for decommissioning. We seek to safeguard the health, safety, and welfare of the public by creating strict building and maintenance guidelines to ensure natural filtration and purification of the Plymouth/Carver sole source aquifer upon which **ALL** of Wareham's residents rely for drinking water and to protect the many small streams of the watersheds and estuaries leading to Buzzards Bay.

Revisions to Section 590 encourages the use of solar energy systems and protects solar access consistent with Massachusetts General Laws Chapter 40A Section 3 and Section 9B (Solar Access) and Green Communities Act M.G.L. Chapter 25A Section 10. This section of the Wareham Zoning By-Law is consistent with Wareham's 2020 Master Plan (page 76) and 2017-2024 Open Space and Recreation plan (pages 88-90) as they recognize the need to protect water and wildlife habitat resources while providing opportunities to increase resiliency from the effects of climate change with green infrastructure and conservation of forests and farmland.

Revisions to Section 590 incorporate the MA state model by-law and Department of Energy Resources SMART program guidance (225 CMR 20.00 September 22, 2021) that strongly discourages siting such projects in areas of important habitat such as our globally rare Pine Barrens. The revisions take into account that significant tree cutting is problematic because of the important water management, cooling, and climate benefits trees provide. According to Tufts.edu, forests pull about one-third of all human-caused carbon dioxide emissions from the atmosphere each year. Researchers have calculated that ending deforestation and allowing mature forests to keep growing could enable forests to take up twice as much carbon.

Revisions to Section 590 discourage developing Large-Scale Ground-Mounted Solar Photovoltaic Installations that result in significant loss of natural resources and encourages rooftop and canopy siting, as well as locating projects in industrial and commercial districts, on farms where appropriate and on vacant, previously disturbed land such as gravel pits and old industrial sites.

**Article S15 is Supported by the Wareham Town Board of Selectmen,
the Finance Committee, and the Planning Board.**

Exhibit 9
October 2021, *Solar Siting Joint Statement*, prepared by Mass
Audubon et al.



BE OUTDOORS
APPALACHIAN MTN CLUB



MASSACHUSETTS
Rivers Alliance



NEW ENGLAND
FORESTRY
FOUNDATION



Solar Siting Joint Statement

October 1, 2021

Rapid, Responsible Deployment:

Integrating and Aligning Climate Mitigation, Resiliency, Biodiversity, and Equity

Goals:

The undersigned organizations call on the Commonwealth of Massachusetts to plan and implement policies and programs for the rapid, responsible siting of solar power systems with the following overarching goals:

1. Maximize deployment of solar power within the more than 1 million acres of land that are already developed or degraded, including rooftops, parking lots, and other low-impact areas with minimal ecosystem service values;
2. If further analysis shows that additional capacity is needed outside those areas, determine which natural or working lands and waters are most and least appropriate for solar energy using spatial analysis and stakeholder input; and
3. Avoid, minimize and mitigate impacts to natural and working lands¹ and waters and the valuable benefits they provide including biodiversity and climate resilience.

¹ "Natural and working lands"- lands within the commonwealth that: (i) are actively used by an agricultural owner or operator for an agricultural operation that includes, but is not limited to, active engagement in farming or ranching; (ii) produce forest products; (iii) consist of forests, grasslands, freshwater and riparian systems, wetlands, coastal and estuarine areas, watersheds, wildlands or wildlife habitats; or (iv) are used for recreational purposes, including parks, urban and community forests, trails or other similar open space land.

<https://malegislature.gov/Laws/SessionLaws/Acts/2021/Chapter8>