Chesapeake Bay Land Change Model (CBLCM v7)
Frequently Asked Questions

1. What is CBLCM?

The CBLCM is a U.S. Geological Survey computer model that spatially simulates the amount, in acres, and pattern, as patches, of future residential and commercial development within a county based on external population and employment projections. The simulation process is iterative, repeating 101 times with the results aggregated and averaged within user-specified overlay units (e.g., watersheds, catchments, Census Tracts). For each iteration, the CBLCM estimates future impervious and pervious development; conversion of natural and agricultural lands; population served by sewer and septic systems; and the number of individual septic systems.

2. What are the CBLCM base assumptions?

a. Residential and commercial development are driven by increases in housing and employment respectively.
b. Base year (2020) vacancy rate, average household size, and population in group housing at the county-level remain constant in the future. This assumption is required to prevent counter-intuitive changes in housing demand, e.g., housing increases coupled with population declines due to ever decreasing average household sizes.
c. The relationship between housing, employment, and development is governed by infill/redevelopment, recent development patterns, and probable development densities.
d. Infill/redevelopment percentages remain constant in the future.
e. Future development will be as dense or denser than current development.
f. Future patterns of growth will generally resemble current patterns.
g. Lands within one kilometer of current sewer service areas are likely to be served by sewer in the future.
h. Only residential development beyond 1km from sewer service areas contributes to new septic systems. Commercial development is not considered in estimating populations served by sewer or septic systems.
i. Only small secondary roads associated with residential housing development are estimated as a component of future growth. Widening of existing roads and new major roads are not considered.
j. Residential and commercial lands are allowed to overlap to form mixed-use development. This occurs rarely (<1% of all simulated growth cells) and only in highly developed jurisdictions with limited land available for development.
k. Decision rules used to translate CBLCM outputs to Phase 7 land uses are discussed in Question #8.

3. How can jurisdictions review and critique CBLCM results?

CBP's Geospatial Science and Applications Team has developed a [data viewer] for CBLCM results. Results of the CBLCM Run #2 for the year 2040 are currently posted and the viewer will be updated when results are revised. The viewer includes 1-km^2 hexagon representations of future development patterns, a land suitability layer, county summary data with attributes enabling the comparison of observed and simulated changes in residential and commercial development. Some questions one might ask when looking at the data are:

Why is there no growth projected in a county?

- View the “County Results” layer (aka make it visible) and hit the home icon (upper left) and view the “Increase in Development based on Historic Trends” layer. Left click on any county.
- Note the difference between observed and simulated housing and residential area change and jobs and commercial area change. If simulated residential and/or commercial area change is zero, then population and employment in the county are projected to remain stable or decline resulting in no simulated growth.
- Changing this base assumption in the model would require revisiting how we estimate demand for growth.

Why is there so little growth projected in a county?

- View the “County Results” layer (aka make it visible) and hit the home icon (upper left) and view the “Increase in Development based on Historic Trends” layer. Left click on any county.
- Note the difference between observed and simulated housing and residential area change and jobs and commercial area change. Lower than expected growth is evident if observed and simulated rates of housing and/or jobs are similar but observed residential and/or commercial area change is significantly greater than simulated residential and/or commercial area change.
- Lower than expected amounts of simulated growth are caused by high rates of infill/redevelopment, high development densities, or in rare cases- limited land suitable for growth.
- Growth is less apparent at the 1-km^2 hexagon scale within counties with very dispersed growth patterns such as Lancaster County, Pennsylvania. At the hexagon scale, reported data represents the average amount of growth over 101 model iterations and the data are thresholded (e.g., developed area >= 5 acres) in the viewer to focus attention on high growth areas. Averaging at least 5 acres of growth over 101 iterations within a particular hexagon can be achieved if at least 5 acres of development are simulated in each iteration or if 505 acres of development are simulated in a single iteration with no growth simulated in others.

Why is there so much growth projected in a county?

- View the “County Results” layer (aka make it visible) and hit the home icon (upper left) and view the “Increase in Development based on Historic Trends” layer. Left click on any county.
- Note the difference between observed and simulated housing and residential area change and jobs and commercial area change. Higher than expected growth is evident if observed and simulated rates of housing and/or jobs are similar but observed residential and/or commercial area change is significantly lower than simulated residential and/or commercial area change.

- Higher than expected amounts of simulated growth are caused by low rates of infill/redevelopment, low development densities, and abundant suitable land for development.

Why is growth projected to occur in places where it should not occur?

- Overlay the "Simulated 2040 Growth" layer over the "Suitability for Development" layer. Make the Suitability 50% transparent (double box icon) and show the aerial imagery (lower left).
- Note how the yellow areas (projected growth) are located within the suitable areas (red).
- Corrections to the suitability layer require updated or additional data on public and protected lands, current land use, new data or new decision rules relevant to land suitability for development.

Why are the patterns of projected growth so dispersed?

- View the "Simulated 2040 Growth" layer and/or the "Increase in Development based on Historic Trends" layer.
- Dispersion is caused by large amounts of land available for development with minimal differentiation (low gradients) of residential and/or commercial probabilities.
- Adjusting dispersion requires the addition of new significant explanatory variables in the logistic regression equations used to estimate development probabilities, mathematical transformations of the probability layer, new statistical and/or machine learning approaches for estimating development probabilities, and/or the exclusion of additional land from the suitability layer.

4. What changed from Run #1 (June 2026) to Run #2 (August 2026)

- Refined lands suitable for development
  - Small gaps created by rasterizing vector parcels and resampling high-resolution land use/land cover from 1m to 30m cells were filled through filtering.
  - Excluded "no growth" areas identified by Metropolitan Planning Organizations.
  - Traffic Analysis Zones with independent forecasts of no growth were excluded.
- Aligned urban vs rural growth patterns to observed changes in impervious cover
  - Proportions of residential and commercial growth in urban areas were recalculated based on observed proportions of residential and commercial impervious change rather than observed proportions of housing and employment change.
- Refined infill/redevelopment rates to better match observed development
  - Increased the number of Census Blocks eligible for infill/redevelopment by eliminating a % impervious criteria, decreased the rates of infill by increasing the expected densities from the 75th to 90th percentile, and considered total change in impervious cover in Census Blocks with increases in housing and/or jobs and no corresponding increases in residential and commercial impervious surfaces.
- Expanded sewer service areas by 1-km to account for future sewer connections near existing service areas.

5. What changed from Run #2 (August 2026) to Run #3 (September 2026)

- Developed separate residential and commercial suitability layers to accommodate unique housing and employment "no growth areas" identified at the Traffic Analysis Zone level by Metropolitan Planning Organizations.
- Updated housing and employment demand with new forecasts from the Baltimore Metropolitan Council and kept population in group housing constant at 2020 levels (rather than extrapolate based on trends)
- Recalculated population in group housing, average household size, and vacancy rates using data from the 2020 Decennial Census in place of data from the American Community Survey.
- Updated the solar probability layer with data from 2023-2026 and simulated utility-scale solar field growth for all states
- Updated existing, planned, and proposed solar field data within information from the Energy Information Agency and Maryland Department of Agriculture.
- Updated average solar acreage/megawatt empirically using data from the National Photovoltaic Database
- Explored the incorporation of planned/proposed data centers
- Reduced job density estimates to align with observed high-resolution commercial development trends and Phase 6 model runs (decreased densities by 63%)
- Included additional variables in the logistic regression generating unique residential and commercial probability surfaces:
    - Travel time to impervious surfaces within sewer service areas;
    - Travel time to large regional employment centers (e.g., Pittsburgh, New York City);
    - Travel time to water amenities > 1000 acres (e.g., large reservoirs, lakes, rivers, estuaries, and the Atlantic Ocean).

6. Why was the CBLCM developed?

Development of the CBLCM began in the late 2000's, motivated by the need to inform land conservation decisions with information on the vulnerability of lands to future development and recognition of the limitations of existing regional-scale land change models. The CBLCM was designed to produce plausible future growth projections driven by population and employment and to be customizable, allowing alteration of infill/redevelopment rates, residential and commercial densities, and land suitability to create alternative future scenarios to inform local land-use plans.

The CBLCM was repurposed in preparation for the Phase 6 Mid-point Assessment of the Chesapeake Bay Total Maximum Daily Load (TMDL). In 2017, the Chesapeake Bay Program (CBP) partnership's Principals' Staff Committee (PSC) approved the jurisdictions' use of the 2025 projected "Current Zoning" baseline scenario to account for growth (e.g., future change in land uses and animal and human populations) in the development and implementation of the jurisdictions' Phase III Watershed Implementation Plans (WIPs) and two-year milestones. The "Current Zoning" scenario represented a historic trend scenario with the addition of Maryland's statewide generalized zoning data, adjusted infill/redevelopment rates, and additional zoning data for several non-Maryland counties. The PSC further decided that jurisdictions may establish alternative future scenarios based on existing and planned programs, policies, and land conservation activities which may alter the magnitude and/or patterns of future growth and thereby impact nutrient and sediment loads to the Bay. Five states developed these scenarios known as "land policy BMPs" in the Chesapeake Assessment Scenario Tool (CAST).

7. How does the CBLCM simulation work?

a. County-level population projections are converted to housing units[1].
b. County-level percentages of observed housing and employment accommodated within existing built-up areas are estimated as residential and commercial infill/redevelopment and deducted from projected increases in housing and employment. Remaining housing and jobs require the construction of new homes and office space in the form of future residential and commercial growth.
c. Future residential and commercial growth is simulated as patches of development (clusters of 30-meter cells) in urban and rural areas informed by the historic distribution of development patch sizes, suitability of land for development, and residential or commercial growth probabilities.
d. For each simulated cell within each patch, the following information is assessed:
    i. Number of iterations of 101 that cell was developed
    ii. Overlay between commercial and residential (yes/no)
    iii. Residential or commercial probability value
    iv. Residential or commercial density
    v. Pre-development land use: (barren, farmland, forest/shrub/wetland)
    vi. Sewer[2] (yes/no)
    vii. Summary units (e.g., Phase 7 units, 1 km2 hexagons, Census Tracts), Average lot size
e. County-level simulation for a single iteration stops when the county demand for housing and jobs equals the total housing and jobs within simulated patches of growth. Simulation for an individual timestep, e.g., 2030, 2035, stops following the completion of 101 iterations and then aggregated by county completing the stochastic simulation process.

[1] housing units in year X = ((total population in year X – 2020 population in group housing) / 2020 average household size) / (1- 2020 vacancy rate)

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[2] New development cells falling within 1-kilometer of mapped sewer service areas are counted as sewered. If not sewered, cells are served by septic systems. Septic system counts are calculated as one system per occupied housing unit, aka "households". Vacancy rates in 2020 are applied to simulated housing units to estimate future households: ((1-vacancy rate in 2020) * simulated housing units). Population on septic is determined by multiplying the septic counts by the 2021 county-specific average household size from the Census Bureau's American Community Survey. Remaining population is assumed to be served by sewer.

8. How are CBLCM simulated results translated into Phase 7 model inputs

Impervious surface equations developed uniquely for each jurisdiction combined with decision rules developed by the Land Use Workgroup in 2016 and 2017 are used to translate residential and commercial growth into the Phase 7 classes. The impervious surface equations were developed by USGS using the 2021/22 high-resolution impervious surface data aggregated to all residential and commercial parcels in each jurisdiction. A curve was fit to these data to enable prediction of impervious surface percentages from parcel sizes (acres). Average parcel size can be estimated for every simulated patch of residential and commercial development from the housing and job density rasters informing the simulation. The spreadsheet "CBLCM-Phase7-xWalk.xlsx provides details on exactly how simulated residential and commercial development and solar fields are translated into the seventeen mapped Phase 7 land uses.

9. Do recent trends reliably predict future growth?

The next 5-10 years are mostly planned, permitted, and informed by the recent conditions. The year 2040 is only 14.5 years away and barring any enduring shocks to economy should be predictable based on trends over the past 10-20 years. Looking out further than 20 years is less predictable but necessary for large-scale, long-term ecosystem restoration plans and projects. Since 1950, the population of the Chesapeake Bay watershed has increased by ~ 1 million persons per decade with urban growth emanating outward from city centers and spilling over from county to county. However, it's unlikely that those living in the 1930's could have accurately predicted conditions in the 1950's and 60's based on trends in the 1910's and 20's. Events and enduring policies and programs established in the 1930's and 40's created a set of conditions influencing development patterns for 70+ years. Because long-term forecasts are inherently uncertain, it is important to try and quantify uncertainty. To represent uncertainty, agent-based and some cellular automata change models simulate emergent properties such as new interstates, new towns, etc. Doing so increases the variability of future conditions which helps characterize uncertainty but at the expense of plausibility. A more common and practical approach to bracket uncertainty when forecasting 30+ years in the future is to generate multiple "what if" scenarios. Alternative future scenarios help bound uncertainty and more importantly, enable the evaluation of specific policies, programs, and assumptions. For example, how might affordable housing policies and programs, coupled with remote work allowances, impact development patterns?

10. What are the sources of population and employment projections?

County-level population and employment projections are developed by state agencies or by universities on behalf of state agencies (Table 1). While all jurisdictions produce population projections, only three project employment. For jurisdictions where employment projections are lacking, future employment is scaled to future housing by the ratio of 2020 Total Employment (Bureau of Economic Analysis) to 2020 Total Housing Units (U.S. Census Bureau).

Table 1. County-level population and employment projection data sources.

Jurisdiction	Source	Dataset	Vintage	Years
	Metropolitan Washington Council of Governments	Round 10.1 Cooperative Forecasts (population and employment)	11/2025	2025-2050 (5-yr intervals)
Delaware	Delaware Population Consortium	Population and Employment Projections	10/2024	2025-2050 (5-yr intervals)
Maryland	Maryland Department of Planning	Population and Employment Projections	11/2025 (pop); 10/2022 (emp)	2030-2055 (pop); 2030-2050 (emp) (5-yr intervals)
	Baltimore Metropolitan Council	Round 10.1 (population and employment)	07/2026	2030-2055 (5-yr intervals)
New York	Cornell Program on Applied Demographics	Population Projections	2025	2025-2050 (1-yr intervals)
Pennsylvania	Center for Rural Pennsylvania	Population Projections	09/2023	2025-2050 (5-yr intervals)
Virginia	Weldon Cooper Center for Public Service (UVA)	Population Projections	07/2025	2030-2055 (5-yr intervals)
West Virginia	Bureau of Business and Economic Research (WVU)	Population Projections	10/2022	2025-2040 (5-yr intervals)

11. How are urban and rural areas defined for allocating growth within a County.

Before simulating future residential and commercial growth, demand for growth in the form of future housing units and jobs is partitioned into “urban” and “rural” zones within each county based on relative proportions of recent growth (Figure 1). This was implemented to more closely replicate historic spatial patterns of growth. A significant portion of forest and farmland conversion, however, occurs outside urban areas along their fringes and shares many characteristics growth inside urban areas even though fringe areas are classed by the Census Bureau as “rural”. To ensure that future fringe growth is adequately simulated, Census Urban Areas were expanded into neighboring blocks using the National Center for Education Statistics (NCES) Locale Classifications and Criteria framework[3]. These criteria rely on definitions and data produced by US Census Bureau and have been adapted by USGS to capture fringe areas within an urban footprint defined by a collection of qualifying Census Blocks and Places.

[3] Geverdt, D. and Maselli, A. (2024). Education Demographic and Geographic Estimates Program (EDGE): Locale Boundaries Technical Documentation. U.S. Department of Education, National Center for Education Statistics. Washington, DC. Retrieved June 2026 from https://nces.ed.gov/programs/edge/Geographic/LocaleBoundaries.

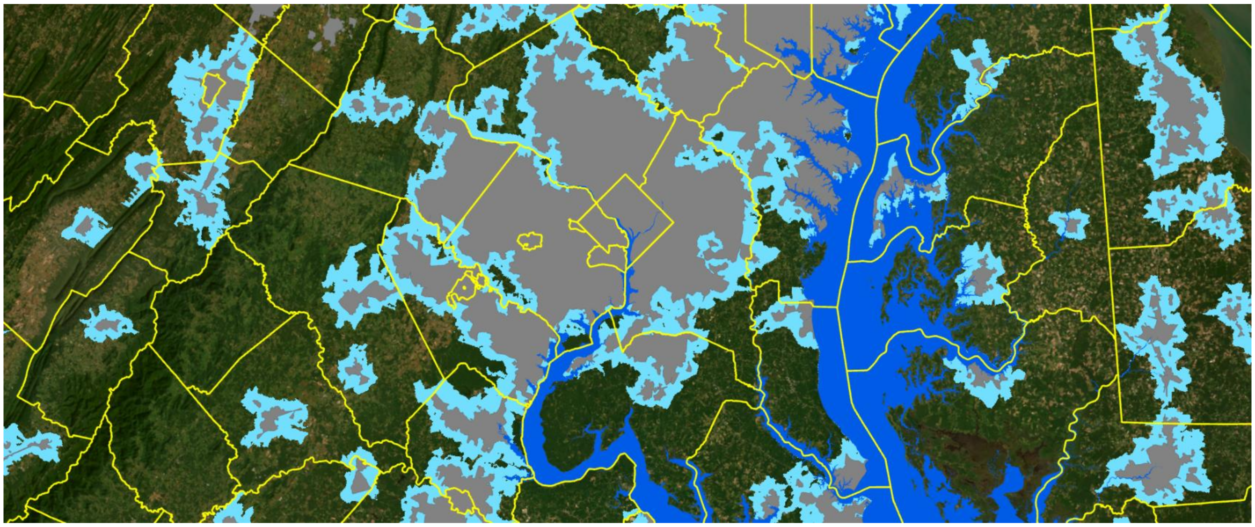

Figure 1. Census Urban Areas (grey) overlaid on the CBLCM "urban" zone (light blue).

12. How are county-level infill/redevelopment rates estimated?

The term "infill" commonly refers to new construction on vacant lots within built-up areas and "redevelopment" commonly refers to new construction on already developed lands, e.g., converting a parking lot into a multi-story office building. Using residential infill as an example, the CBLCM estimates the rate of infill/redevelopment as the percentage of reported housing unit change (2010-2020) within urban and adjacent Census Blocks that does not manifest as observed change in residential impervious surfaces from 2013/14 to 2021/22 in CBP's high-resolution land use/land cover data. For example, if the Census Bureau reports a 50-unit housing increase from 2010-2020 within a block and we observe no corresponding increase in residential impervious area in the block, then we presume that all 50 units must have been present in 2013/14 and these units are credited towards infill/redevelopment. If we observed an increase in impervious surfaces but not enough to accommodate 50 units at the maximum expected density for that block, then only a portion of the 50 units would be credited as infill/redevelopment. To estimate this portion, a curve equation was developed for each state relating the observed residential density in 2013/14 to the 90th percentile residential density for blocks with similar proportions of housing to impervious surfaces. This equation enables the estimation of the minimum expected amount of impervious associated with a change in housing. If we observe less than the minimum, the difference in acres is converted to its housing unit equivalent and credited as infill/redevelopment. For example, suppose a Census Block adds 16 new housing units over the 2010's and has a housing density of 2 units/acre and maximum expected density of 4 units/acre. We expect to observe 4 acres of impervious change (16 units / 4 units per acre) to accommodate the 16 units. If only 3 acres of impervious change were observed, then the area of new development is underestimated by 1 acre corresponding to 4 housing units of infill/redevelopment. The infill/redevelopment housing and job values were aggregated across all Census Blocks within each county and divided by the total increase in housing and jobs to generate county-level residential and commercial infill/redevelopment rates.

13. How are residential and commercial densities estimated?

Residential and commercial densities were estimated by Census block. Housing unit counts by block were provided by the 2010 and 2020 Decennial Population and Housing Census. Total job counts at place of work were provided by the Census Bureau's Longitudinal Employer-Household Dynamics Program. Residential and commercial areas within each Block were mapped using 2023 REGRID parcel data attributed with USPS Residential Delivery Indicator, impervious area, and impervious area in structures in addition to overlays of institutional properties, protected lands, and other developed lands (e.g., cemeteries, landfills, golf courses, solar fields, etc.). Compared to Maryland's Statewide Land Use Data (2018) in Montgomery County, the CBLCM commercial area captured 87% of what Maryland Department of Planning (MDP) classed as "Commercial", "Industrial", or "Institutional" and 92% of what MDP classed as "Low Density Residential", "Medium Density Residential", or "High Density Residential". Within CBLCM commercial areas, 58% was classed by MDP as "Commercial", "Industrial", or "Institutional" with an additional 34% classed as "Open Urban Land" or "Other Land". Within CBLCM residential areas, 86% was classed as "Low Density Residential", "Medium Density Residential", or "High Density Residential" by MDP with an additional 8% classed as "Open Urban Land" or "Other Land".

Residential density = total housing units / residential area (acres).
Commercial density = total jobs / commercial area (acres).

14. What proportion of observed changes in impervious cover are associated with residential and commercial development?

From 2013/14 to 2021/22 (high-resolution land use mapping period), impervious surfaces in the 205 counties intersecting and adjacent to the Bay watershed increased by 136,150 acres. Most of this increase falls within areas mapped as residential and/or commercial. Local exceptions exist, however, and are associated with road construction and expansion, natural gas extraction in northern Pennsylvania, new poultry houses in Delaware and on Maryland's eastern shore, and utility-scale solar fields in Virginia. In local areas where such activities could be extensive, they may represent most of the impervious surface change over the mapping period.

15. How is land suitability determined?

Lands suitable for future development are undeveloped, unprotected, and on gentle to moderate slopes[4]. Floodplains (100-year), floodways, open water, emergent wetlands (mostly tidal), surface mines, federal lands, and areas forecast for no future growth by Metropolitan Planning Organizations or transportation agencies (e.g., Baltimore Metropolitan Council, Metropolitan Washington Council of Governments, Virginia Department of Transportation, and nine MPO's associated with Planning District Commissions in Virginia) are excluded and not suitable for future development.

[4] The highest 1% of the non-road impervious slope range within each county are excluded.

16. How are residential and commercial growth probabilities estimated?

Residential and commercial probabilities are estimated uniquely for each state using logistic regression models that relate observed changes in residential and commercial impervious surfaces with eight potential explanatory variables:

I. Travel time (over the current road network) to impervious surfaces within 2020 Census Urban Areas and Clusters;
II. Travel time to residential impervious surfaces within Census Blocks with large increases (95th percentile) of housing over the previous decade;
III. Travel time to commercial impervious surfaces within Census Blocks with large increases (95th percentile) of jobs over the previous decade;
IV. Travel time to impervious surfaces within sewer service areas;
V. Current land use (natural or farmland);
VI. Slope;
VII. Travel time to large regional employment centers (e.g., Pittsburgh, New York City);
VIII. Travel time to water amenities > 1000 acres (e.g., large reservoirs, lakes, rivers, estuaries, and the Atlantic Ocean).

Given the patterns of observed development in the Chesapeake Bay watershed, this approach essentially produces a gravity surface where probabilities are highest near the convergence of significant variables and decrease gradually moving further away from those areas.

17. How accurate is the CBLCM?

The original CBLCM run to support development of Phase III Watershed Implementation Plans forecast growth from 2013 to 2025 produced plausible relative results by county (R^2 = 0.86) relating modeled acres of development with high-resolution land use change from 2013/14 to 2021/22. However, it also systematically overestimated observed growth by ~50%. Overestimated growth in the model can be caused by too high population projections, too low infill/redevelopment rates, and too low residential and commercial densities - all of which are being addressed with more accurate data in this latest version of the CBLCM (v7).

The initial draft run of CBLCM v7 produced similar annual growth rates out through 2050 compared to the observed data from 2013/14 to 2021/22 in the three highest growth jurisdictions: Delaware, Maryland, Virginia. Growth rates through 2050 in New York, Pennsylvania, and West Virginia are lower than recently observed growth rates and are being further investigated.

Run #2 indicated that the annualized simulated rates of residential growth aligned well with annualized observed increases in impervious surfaces within residential areas, but simulated rates of commercial growth were still low compared to the range of values observed. Commercial development densities were universally lowered in Run #3 to better align simulated commercial growth with observed development (Table 2).

Table 2. Annualized observed and simulated growth (acres) and surveyed and projected housing units and jobs by jurisdiction through 2040 for Run #3

Jurisdiction	Residential		Commercial		Housing Units		Jobs	
	2010-2020	2020-2040	2010-2020	2020-2040	2010-2020	2020-2040	2010-2020	2020-2040
Delaware	1,067	1,185	257	314	4,285	3,882	6,977	2,275
District of Columbia	11	3	9	2	5,365	2,635	5,696	9,284
Maryland	2,236	2,017	848	693	15,707	15,857	28,322	29,807
New York	769	277	291	75	2,252	1,058	174	1,183
Pennsylvania	3,347	821	1,371	337	7,567	4,419	11,294	6,512
Virginia	4,483	3,905	1,563	1,397	26,936	22,993	55,481	41,982
West Virginia	345	350	84	111	796	1,159	1,142	1,123
Region	12,257	8,558	4,422	2,929	62,907	52,003	109,084	92,165

Comparing observed and simulated annualized rates of forest vs farmland conversion reveals that for all jurisdictions, natural lands were converted more often in the observed high-resolution land use change data from 2013/14 to 2021/22 compared to simulated growth. When simulating growth, the CBLCM is essentially performing a probability-weighted stochastic allocation and while the pre-development land use (natural vs farmland) is a significant variable in the statewide regressions used to produce the probability surfaces, it may not exert sufficient weight to strongly impact the results. In addition, relatively little solar development occurred over the observation period while a lot is being simulated through 2040 and therefore the county-level allocation of solar demand to some heavily agricultural counties combined with the solar probability distribution favoring gentle slopes are likely influencing the ratios for the simulated period.

Table 3. Annualized observed and simulated conversion (acres) of natural lands and farmland by jurisdiction through 2040 for Run #3.

Jurisdiction	Natural Land Conversion		Farmland Conversion		Observed	Simulated
	2010-2020	2020-2040	2010-2020	2020-2040	Ratio (FOR:AG)	Ratio (FOR:AG)
Delaware	323	593	301	823	1.07	0.72
District of Columbia	10	5	-	-	0.00	0.00
Maryland	1,303	1,614	455	1,371	2.87	1.18
New York	486	267	328	538	1.48	0.50
Pennsylvania	2,357	576	1,292	1,127	1.82	0.51
Virginia	3,592	4,580	828	2,059	4.34	2.22
West Virginia	182	215	79	354	2.29	0.61
Region	8,253	7,851	3,283	6,273	2.51	1.25

Claggett et al., 2023 demonstrated that a “Historic Trend” scenario for Maryland was more accurate than the “Current Zoning” scenario and therefore the CBP Land Data Team recommends that an unadjusted historic trend scenario serve as the baseline for the Phase 7 model.

Regarding the patterns of simulated growth, the accuracy of those patterns can be partly evaluated by the R-squared values produced by the logistic regressions for residential and commercial growth (Table 4).

Table 4. Logistic regression results from Run #3 of the CBLCM (September 2026)

Jurisdiction	Residential Probability	Commercial Probability
District of Columbia	n/a	n/a
Delaware	0.58	0.55
Maryland	0.68	0.82
New York	0.70	0.83
Pennsylvania	0.58	0.77
Virginia	0.72	0.80
West Virginia	0.69	0.90

Additional planned validation analyses include comparing infill/redevelopment estimates derived from MD and DE parcel data with CBLCM estimates, comparing observed and simulated growth relative to distance to roads and urban areas, and comparing observed and simulated patterns of growth at different spatial scales: 0.1 km2, 1 km2, 10 km2.

18. How does the CBLCM simulate growth on sewer?

Future development occurring within 1 km of existing sewer service areas is assumed to be served by sewer. To accomplish this, the 2020 sewer service area layer, approved by the Wastewater Treatment Workgroup, was expanded by 1 km (Euclidean distance). Growth simulated outside this buffered layer is assumed to be on septic. To calculate septic counts, developed housing units on septic ("ghu_sep") for each forecasted year is adjusted to account for vacancies using the 2020 Census Bureau vacancy rate. This figure is then added to the existing 2020 septic counts, which results in the total septic count for each year that is simulated.

Note: In alignment with the CBP partnership-approved methods, the 2020 sewer service area assumes all parcels within the sewer service area footprint are hooked up to sewer and, therefore, no septic systems exist within the sewer footprint. As such, these methods do not account for “legacy” systems – i.e., households that never hooked up to sewer when the service area initially expanded and remain served by septic systems. This is noted in the official Phase 7 documentation, which will be published as part of the 2027 year of review for the Chesapeake Bay Watershed Model.

19. How does the CBLCM forecast population on sewer and septic?

Populations on sewer and septic are calculated using county-specific average household size values from the 2020 Census and the population projections submitted by states and localities (see Table 1 in the FAQ). Forecasted housing units on septic ("ghu_sep") for each year are adjusted to account for vacancies using the 2020 Census Bureau vacancy rate. This figure is then multiplied by the average household size to estimate how many people will be living in those new housing units and added to the existing population on septic to determine the future population on septic. The methods for sewer are similar. All future populations in group housing (prisons, universities, etc.) are assumed to be served by sewer. Future group housing is determined by county-specific group housing values from the 2020 Census, held constant into the future.

20. Can the CBLCM simulate other activities in addition to residential and commercial development?

Yes. Data required to simulate a new type of activity, e.g., land conservation, include:

- land demand by county for each modeled outyear
    - 2030, 2040, and 2050 land conservation acres in Anne Arundel County, Maryland.
    - If land demand is expressed in a unit other than area, such as AC megawatt, generation for solar fields, translation to area is required, e.g., 1 MW of utility-scale solar requires 7 acres of land;
- probability surface (30-m raster) representing the relative likelihood an activity will occur on any suitable location;
- suitability surface (30-m raster) representing where the activity is allowed to occur (e.g., undeveloped and unprotected lands);
- frequency distribution of observed activity patches (e.g., residential subdivisions, solar fields, conserved parcels).

21. Why and how are solar fields being simulated as part of the "Business-As-Usual" scenario?

Over the next 15 years, the construction of utility-scale solar (USS) fields may result in as much conversion of forests and farm fields as residential development. They are also decoupled from long-term job growth because they employ few people following construction. USS fields Utility-scale solar fields produce at least one megawatt of AC electricity and utilize about 7 acres of land per megawatt. It is not uncommon for USS fields to cover hundreds of acres, and some cover several thousand acres. While the largest USS fields in the Chesapeake Bay watershed are in Virginia, USS fields are being developed in all states in the Bay watershed. Industry associations and energy providers anticipate significant expansion of solar energy production in the mid-Atlantic states over the next decade. Part of what is fueling this expansion is the rapid construction of data centers and associated corporate sustainability goals. USGS does not have the information needed to simulate data centers using the CBLCM, however, we do have data on approved and proposed data centers and plan to incorporate them into the 2030, 2035, and 2040 forecasts.

To simulate USS in the Bay watershed, data are needed to estimate the land area necessary to accommodate future solar fields (demand), suitable locations for future solar (suitability), the relative spatial probability of solar development, and the size distribution of USS fields. The following data were used, and studies referenced, to produce the necessary CBLCM inputs:

a. National Photovoltaic Database of large-scale solar facilities developed by USGS and Lawrence Berkeley National Laboratory (DOE): https://eerscmap.usgs.gov/uspvdb/
b. Renewable Energy Permits Database, Virginia DEQ, https://www.deq.virginia.gov/news-info/shortcuts/permits/renewable-energy
c. UVA Weldon Cooper Center, data through March 2026, https://solardatabase.coopercenter.org/solar/
d. Maryland Department of Agriculture Solar Fields, obtained directly from MDA, August 2026.

e. Preliminary Monthly Electric Generator Inventory (based on Form EIA-860M as a supplement to Form EIA-860), June 2026 download: https://www.eia.gov/electricity/data/eia860m/
f. State Solar Fact Sheets, Solar Energy Industries Association, seia.org/states
g. Cleanview Data Center Tracker: https://cleanview.co/data-centers
h. PJM Long-Term Load Forecast Report, January 24, 2025, Prepared by PJM Resource Adequacy Planning Department, PJM Long-Term Load Forecast Report
i. Pitt, D., J. Ciminelli, and J. LaPrad (2025). Utility-Scale Solar in Virginia – Current Trends and Future Impacts
j. Stewart, R., et al., 2025. Preliminary Report on Runoff Characteristics from Utility-Scale Solar Sites, College of Agriculture and Life Sciences, Virginia Tech
k. STAC, 2023. Best Management Practices to Minimize Impacts of Solar Farms on Landscape Hydrology and Water Quality, STAC Workshop Report, Publication 24-001.

To simulate future solar within the Chesapeake Bay region, the amount of land (acres) needed to accommodate future utility scale solar was estimated based on the forecasted future amount of energy generated from USS (Table 4). Data sources and calculations are noted along the bottom row. USS solar fields built between 2021/22 and 2025 (SOL_25) are mapped as polygons in the National Photovoltaic Database and will be incorporated explicitly in all forecasts. New USS solar fields needed to meet future solar energy demands (SOL_30, SOL_35, and SOL_40) will be stochastically simulated by county in areas suitable for development and informed by spatially explicit solar probabilities. The proportions of existing and/or planned and permitted megawatts of USS within each county are used to allocate jurisdictional land demands in Table 4 to individual counties. While these estimates may appear high to some, for context UVA's Weldon Cooper Center has reported a total of 408 USS projects in Virginia that have been either constructed or received local permit approvals through March 2026 accounting for 17,264 MW of generation and 147,378 project acres with an additional 18 projects pending accounting for 1,077 MW and 9,785 project acres. Note that all project acres may not be disturbed/converted. The acreage estimates in Table 5 represent converted acres-from either farmland or forest to solar panel arrays and pervious surfaces between and surrounding the arrays.

Table 5. Estimation of future land demand for USS by major jurisdiction for Run #3.

	A	B	C	D	E	F	G	K	L	M	N	O	P
Jurisdiction	USS_21	USS_25	MW(USS)_2025	MW(TOT)_2025	% USS_MW	% ChesBay	Acres/MW	SOL_25	RSOL30	RSOL35	RSOL40	Total	% Total Acres
DE	142	437	95	352	27%	100%	6.14	295	1,078	747	1,082	3,203	1.9%
DC	0	31	15	350	4%	100%	2.75	31	36	35	50	152	0.1%
MD	1,557	4,759	871	3,200	27%	100%	5.47	3,202	3,867	3,874	5,613	16,556	9.9%
NY	1,307	12,705	2,702	8,200	33%	36%	6.30	11,398	9,180	6,848	9,923	37,350	22.3%
PA	619	3,827	999	3,200	31%	84%	5.14	3,208	6,888	5,034	7,294	22,425	13.4%
VA	4,993	21,868	4,699	7,800	60%	64%	6.24	16,875	21,839	18,212	26,389	83,314	49.6%
WV	-	423	140	383	37%	83%	4.03	423	1,853	1,042	1,510	4,829	2.9%
Source:	2021/22 High-res LULC	USGS-LBL & MDA database	USGS-LBL & MDA database	SEIA	C/D		B/C	B-A	(G*E*(F*)*J)	(H*E*(F*)*J)	(I*E*(F*)*J)	K+L+M+N	O / ∑(O)

Explanation of columns and calculations:

A. Mapped acres USS in the 2021/22 high-resolution LULC data for all counties in the Chesapeake Bay region.

B. Mapped acres of ground-based USS through 2025 for all counties in the Chesapeake Bay region from the National photovoltaic database. This area represents the acres of panel arrays including land between panels and tends to underestimate the disturbed area associated with very large USS fields.
C. Megawatts produced from ground-based USS through 2025 for all counties in the Chesapeake Bay region from the National photovoltaic database and Maryland Department of Agriculture's data.
D. Megawatts produced from all solar sources (i.e., ground, roof-top, canopy) in 2025 for each state from the Solar Energy Industry Association state fact sheets
E. Percentage of megawatts produced from all solar sources that are from ground-based USS.
F. Percentage of megawatts produced by each jurisdiction in 2025 from ground-based USS within counties in the Chesapeake Bay region.
G. Average area of land required to produce 1 MW of from ground-based USS multiplied by 1.34 (representing the ratio of total solar area to solar impervious area in the 2021/22 high-res land use data). Note that this replaces the 7-acre/MW average used for the initial estimates of solar demand.
H. (hidden- for brevity) Five-year industry outlook for additional megawatts produced from all solar sources by 2030 from the Solar Energy Industry Association state fact sheets.
I. (hidden- for brevity) Five-year extrapolation of additional megawatts produced from all solar sources.
J. (hidden- for brevity) Ten-year extrapolation of additional megawatts produced from all solar sources.
K. Estimate of existing solar acres in 2025 not yet mapped in the high-resolution LULC
L. Estimate of additional acres of land required to meet USS energy requirements from 2025-2030
M. Estimate of additional acres of land required to meet USS energy requirements from 2030-2035
N. Estimate of additional acres of land required to meet USS energy requirements from 2035-2040
O. Total additional acres of land required to accommodate USS solar from 2021/22 to 2040.
P. Percent of total acres of new USS in the region within each jurisdiction.

To produce the solar probability surface, the Chesapeake Conservancy's Conservation Innovation Center (CIC) first mapped ground-mounted solar arrays within the six states overlapping the Chesapeake Bay watershed (DE, ME, NY, PA, VA, WV) and the District of Columbia constructed through August 1, 2026. The CIC used a custom-trained U-Net image segmentation model to ingest Sentinel-2 multispectral satellite images and generate polygons capturing the spatial footprint of ground-mounted arrays. Each polygon was visually compared to recent aerial imagery and the most recent cloud-free Sentinel-2 imagery to confirm the presence of a solar array and eliminate instances of commission error. These data were merged with polygons in the National Photovoltaic Database (NPVD) for the same geographic extent. A construction year was assigned to each polygon using attributes from the NPVD, when available, and by iteratively applying the U-Net model to the previous year's Sentinel-2 imagery for polygons not in the database.

The CIC estimated the relationship between geospatial landscape and socioeconomic characteristics and the occurrence of solar arrays via logistic regression using a generalized additive model. The logistic regression was formulated as a GAM to capture potentially varying relationships between covariates and land use over time using flexible polynomial terms. Only arrays constructed since 2016 were used in this analysis, with 2016 being the first year that Sentinel-2 imagery was consistently available globally and therefore the first year in which complete information regarding construction dates were available.

The following covariates at each solar array were assessed: mean percent impervious cover from the National Land Cover Database (NLCD); mean percent tree cover (NLCD); mean percent open space (NLCD); mean cultivated status (NASS Cropland Data Layer); max protection status (GAP status); mean agricultural soil quality (gSSURGO); log mean slope; log distance from roads; log distance from transmission lines; census tract population density; census tract median household income; and census tract housing density. For census variables, the CIC extracted the value from the most recent American Community Survey data one year prior to the date of solar array construction. Likewise, landcover variables were extracted from annual NLCD and CDL products from the year prior to array construction. Distance from transmission lines, roads, and slope were extracted from current data from EIA, TIGER, and 3DEP, respectively. The same set of covariates from a set of 10,000 rectangles randomly located throughout the Bay States were also extracted and randomly assigned to a construction year between 2016 and 2026. Multiple combinations of covariates were evaluated with the most supported model including an intercept per state, and temporally varying coefficients for tree cover and cultivated status. Values of the estimated coefficients at year = 2026 were used to calculate development probability at 30m resolution across the Bay jurisdictions.

22. Are data centers considered in the CBLCM?

Modern-day data centers emerged in the 2000's with the development of cloud storage and architecture. The current boom in data center development is spurred by the maturation of cloud computing, widespread adoption of artificial intelligence, and emergence of crypto-currency mining. Unfortunately, there does not exist a single authoritative source of information on data centers (Table 6). According to the FracTracker Alliance, as of 2026 there are about 501data centers in the Chesapeake Bay Region (205 counties intersecting and adjacent to the Bay watershed) of which 225 are currently operating or expanding, 16 are permitted and/or under construction, and 260 are planned and/or proposed. Examining data from multiple sources (e.g., FracTracker, IM3, and S&P Global) and attempting to remove duplicates and extracting 2021/22 high-resolution land use information to these data points, reveals 361 data centers that have been either constructed since the summer of 2021/22 or are under construction, permitted, proposed, or planned. Eighty-five percent of these data centers are in Virginia which has the highest concentration of data centers in the world. The Chesapeake Research Consortium conducted a land use assessment of 127 data center land parcels and estimated the average amount of impervious surfaces per parcel at 11.7 acres including structures, roads, driveways, and parking lots. If all currently proposed data centers are constructed by 2040, their direct impact could be the conversion of ~ 4,224 acres (361 x 11.7) of undeveloped land to impervious, turf grass, and compacted pervious surfaces. From the perspective of land use change over a 15-year period, this is a modest impact, particularly because data centers tend to be clustered in areas already supporting dense commercial and industrial development. However, direct conversion is not their biggest impact on land use. Data centers require significant amounts of energy and water which, in some cases, must be conveyed to their locations via new transmission lines and pipelines. Moreover, Lawrence Berkeley National

Laboratory estimates a nationwide 21% compound annual growth rate in data center energy use[5]. Greater energy consumption will require more energy generation, more diesel backup generators and more water for cooling. Technology companies like Amazon, Google, and Meta have policies to partially power their data centers with renewable energy which has contributed, and will continue to contribute, to the rapid growth of utility-scale solar fields in the region.

Table 6. Operating and Planned/Proposed Data Centers (statewide counts through Aug/Sep 2026)

Jurisdiction	Cleanview			FracTracker				IM3	S&P Global
	Operating	Planned	Total (#)	Operating	Approved	Planned	Total (#)	Operating	Operating/Planned
Delaware	-	1	1						2
District of Columbia			-						10
Maryland	6	9	15	3	1	9	13	8	27
New York	12	25	37	17	2	11	30	16	82
Pennsylvania	15	93	108	45	6	47	98	8	77
Virginia	371	458	829	214	12	221	447	281	458
West Virginia	-	11	11		3	9	12	15	2
Total	404	597	1,001	279	24	297	600	328	658

Due to the potential impacts of data centers on energy and water resources, New York state and over half the counties in Maryland, and a few cities and one town in Virginia have issued temporary moratoriums on permitting them (Harford County, Maryland has banned them outright)[6]. In addition, some counties in northern Virginia are now considering moratoriums. The Chesapeake Bay Program's Land Use Workgroup will decide how best to consider proposed data centers in the Phase 7 "Business-As-Usual" 2040 land use forecast during their September 23rd joint meeting with the Urban Stormwater Workgroup.

The following data and information sources were consulted to identify permitted, under construction, and operational data centers in the Chesapeake Bay region:

- U.S. Data Centers Tracker: https://fractracker.org/data-centers/ FracTracker Alliance (operating, approved, and proposed), downloaded August 2026.
- IM3 Data Center Atlas derived from Open Street Map: https://data.msdlive.org/records/p147s-4h760, constructed data centers, downloaded August 2026
- 451 Research Platform, S&P Global, Datacenter KnowledgeBase, Proprietary and licensed. Operational & Under Construction, downloaded September 2026
- Cleanview: https://cleanview.co/data-centers/us, operational and constructed, downloaded September 2026
- United States Data Center Energy Usage Report: 2025 Update. Lawrence Berkeley National Laboratory https://escholarship.org/uc/item/33m6w3x0

[5] Smith, S.J., Hubbard, A., Newkirk, A., Ganeshalingam, M., Holecek, B., Sartor, D., Mills, M., Shehabi, A. 2026. United States Data Center Energy Usage Report: 2025 Update. Lawrence Berkeley National Laboratory, Berkeley, California. LBNL-2001758. https://doi.org/10.71468/P1RP4F

[6] https://www.bayjournal.com/news/local_government/data-centers-face-bans-moratoriums-across-bay-region/article_9dd9ac7d-68a9-483a-9363-368f7766fcf5.html