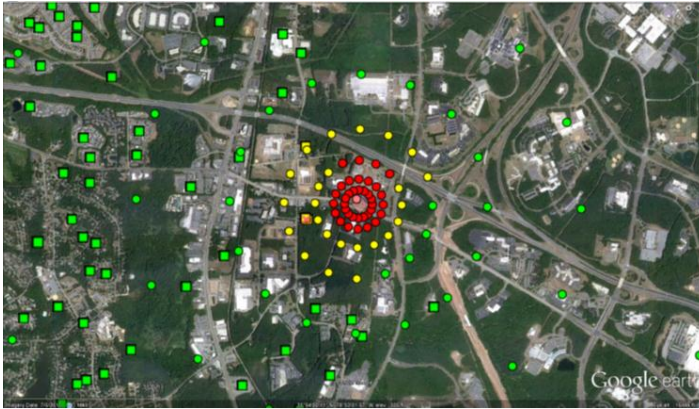


# Human Exposure Model, Version 4 (HEM4)



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Mark Morris, Ted Palma, and Matthew Woody  
U.S. EPA Office Of Air Quality Planning And Standards

Steve Fudge, Chris Stolte, David Lindsey, Jill Mozier  
SC&A Incorporated



# Overview

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What is the Human Exposure Model (HEM)?

Why do we need HEM?

How does HEM work?

What's new in the most recent HEM version (HEM4)?





# What is HEM?



## Inhalation Exposure Modeling System

- Used to assess risks from multiple air toxic emissions
  - Regulatory uses – Risk and Technology Review analyses
  - Non-regulatory uses – Past NATA analyses, special projects

Uses the AERMOD dispersion model to estimate pollutant concentrations

Uses health reference values and Census data to estimate individual risks and population risks





# Why do we need HEM?

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## **We need to model:**

- Many facilities (for example, for EPA's RTR program)
  - Some source categories can have >1000 facilities
- Many pollutants (HAPs)\*
  - Some source categories emit > 100 HAPs
- Specific receptors
  - Census block locations (for chronic exposures) are included in HEM

## **We need to estimate:**

- Maximum individual cancer risk (MIR)
- Maximum chronic non-cancer hazard indices (HI)
- Cancer incidence
- Population risks (numbers of people in certain risk ranges)
- Maximum acute non-cancer hazard quotients (HQ)
- Each metric for baseline and control scenarios

\* AERMOD is run for a single-pollutant



# How does HEM work?

HEM creates an AERMOD-ready input file using spreadsheet input files

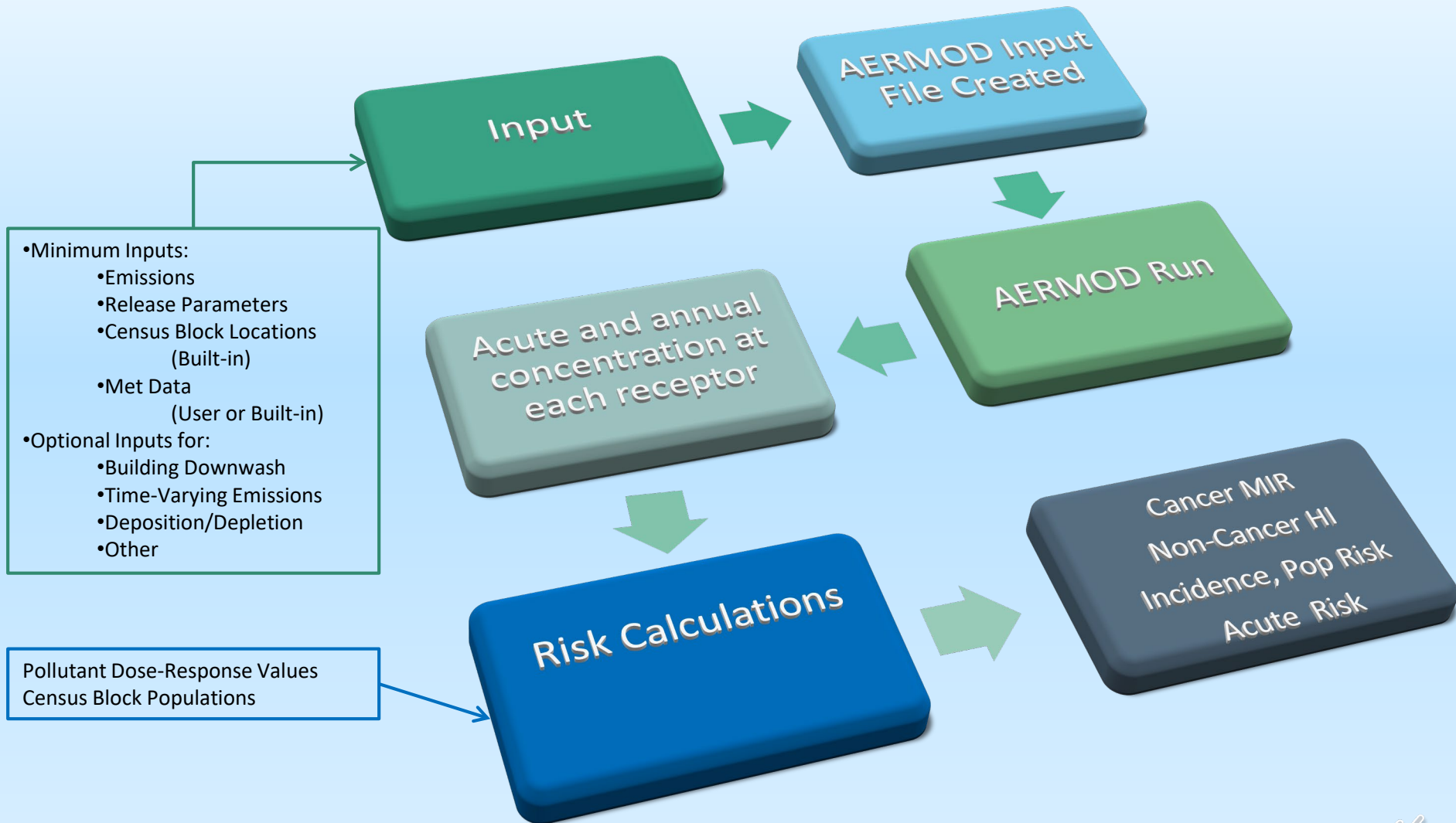
- Emissions from multiple source types including: point (vertical, horizontal, and capped), volume, area, polygon, line, and buoyant line
- Receptors:
  - Census block centroids - for chronic exposure and risk - assumes 24/7 and 70 years exposure
    - Block information (location, population, elevation) included in HEM
  - Polar receptors - for acute exposure where people may be for short periods and to interpolate concentrations/risks for distant Census blocks
  - User-defined receptors – nearby residents, schools, monitor sites...

HEM runs AERMOD - EPA's preferred dispersion model (40 CFR Part 51 Appendix W) - as a compiled executable program

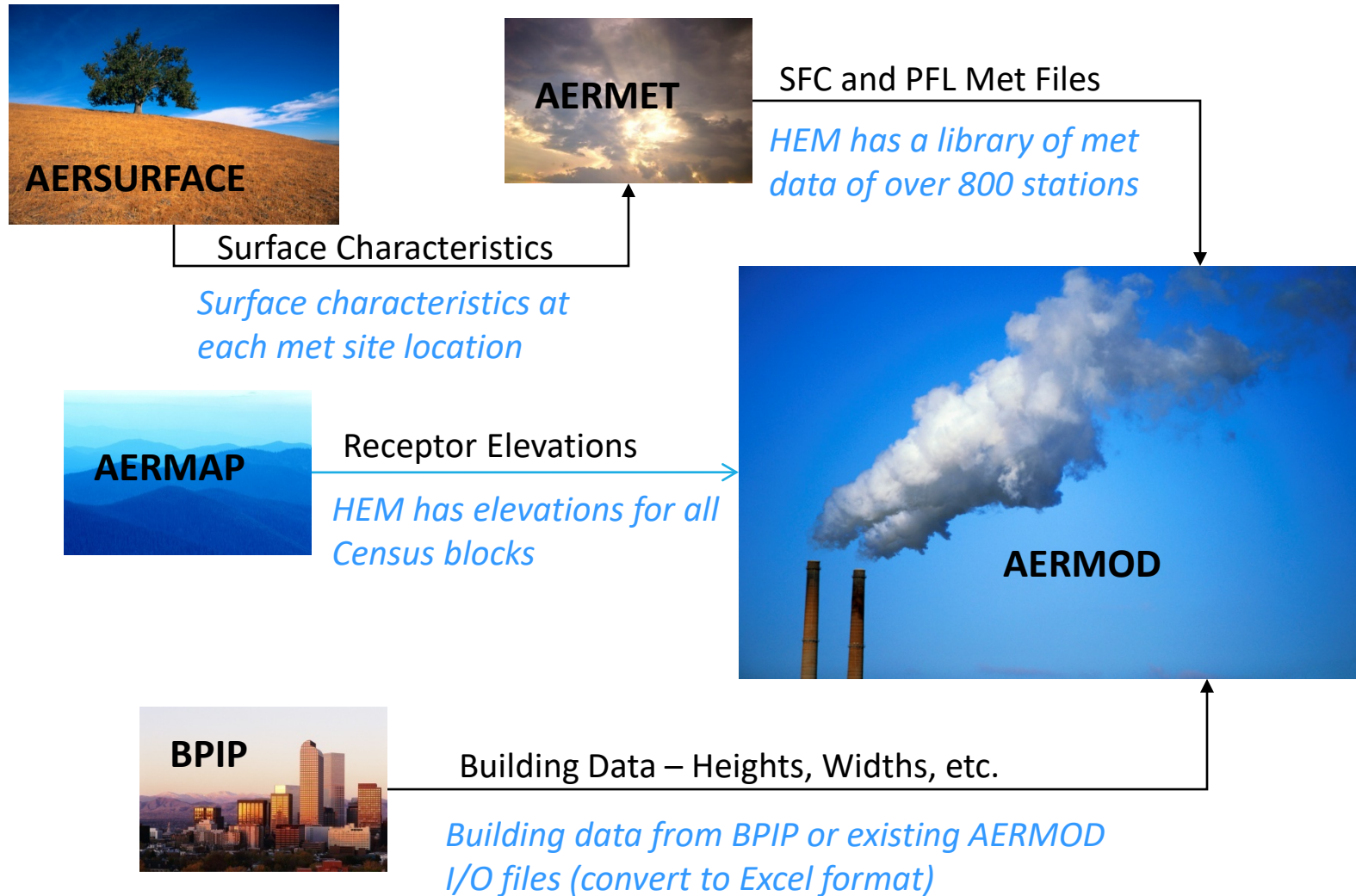
HEM post-processes AERMOD-created output files to predict exposure and risk metrics for multiple pollutants and facilities at numerous census block, polar and user-defined receptors.



# HEM Schematic



# AERMOD Components



# AERMOD Options in HEM

AERMOD	HEM	Comment
User-supplied met data	YES	If not user-supplied, met library used
Time-varying emissions	YES	Allowed AERMOD variation factors: SEASON, MONTH, HROFDY, SEASHR, SHRDOW, SHRDOW7, MHRDOW, and WSPEED
Building downwash	YES	
Deposition/depletion	YES	
Urban or rural	YES	Option to let HEM determine
Multiple urban areas or rural and urban areas in a single run	NO	These are not typical scenarios
Terrain	YES	Database built into HEM
Capped/horizontal, open-pit sources	YES, NO	Yes to Capped/horizontal; No to open pit, which rarely appear in our modeling.
Pollutant decay	NO	App W: "Chemical transformations are generally not treated by AERMOD...this option is typically not used in regulatory applications."





# What's new in HEM4?

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## **All functionality in one tool**

- Previously, there were two HEM models and multiple post-processing tools

## **Open source – Python**

## **Can be used anywhere in the world**

- Previous versions could only be used for US modeling (outside the US requires met data and receptor data be provided by the user)

## **Graphical Outputs**

## **Additional options**

- User can revise census block dataset to move/remove blocks as needed
- Allows period averages for partial year or multiple years
- Allows both Method 1 and Method 2 particle deposition
- Allows facility-specific acute “hivalu” other than the max hour (e.g., 99<sup>th</sup> percentile)



# What can HEM be used for?

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## **Model an individual facility**

- Concentration and risk estimates at census blocks, monitors, schools, user-defined receptors, etc.
- Deposition outputs to use in multipathway assessment

## **Model a facility cluster**

- Concentration and risk estimates for each facility
- Cancer incidence, population risks, and overall max risk location based on contributions from all facilities

## **Model a community**

- Consider multiple source types, including stationary, mobile, etc.

## **Model a source category across the US**

- EPA does this for the Risk and Technology Review program

## **Model facilities outside the US**

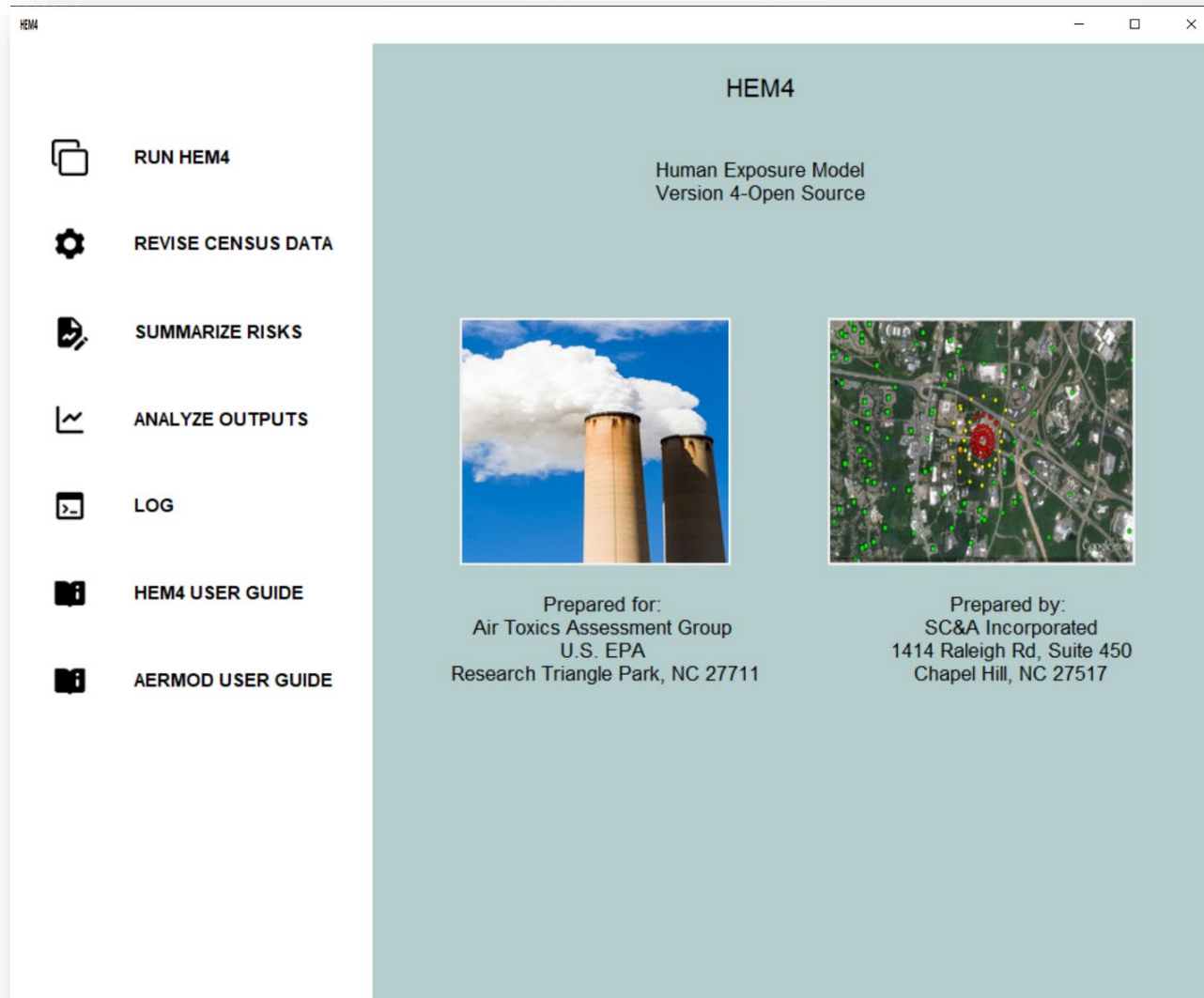
- User would need to supply receptor and meteorology data

## **HEM4 can be found on the EPA's FERA website:**

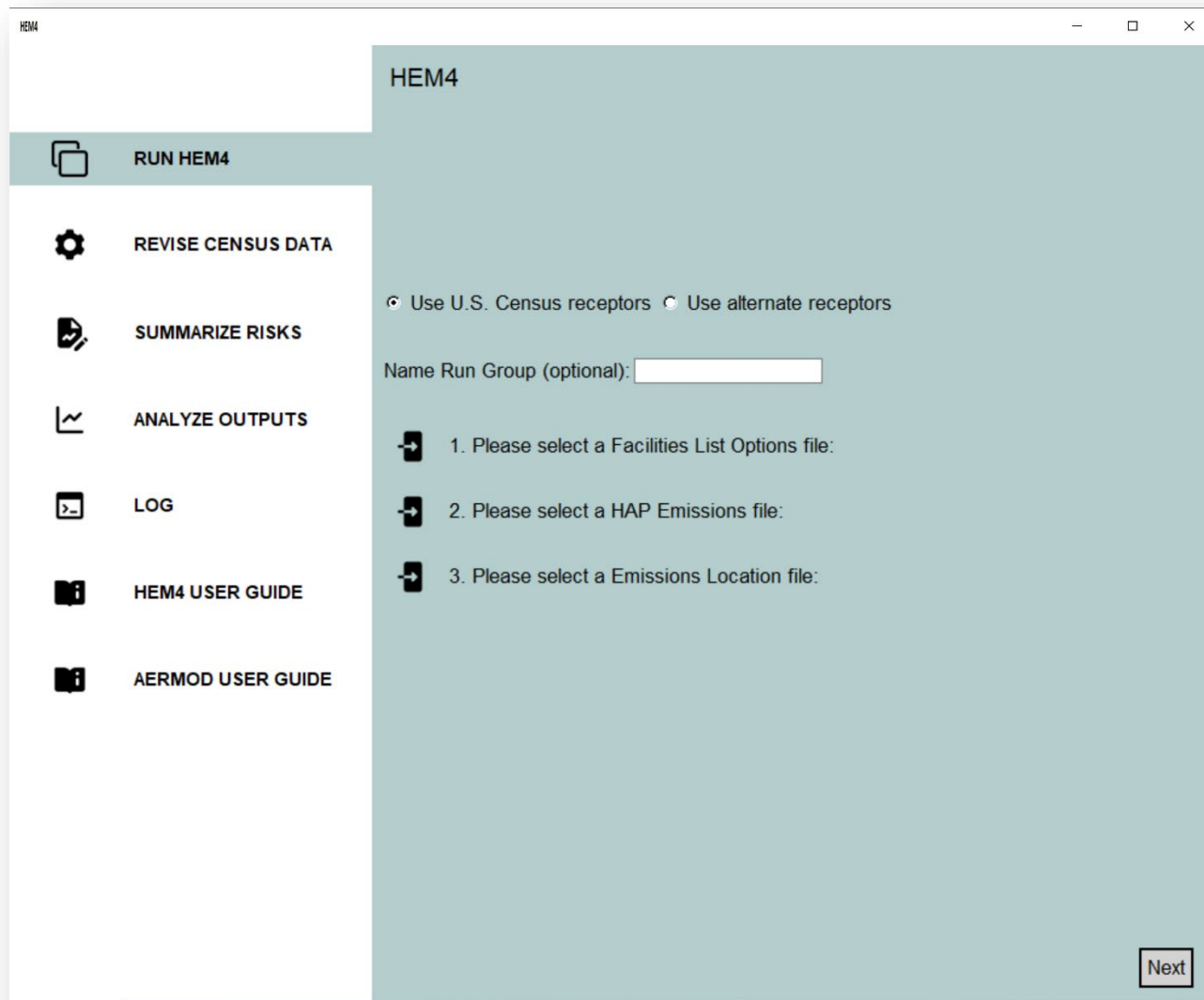
- <https://www.epa.gov/fera/download-human-exposure-model-hem>



# HEM4 System



# HEM4's Required Input Screen



HEM4

**RUN HEM4**

**REVISIONS**

**REVISE CENSUS DATA**

**SUMMARIZE RISKS**

**ANALYZE OUTPUTS**

**LOG**

**HEM4 USER GUIDE**

**AERMOD USER GUIDE**

**HEM4**

☒ Use U.S. Census receptors ☐ Use alternate receptors

Name Run Group (optional):

1. Please select a Facilities List Options file:

2. Please select a HAP Emissions file:

3. Please select a Emissions Location file:

**Next**



# HEM4's Required Input Screen

The screenshot displays the HEM4 software interface. At the top, there is a 'RUN HEM4' button. Below it, a table lists input parameters for two facilities: Fac1-NC and Fac2-IL. The table is organized into four main sections: List of Facilities, Modeling Domain Defined, Acute Options, and Deposition and Depletion Parameters.

FacilityID	fac_center	ring_dists	acute	hours	multiplier	high_value	dep	depl	pdep	pdepl	vdep	vdepl
Fac1-NC	L, 35.91, -78.89	100,500,1000,5000,10000,25000	Y		50	87						
Fac2-IL	L, 41.49, -88.27	100,500,1000,5000,10000,25000					Y	Y	WD	WD	WD	WD

Below the table, there are four menu items: ANALYZE OUTPUTS, LOG, HEM4 USER GUIDE, and AERMOD USER GUIDE. On the right side, there are three instructions for file selection, each preceded by a folder icon:

1. Please select a Facilities List Options file:
2. Please select a HAP Emissions file:
3. Please select a Emissions Location file:

A 'Next' button is located at the bottom right of the interface.



# HEM4's Required Input Screen

HEM4

RUN HEM4

REVISE CENSUS DATA

SUMMARIZE RISKS

ANALYZE OUTPUTS

LOG

HEM4

☒ Use U.S. Census receptors
 ☐ Use alternate receptors

Name Run Group (optional):

1. Please select a Facilities List Options file:

2. Please select a HAP Emissions file:

3. Please select a Emissions Location file:

	A	B	C	D	E
	Facility ID	Source ID	Pollutant	Emissions (tons/year)	Fraction emitted as particulate matter (%)
2	Fac1-NC	CT000001	2,3,4,7,8-Pentachlorodibenzofuran	0.0000000370	73.7
3	Fac1-NC	CT000001	1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	0.0000000018	97.1
4	Fac1-NC	CT000001	1,2,3,7,8-Pentachlorodibenzo-p-dioxin	0.0000000024	78.1
5	Fac1-NC	CT000001	1,2,3,6,7,8-Hexachlorodibenzofuran	0.0000000179	94.8
6	Fac1-NC	CT000001	1,2,3,4,7,8-Hexachlorodibenzofuran	0.0000000199	95.1
7	Fac1-NC	CT000001	1,2,3,7,8,9-Hexachlorodibenzofuran	0.0000000032	94.2
8	Fac1-NC	CT000001	2,3,4,6,7,8-Hexachlorodibenzofuran	0.0000000131	94.5
9	Fac1-NC	CT000001	1,2,3,4,6,7,8-Heptachlorodibenzofuran	0.0000000083	96.5



# HEM4's Required Input Screen

HEM4

RUN HEM4

REVISE CENSUS DATA

SUMMARIZE RISKS

ANALYZE OUTPUTS

LOG

HEM4 USER GUIDE

HEM4

☒ Use U.S. Census receptors
 ☐ Use alternate receptors

Name Run Group (optional):

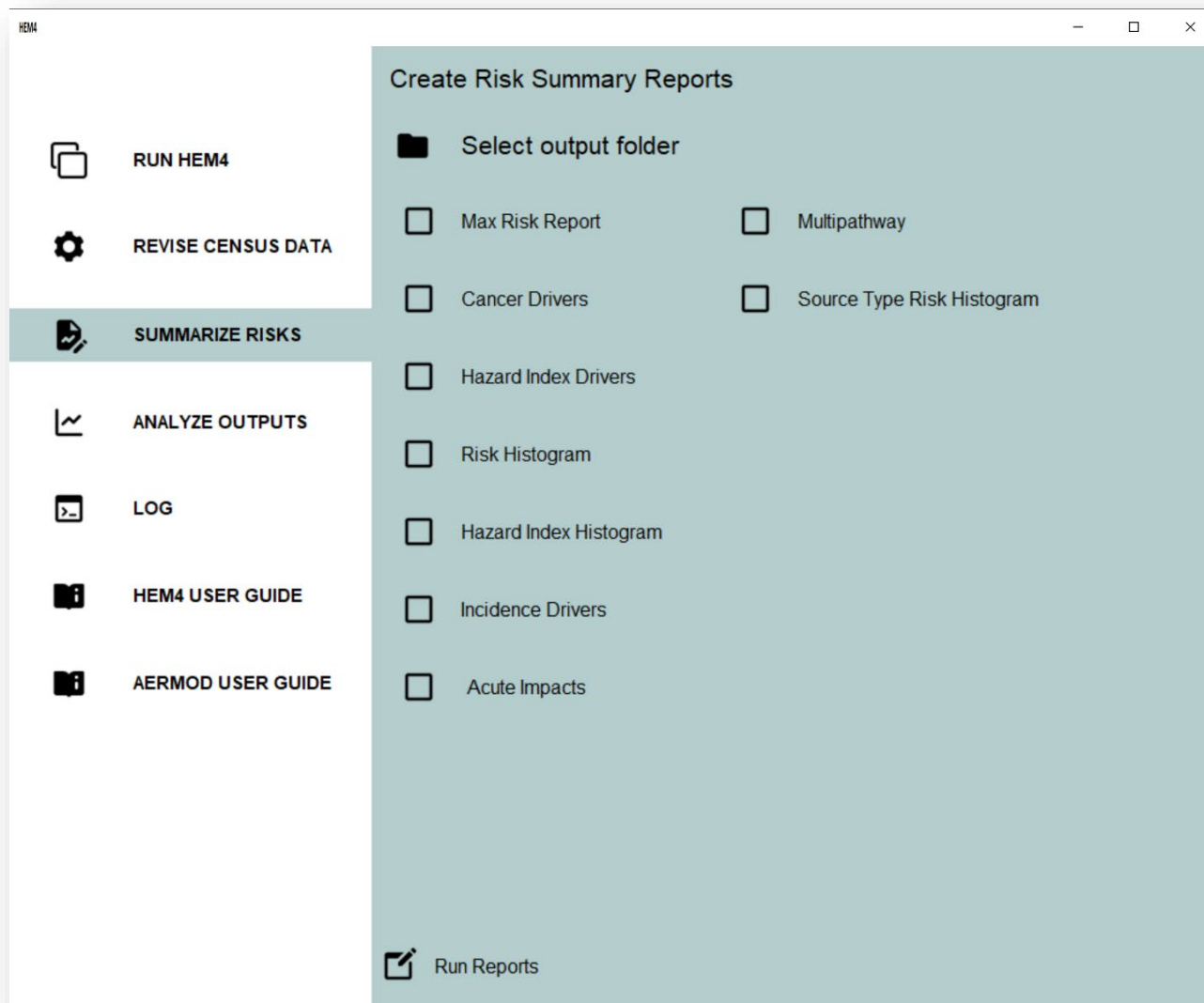
1. Please select a Facilities List Options file:

2. Please select a HAP Emissions file:

3. Please select a Emissions Location file:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1			Source Locations & Types					Dimensions & Release Height (non-point sources)						Point Source	
2	Facility ID	Source ID	Coordinate system	X coordinate Longitude (decimal) or	Y coordinate Latitude (decimal) or	UTM zone number with hemisphere	Source type	Length in x direction (m)	Length in y direction (m)	Angle (degrees)	Initial lateral dimension (m)	Initial vertical dimension (m)	Release height (m)	Stack height (m)	Stack diameter (m)
3	Fac1-NC	CT000001	L	-78.884072	35.900550		P							50.3	2.82
4	Fac1-NC	CV000001	L	-78.885586	35.901800		C							60.0	1.80
5	Fac1-NC	HV000001	L	-78.888396	35.902618		H							45.0	3.00
6	Fac1-NC	FU000001	L	-78.884072	35.900159		A	100	100	45			2		
7	Fac1-NC	SR000001	L	-78.883686	35.900628		V				10	10	10		
8	Fac1-NC	RW000001	L	-78.88843	35.90181		N	75				3	3		
9	Fac1-NC	RV000001	U	690891	3975044	17N	B						16.76		
10	Fac1-NC	RV000002	U	690891	3975124	17N	B						16.76		
11	Fac1-NC	RV000003	U	690891	3975204	17N	B						16.76		
12	Fac1-NC	RV000004	U	690891	3975284	17N	B						16.76		
13	Fac1-NC	MS000001	L	-78.888792	35.90592		I						1.3		
14	Fac2-IL	CT000001	L	-88.257293	41.480164		P							50.3	2.22
15	Fac2-IL	FU000001	L	-88.256715	41.481944		A	100	100	45			2		
16															

# HEM4's Risk Summary Report Screen



The screenshot shows the HEM4 Risk Summary Report Screen. The interface is divided into a left sidebar and a main content area. The sidebar contains a list of menu items: 'RUN HEM4' (document icon), 'REVISE CENSUS DATA' (gear icon), 'SUMMARIZE RISKS' (document with pencil icon, highlighted), 'ANALYZE OUTPUTS' (line graph icon), 'LOG' (terminal icon), 'HEM4 USER GUIDE' (book icon), and 'AERMOD USER GUIDE' (book icon). The main content area is titled 'Create Risk Summary Reports' and features a 'Select output folder' button. Below this, there are several checkboxes for report types: 'Max Risk Report', 'Cancer Drivers', 'Hazard Index Drivers', 'Risk Histogram', 'Hazard Index Histogram', 'Incidence Drivers', 'Acute Impacts', 'Multipathway', and 'Source Type Risk Histogram'. At the bottom of the main area is a 'Run Reports' button with a document and pencil icon.

HEM4

**Sidebar:**

- RUN HEM4
- REVISE CENSUS DATA
- SUMMARIZE RISKS**
- ANALYZE OUTPUTS
- LOG
- HEM4 USER GUIDE
- AERMOD USER GUIDE

**Create Risk Summary Reports**

Select output folder

☐ Max Risk Report

☐ Cancer Drivers

☐ Hazard Index Drivers

☐ Risk Histogram

☐ Hazard Index Histogram

☐ Incidence Drivers

☐ Acute Impacts

☐ Multipathway

☐ Source Type Risk Histogram

Run Reports





# HEM4's Tabular Output

C:/Git\_HEM4/HEM4/output/test4-20/test4-20\_hazard\_index\_drivers.xlsx

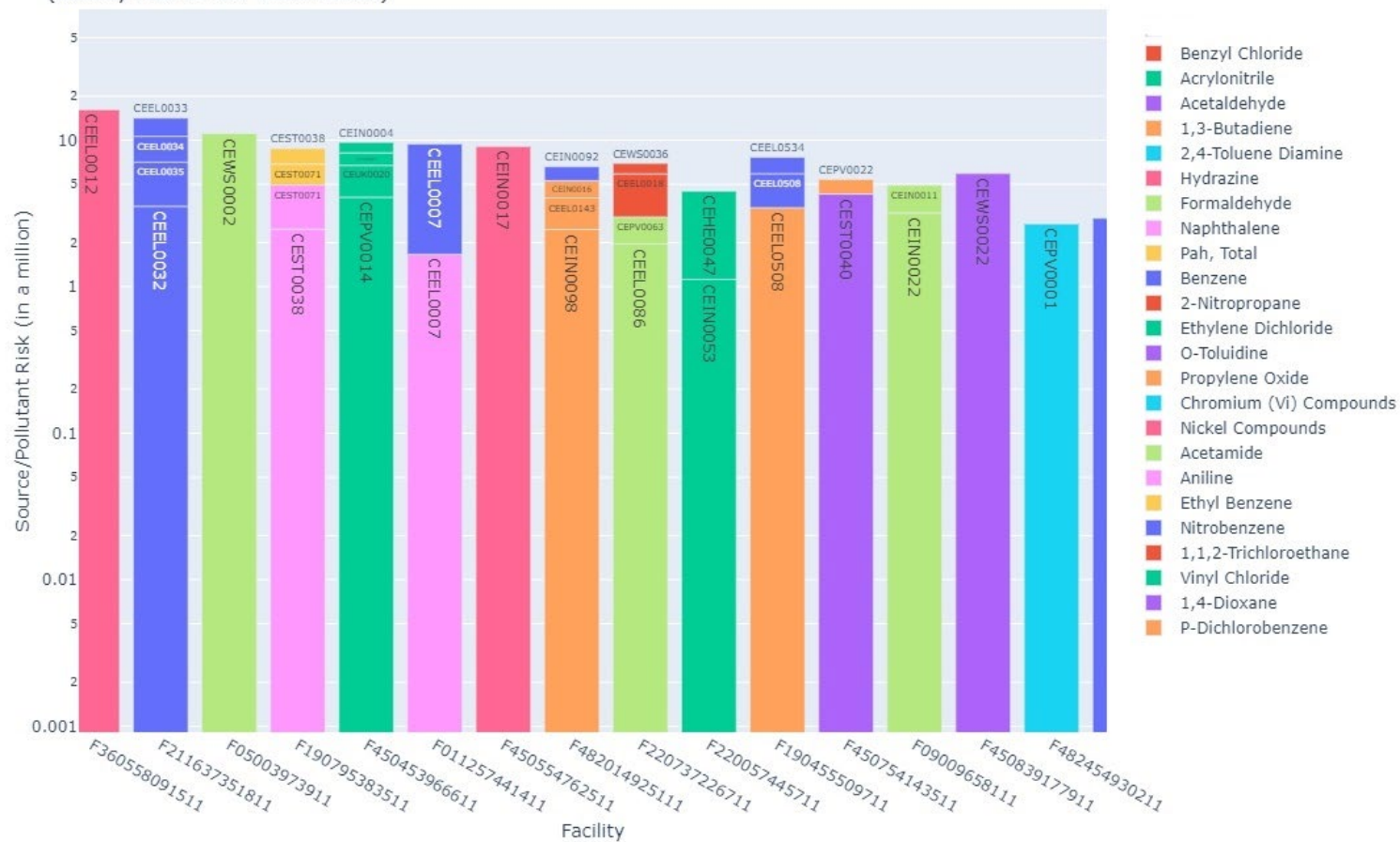
	Facility_ID	HI_Type	HI_Total	Source_ID	Pollutant	Hazard_Index	Percentage
1	Fac1-NC	Developmental HI	9.479141	SR000001	arsenic compounds	9.431920	99.500000
2	Fac1-NC	Kidney HI	1.570466	SR000001	cadmium compounds	1.506065	95.900000
3	Fac1-NC	Respiratory HI	0.47091	RW000001	acrolein	0.29061	61.710000
4	Fac1-NC	Respiratory HI	0.47091	FU000001	bis(2-ethylhexyl)phthalate	0.132177	28.070000
5	Fac1-NC	Respiratory HI	0.47091	RW000001	acrolein	0.0321697	6.830000
6	Fac1-NC	Liver HI	0.190013	FU000001	bis(2-ethylhexyl)phthalate	0.144408	76.000000
7	Fac1-NC	Liver HI	0.190013	RW000001	trichloroethylene	0.0312142	16.430000
8	Fac1-NC	Reproductive HI	0.090131	RV000001	1,3-butadiene	0.0887254	98.440000
9	Fac1-NC	Neurological HI	0.065151	RW000001	trichloroethylene	0.0348731	53.530000
10	Fac1-NC	Neurological HI	0.065151	FU000001	mercury (elemental)	0.0229932	35.290000
11	Fac1-NC	Neurological HI	0.065151	RW000001	trichloroethylene	0.00386036	5.930000
12	Fac1-NC	Immunological HI	0.039509	RW000001	trichloroethylene	0.0348731	88.260000
13	Fac1-NC	Immunological HI	0.039509	RW000001	trichloroethylene	0.00386036	9.770000
14	Fac2-IL	Liver HI	0.024612	FU000001	bis(2-ethylhexyl)phthalate	0.0225351	91.560000
15	Fac2-IL	Respiratory HI	0.024087	FU000001	bis(2-ethylhexyl)phthalate	0.0225351	93.550000
16	Fac2-IL	Neurological HI	0.016217	FU000001	mercury (elemental)	0.0141467	87.230000
17	Fac2-IL	Neurological HI	0.016217	FU000001	mercury (elemental)	0.00155341	9.580000
18	Fac1-NC	Hematological HI	0.000931	FU000001	selenium compounds	0.00090521	97.180000
19	Fac2-IL	Hematological HI	0.000522	FU000001	selenium compounds	0.000517802	99.180000
20	Fac1-NC	Skeletal HI	0.000461	RW000001	hydrofluoric acid	0.000415156	90.030000
21	Fac1-NC	Endocrine HI	7.09803e	RV000001	cumene	5.67842e-06	80.000000
22	Fac1-NC	Endocrine HI	7.09803e	RV000001	cumene	1.41961e-06	20.000000
23	Fac2-IL	Reproductive HI	1.28789e	FU000001	benzo[a]pyrene	9.69533e-07	75.280000
24	Fac2-IL	Developmental HI	1.28789e	FU000001	benzo[a]pyrene	9.69533e-07	75.280000
25	Fac2-IL	Reproductive HI	1.28789e	FU000001	benzo[a]pyrene	3.18352e-07	24.720000
26	Fac2-IL	Developmental HI	1.28789e	FU000001	benzo[a]pyrene	3.18352e-07	24.720000

26 rows x 7 columns



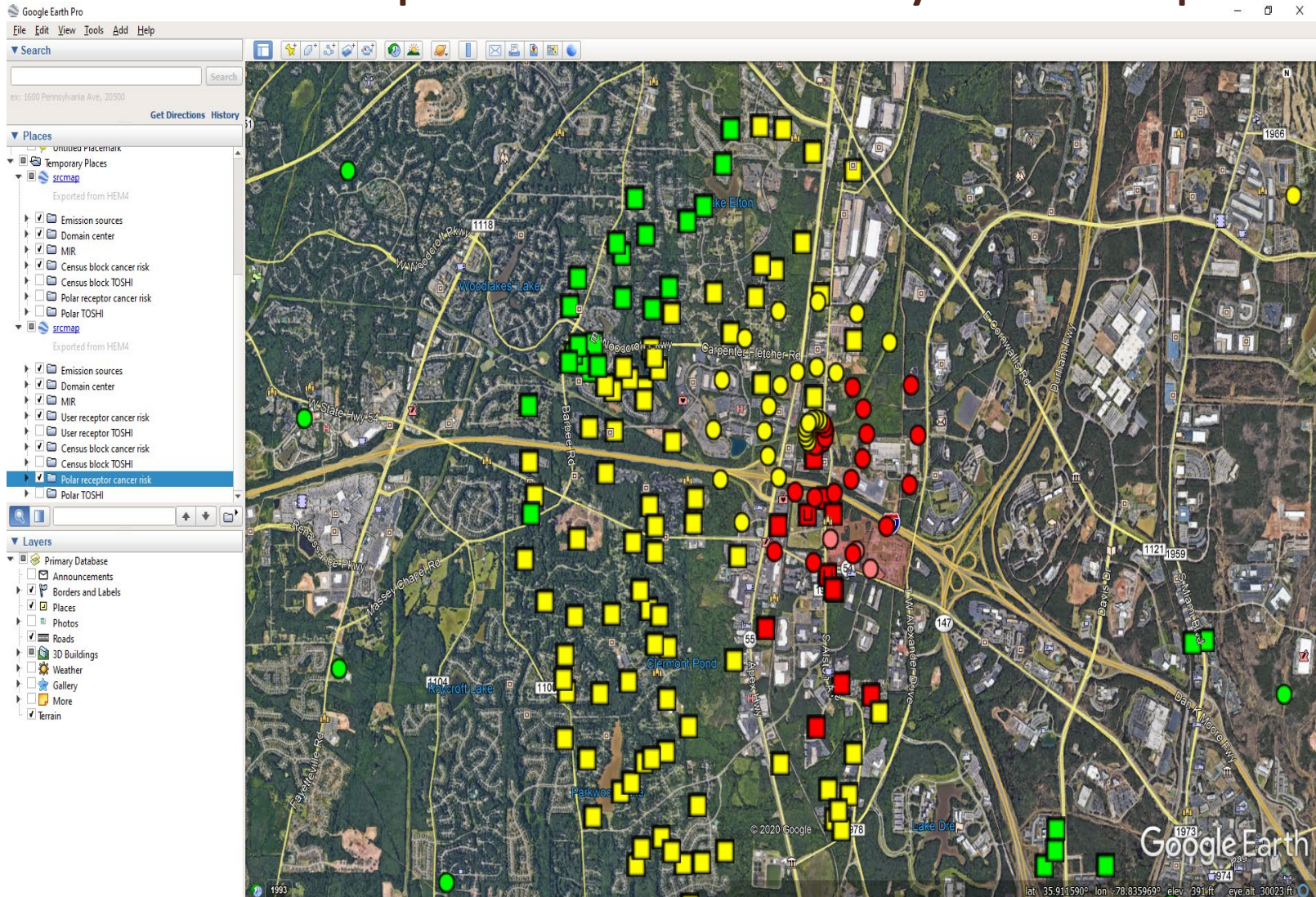
# HEM4's Graphical Summary Charts

Source and Pollutant Risk Drivers of Max Risk  
(facility risk  $\geq 0.5$  in a million)



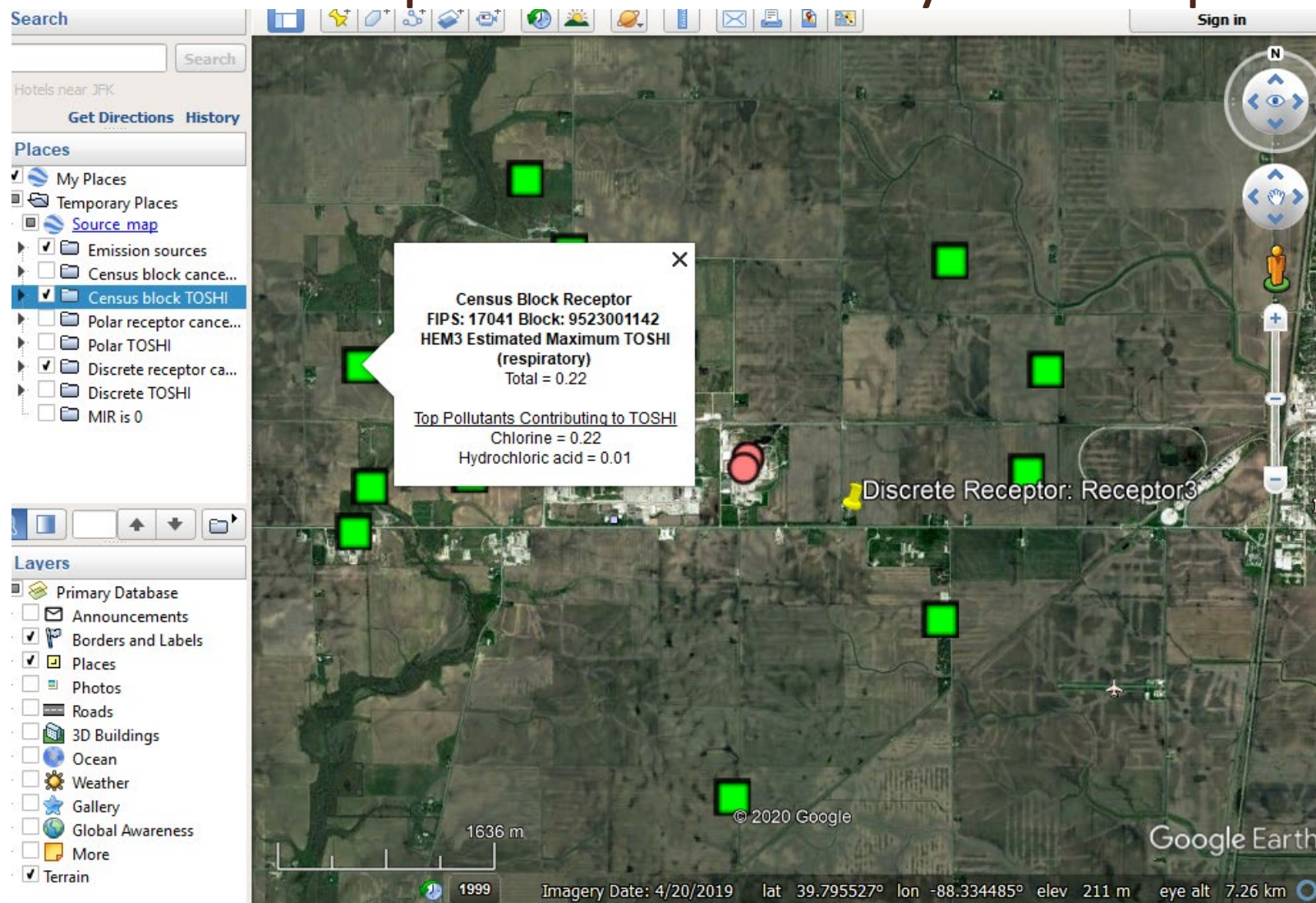


# HEM4's Output Chronic Facility Risk Map

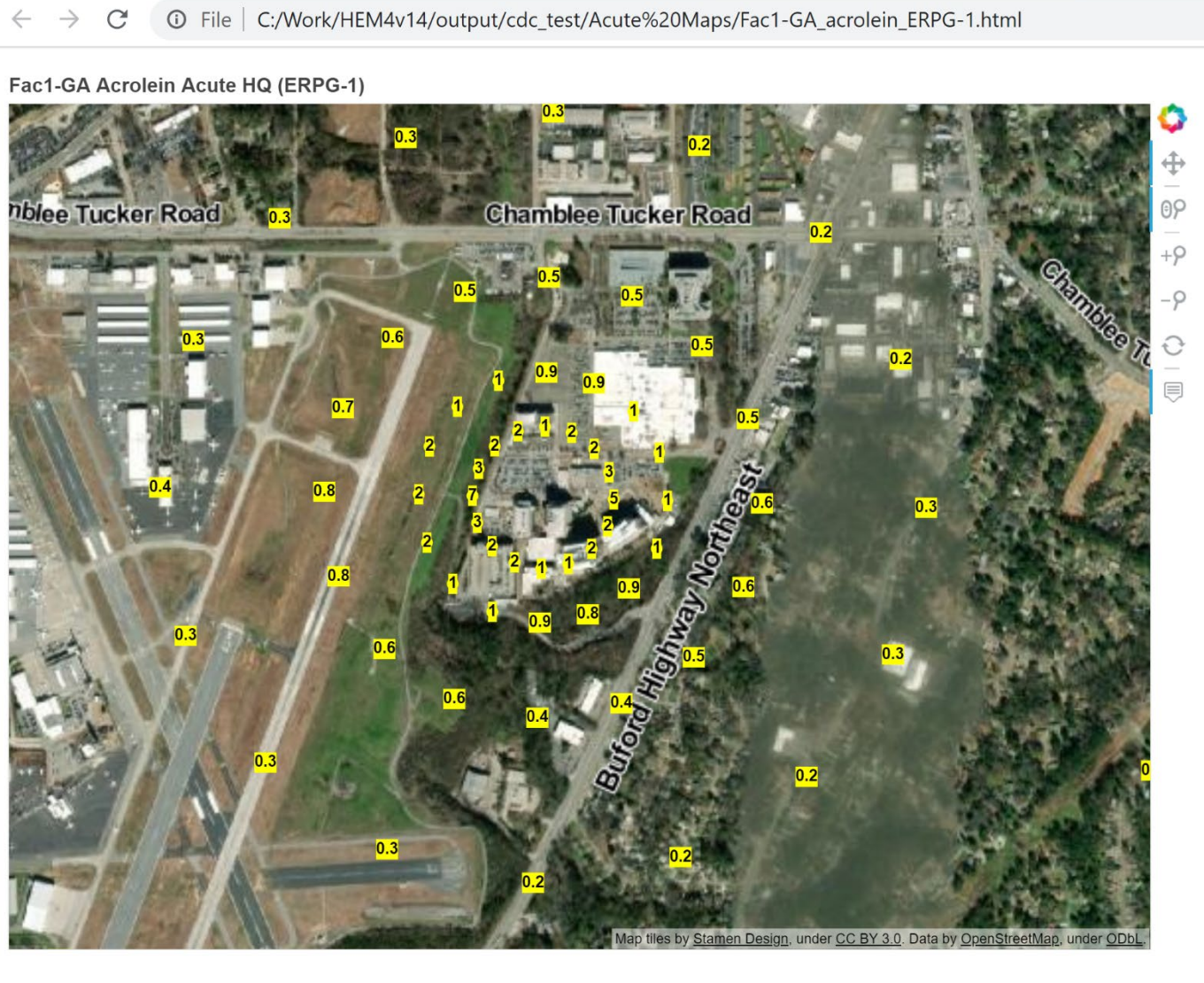




# HEM4's Output Chronic Facility Risk Map

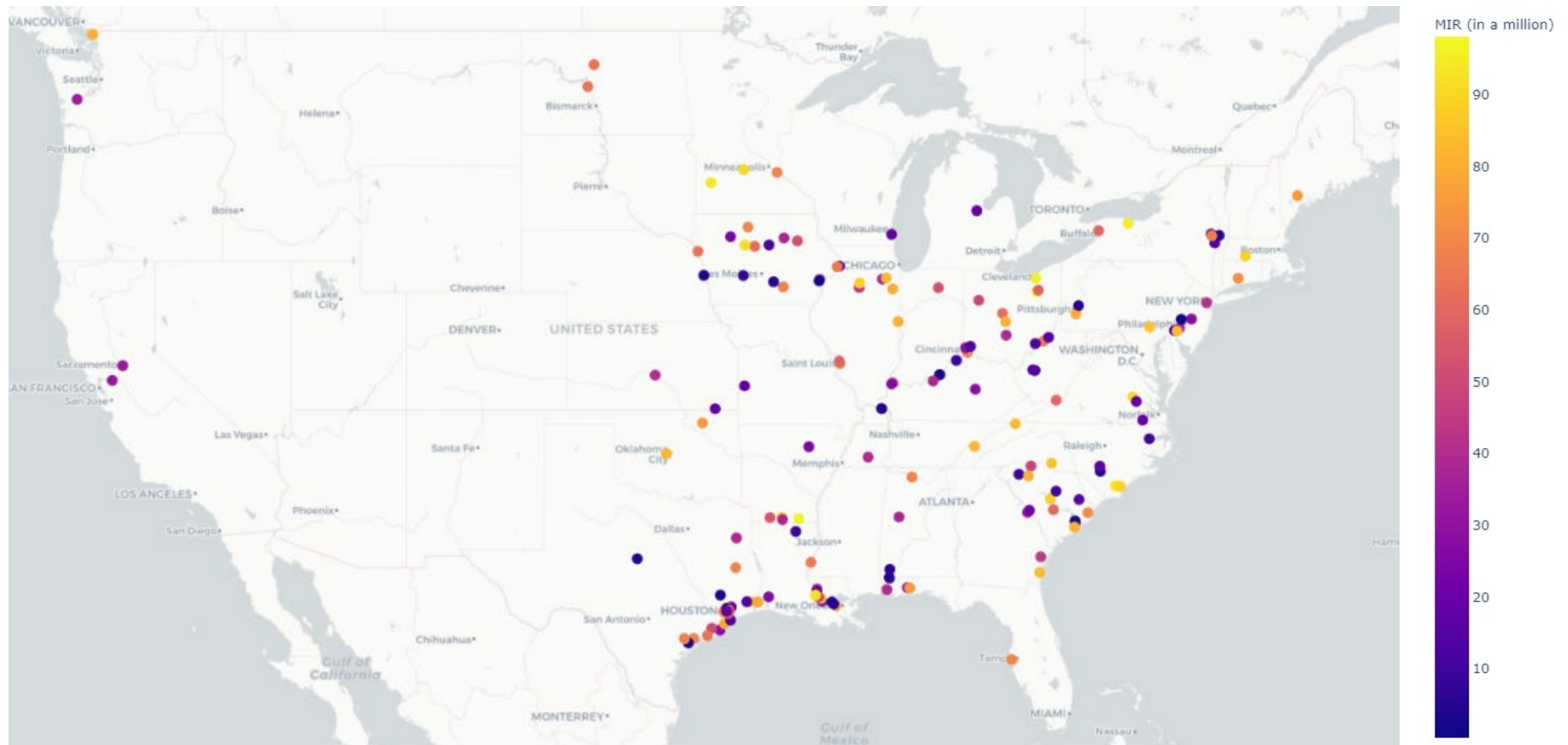


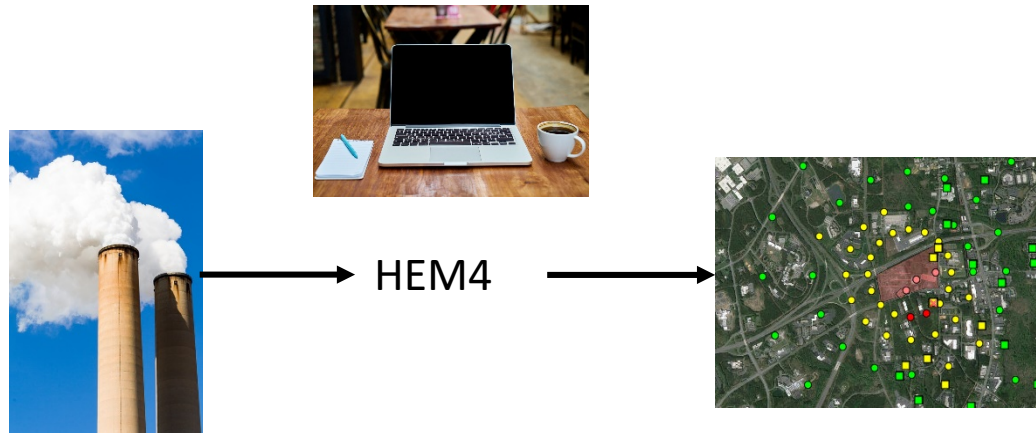
# HEM4's Output Acute Facility Risk Map





# HEM4's Graphical Summary Map





**HEM4 can be found on the EPA's FERA website:**

<https://www.epa.gov/fera/download-human-exposure-model-hem>

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**Contacts:**

Mark Morris (EPA) – [morris.mark@epa.gov](mailto:morris.mark@epa.gov)

Ted Palma (EPA) – [palma.ted@epa.gov](mailto:palma.ted@epa.gov)

Matt Woody (EPA) – [woody.matthew@epa.gov](mailto:woody.matthew@epa.gov)

SC&A - [www.scainc.com](http://www.scainc.com); 919-484-0222

