Spatial Optimization of Renewable Energy Power Plants

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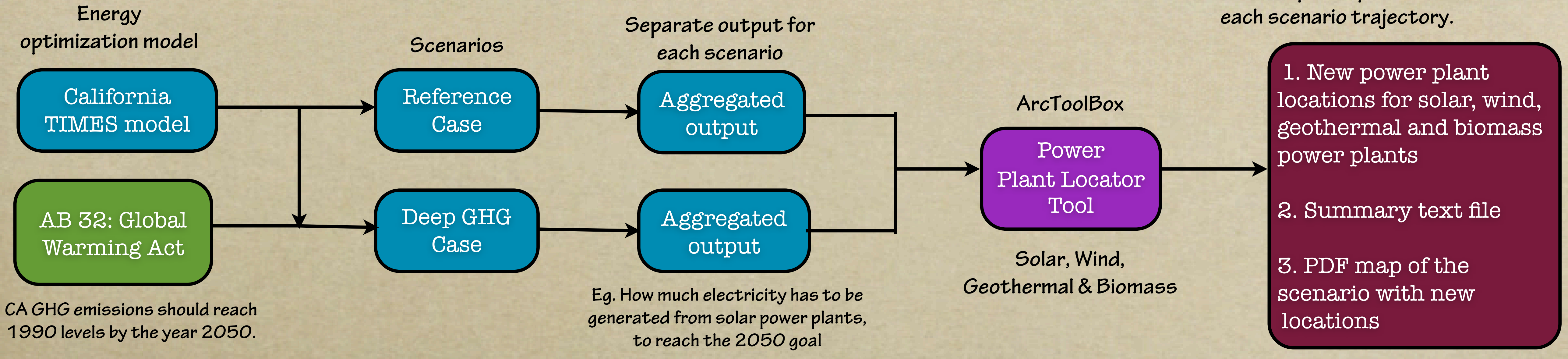
Project Description

Provides output for the year requested, so that the user can see how the power plants are installed in each scenario trajectory.



Energy optimization model

California TIMES model

AB 32: Global Warming Act

CA GHG emissions should reach 1990 levels by the year 2050.

Scenarios

Reference Case

Deep GHG Case

Separate output for each scenario

Aggregated output

Aggregated output

Eg. How much electricity has to be generated from solar power plants, to reach the 2050 goal

ArcToolBox

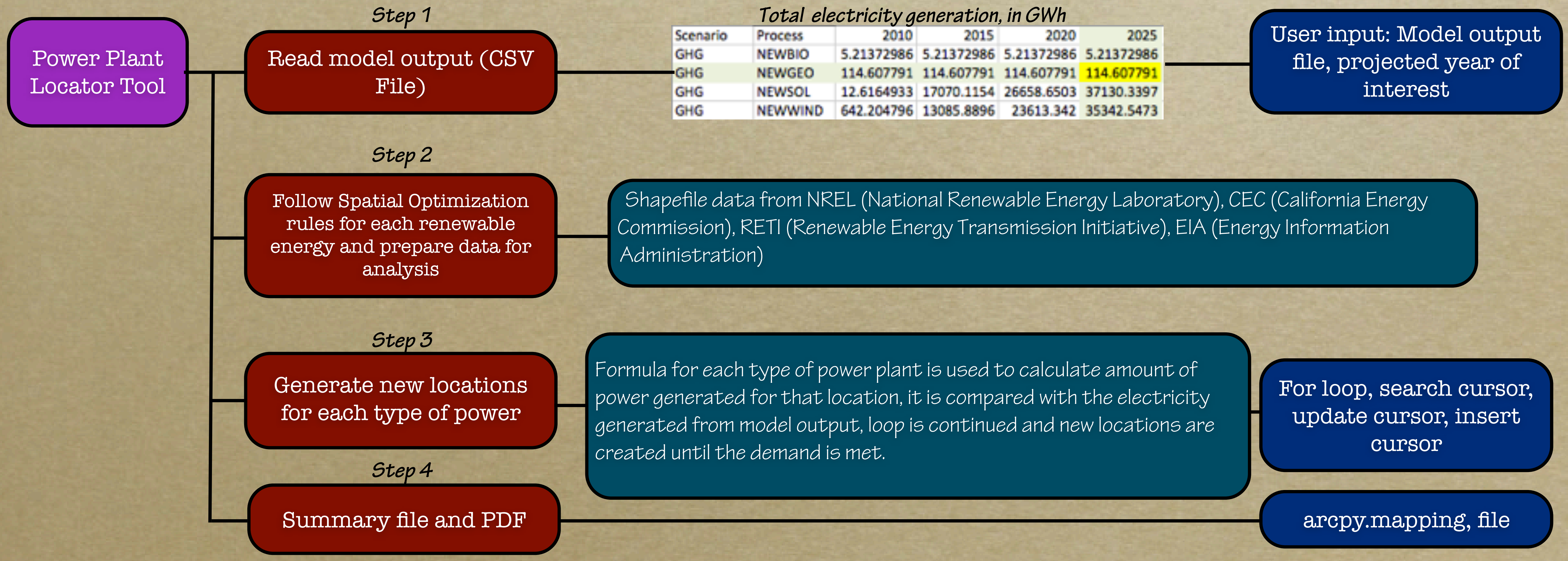
Power Plant Locator Tool

Solar, Wind, Geothermal & Biomass

1. New power plant locations for solar, wind, geothermal and biomass power plants

2. Summary text file

3. PDF map of the scenario with new locations



Power Plant Locator Tool

Step 1

Read model output (CSV File)

Total electricity generation, in GWh

Scenario	Process	2010	2015	2020	2025
GHG	NEWBIO	5.21372986	5.21372986	5.21372986	5.21372986
GHG	NEWGEO	114.607791	114.607791	114.607791	114.607791
GHG	NEWSOL	12.6164933	17070.1154	26658.6503	37130.3397
GHG	NEWWIND	642.204796	13085.8896	23613.342	35342.5473

User input: Model output file, projected year of interest

Step 2

Follow Spatial Optimization rules for each renewable energy and prepare data for analysis

Shapefile data from NREL (National Renewable Energy Laboratory), CEC (California Energy Commission), RETI (Renewable Energy Transmission Initiative), EIA (Energy Information Administration)

Step 3

Generate new locations for each type of power

Formula for each type of power plant is used to calculate amount of power generated for that location, it is compared with the electricity generated from model output, loop is continued and new locations are created until the demand is met.

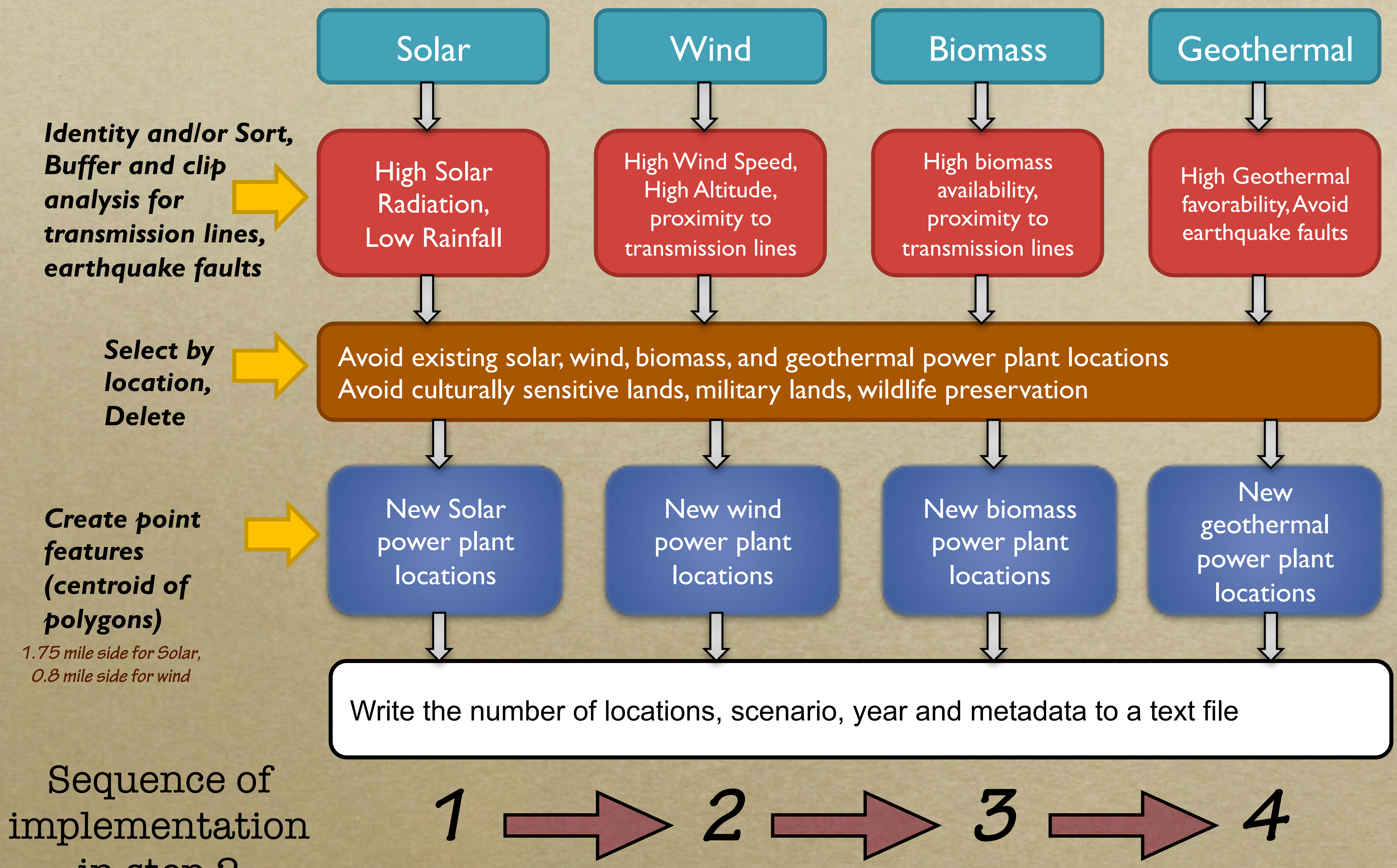
For loop, search cursor, update cursor, insert cursor

Step 4

Summary file and PDF

arcpy.mapping, file

Schematic Flow of Step 2



Solar

Wind

Biomass

Geothermal

Identity and/or Sort, Buffer and clip analysis for transmission lines, earthquake faults

High Solar Radiation, Low Rainfall

High Wind Speed, High Altitude, proximity to transmission lines

High biomass availability, proximity to transmission lines

High Geothermal favorability, Avoid earthquake faults

Select by location, Delete

Avoid existing solar, wind, biomass, and geothermal power plant locations
Avoid culturally sensitive lands, military lands, wildlife preservation

Create point features (centroid of polygons)

1.75 mile side for Solar, 0.8 mile side for wind

New Solar power plant locations

New wind power plant locations

New biomass power plant locations

New geothermal power plant locations

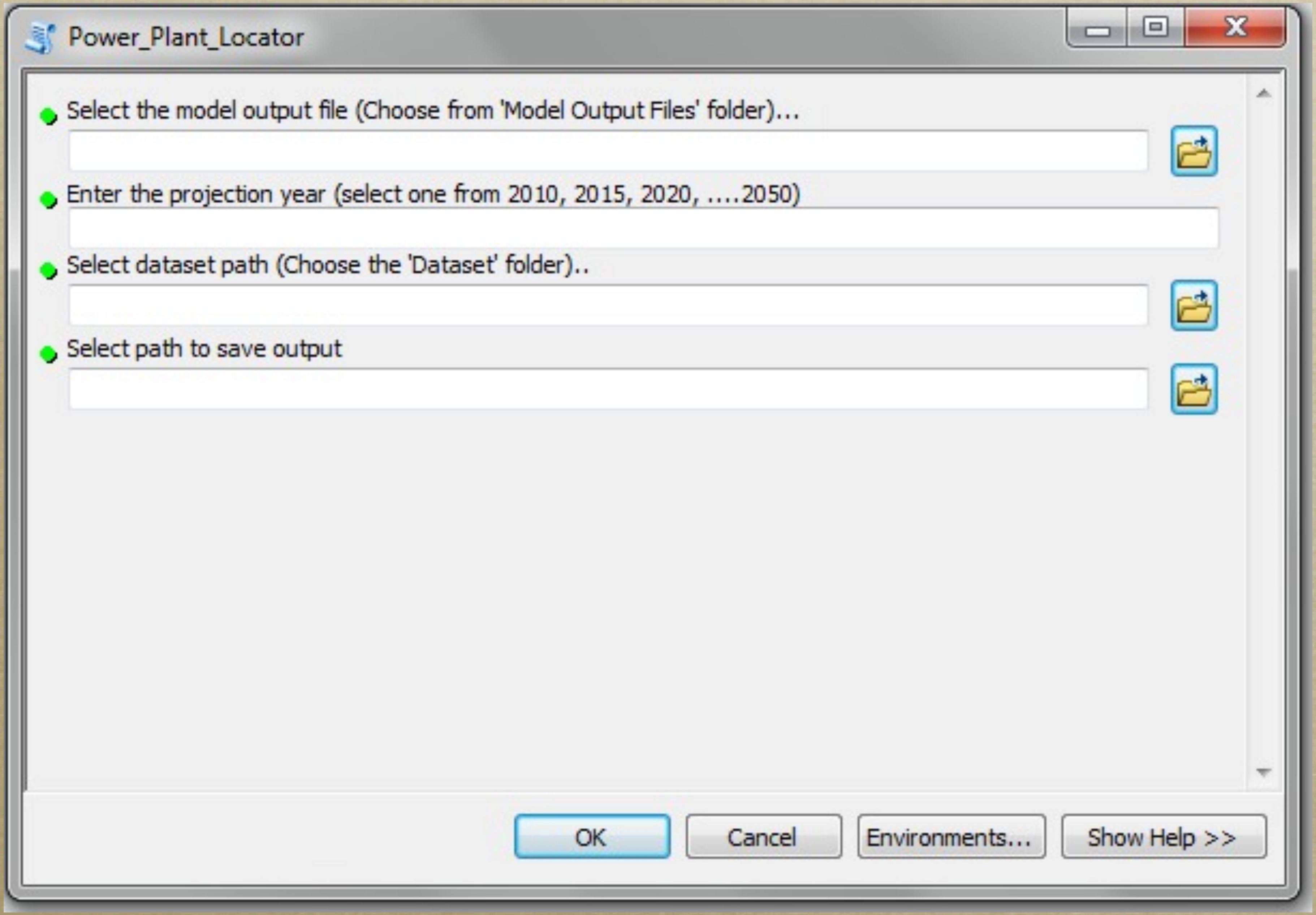
Write the number of locations, scenario, year and metadata to a text file

Sequence of implementation in step 2

1 → 2 → 3 → 4

Note: The temporary shapefiles in this analysis are created and saved in a ‘temp’ folder under the path selected by the user. “NewShapefiles” folder is created every time the tool is run.

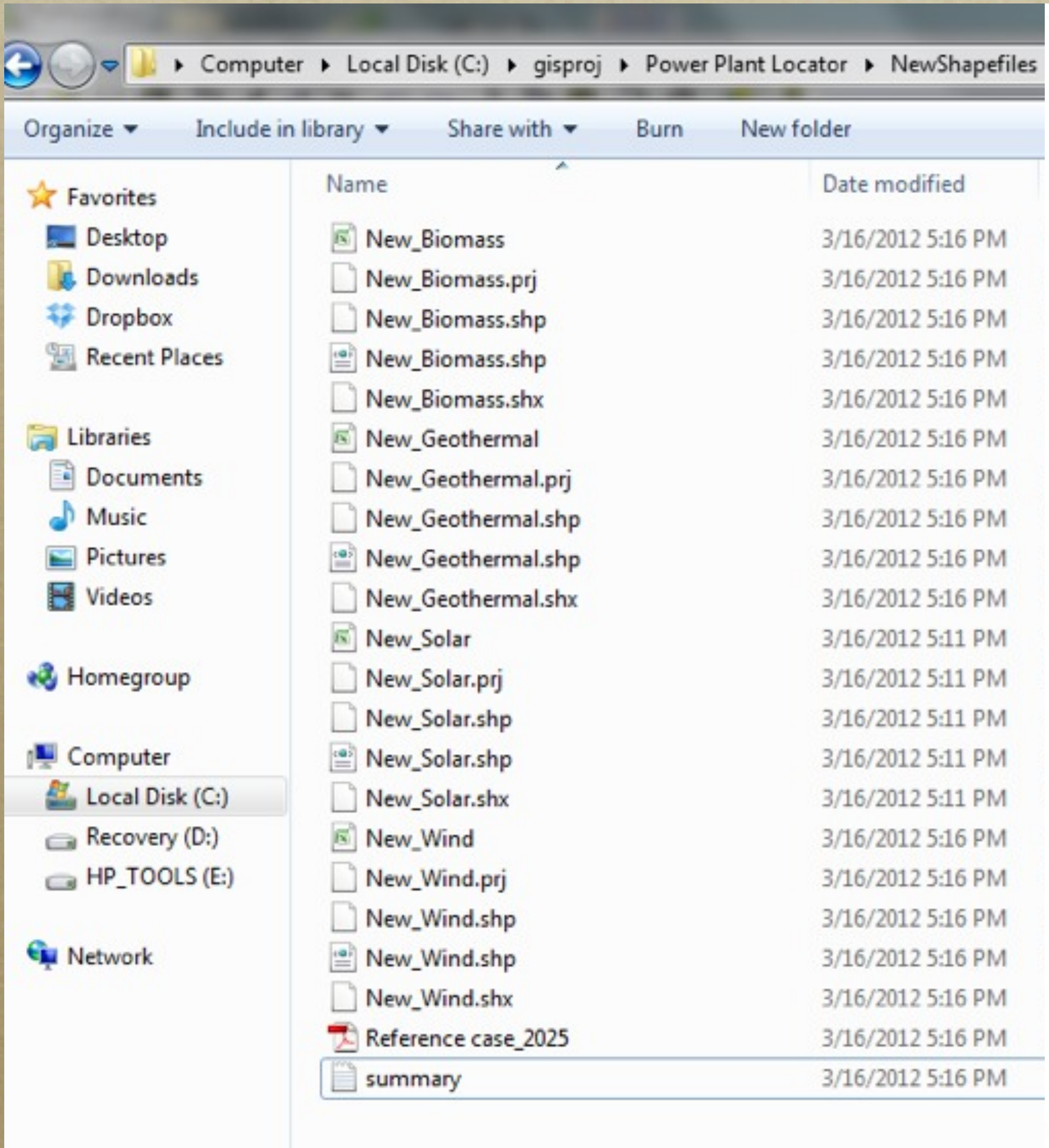
‘Power Plant Locator’ GUI



Power_Plant_Locator

- Select the model output file (Choose from 'Model Output Files' folder)...
- Enter the projection year (select one from 2010, 2015, 2020, ...2050)
- Select dataset path (Choose the 'Dataset' folder)..
- Select path to save output

Output



Computer ▸ Local Disk (C:) ▸ gisproj ▸ Power Plant Locator ▸ NewShapefiles

Organize ▾ Include in library ▾ Share with ▾ Burn New folder

Favorites
- Desktop
- Downloads
- Dropbox
- Recent Places

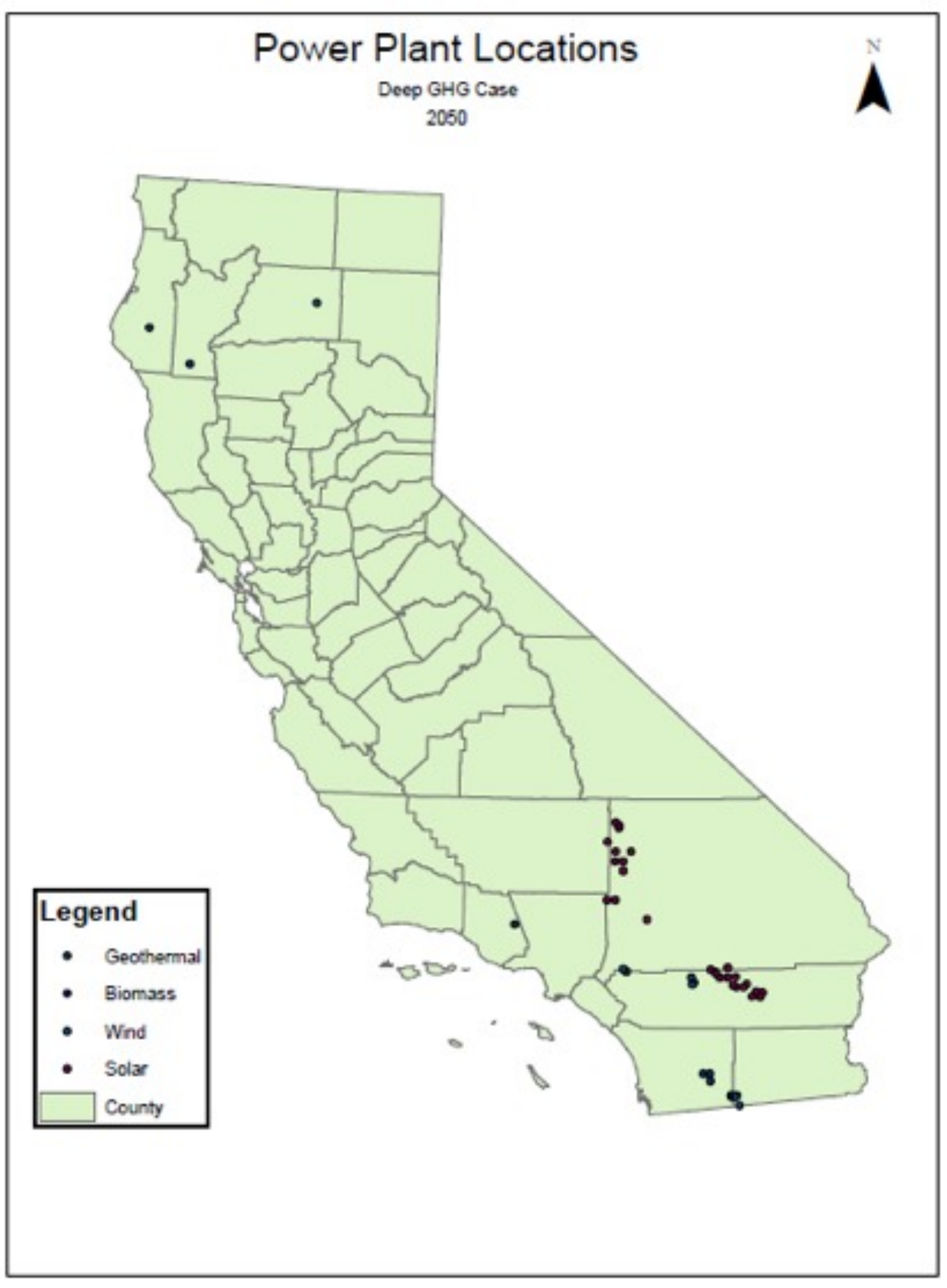
Libraries
- Documents
- Music
- Pictures
- Videos

Homegroup

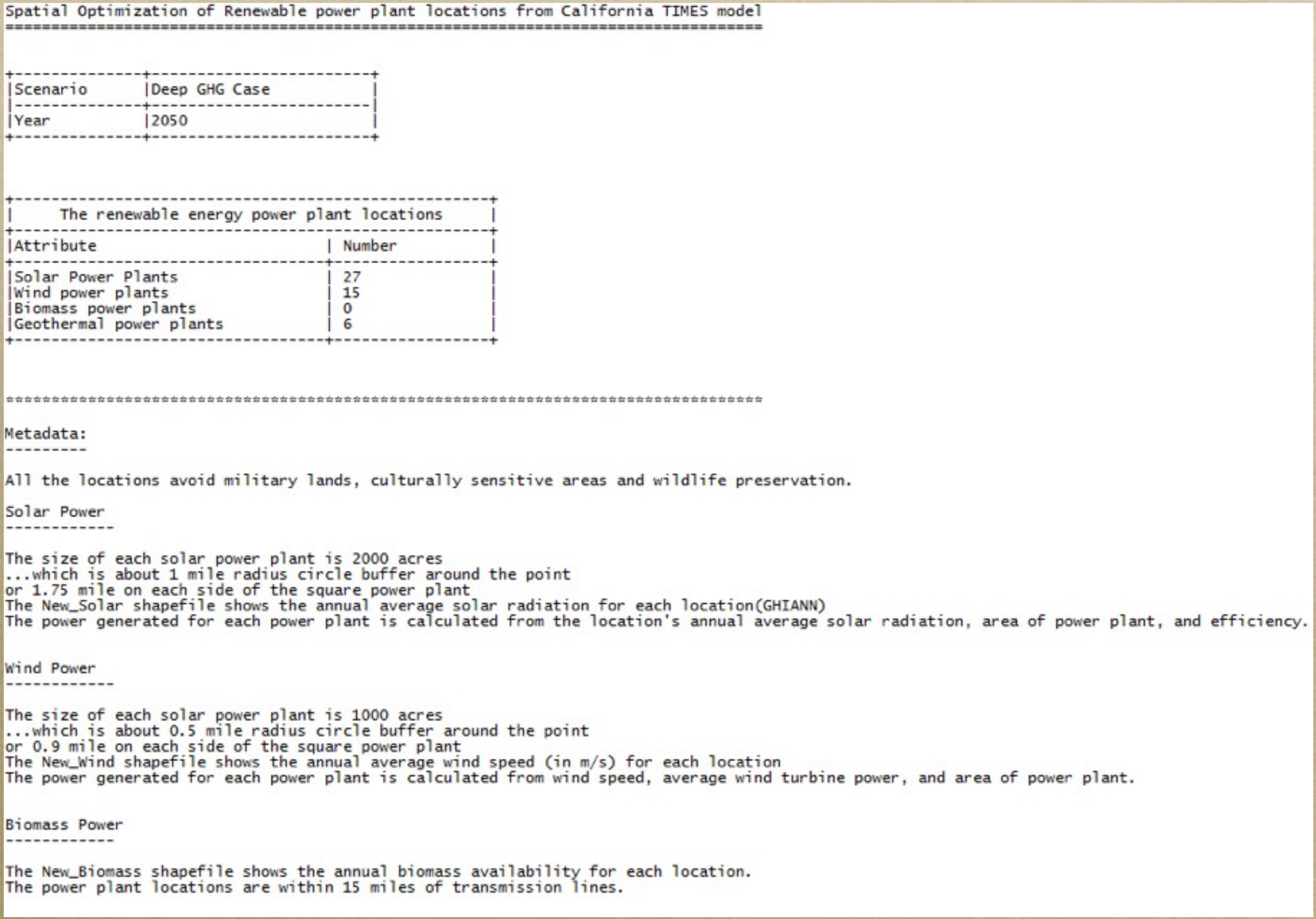
Computer
- Local Disk (C:)
- Recovery (D:)
- HP_TOOLS (E:)

Network

Name	Date modified
New_Biomass	3/16/2012 5:16 PM
New_Biomass.prj	3/16/2012 5:16 PM
New_Biomass.shp	3/16/2012 5:16 PM
New_Biomass.shp	3/16/2012 5:16 PM
New_Biomass.shx	3/16/2012 5:16 PM
New_Geothermal	3/16/2012 5:16 PM
New_Geothermal.prj	3/16/2012 5:16 PM
New_Geothermal.shp	3/16/2012 5:16 PM
New_Geothermal.shp	3/16/2012 5:16 PM
New_Geothermal.shx	3/16/2012 5:16 PM
New_Solar	3/16/2012 5:11 PM
New_Solar.prj	3/16/2012 5:11 PM
New_Solar.shp	3/16/2012 5:11 PM
New_Solar.shp	3/16/2012 5:11 PM
New_Solar.shx	3/16/2012 5:11 PM
New_Wind	3/16/2012 5:16 PM
New_Wind.prj	3/16/2012 5:16 PM
New_Wind.shp	3/16/2012 5:16 PM
New_Wind.shp	3/16/2012 5:16 PM
New_Wind.shx	3/16/2012 5:16 PM
Reference case_2025	3/16/2012 5:16 PM
summary	3/16/2012 5:16 PM



Output (Summary text file)



```
Spatial Optimization of Renewable power plant locations from California TIMES model
===================================================================================


+--------------+-------------------------+
|Scenario      |Deep GHG Case            |
|--------------+-------------------------|
|Year          |2050                     |
+--------------+-------------------------+



+-----------------------------------------------------+
|     The renewable energy power plant locations      |
+-----------------------------------+-----------------+
|Attribute                          | Number          |
+-----------------------------------+-----------------+
|Solar Power Plants                 | 27              |
|Wind power plants                  | 15              |
|Biomass power plants               | 0               |
|Geothermal power plants            | 6               |
+-----------------------------------+-----------------+



***********************************************************************************

Metadata:
---------

All the locations avoid military lands, culturally sensitive areas and wildlife preservation.

Solar Power
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The size of each solar power plant is 2000 acres
...which is about 1 mile radius circle buffer around the point
or 1.75 mile on each side of the square power plant
The New_Solar shapefile shows the annual average solar radiation for each location(GHIANN)
The power generated for each power plant is calculated from the location's annual average solar radiation, area of power plant, and efficiency.


Wind Power
------------

The size of each solar power plant is 1000 acres
...which is about 0.5 mile radius circle buffer around the point
or 0.9 mile on each side of the square power plant
The New_Wind shapefile shows the annual average wind speed (in m/s) for each location
The power generated for each power plant is calculated from wind speed, average wind turbine power, and area of power plant.


Biomass Power
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The New_Biomass shapefile shows the annual biomass availability for each location.
The power plant locations are within 15 miles of transmission lines.
```
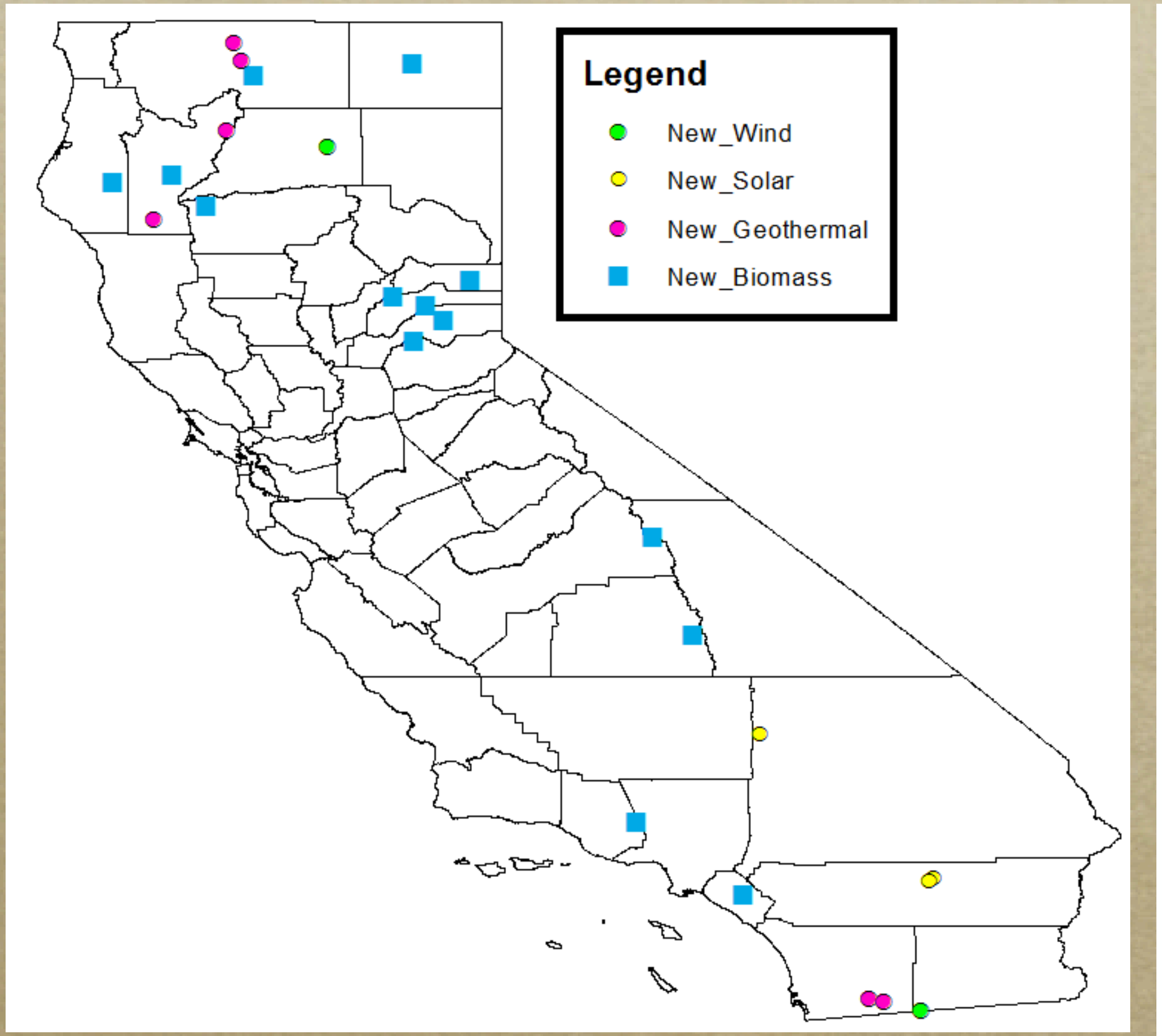
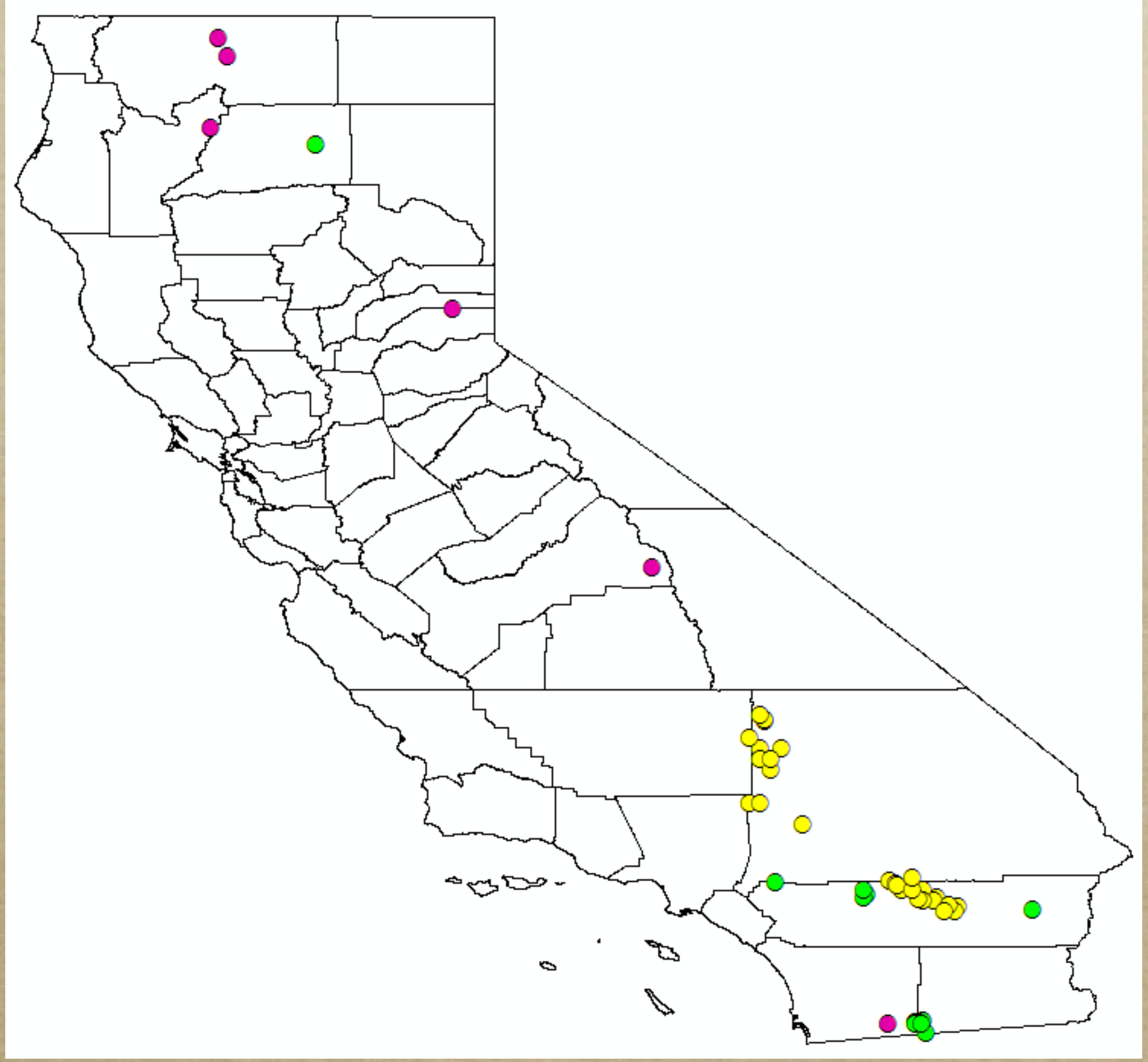

Output (Shapefiles)

Reference Case, 2050



Deep GHG Case, 2050



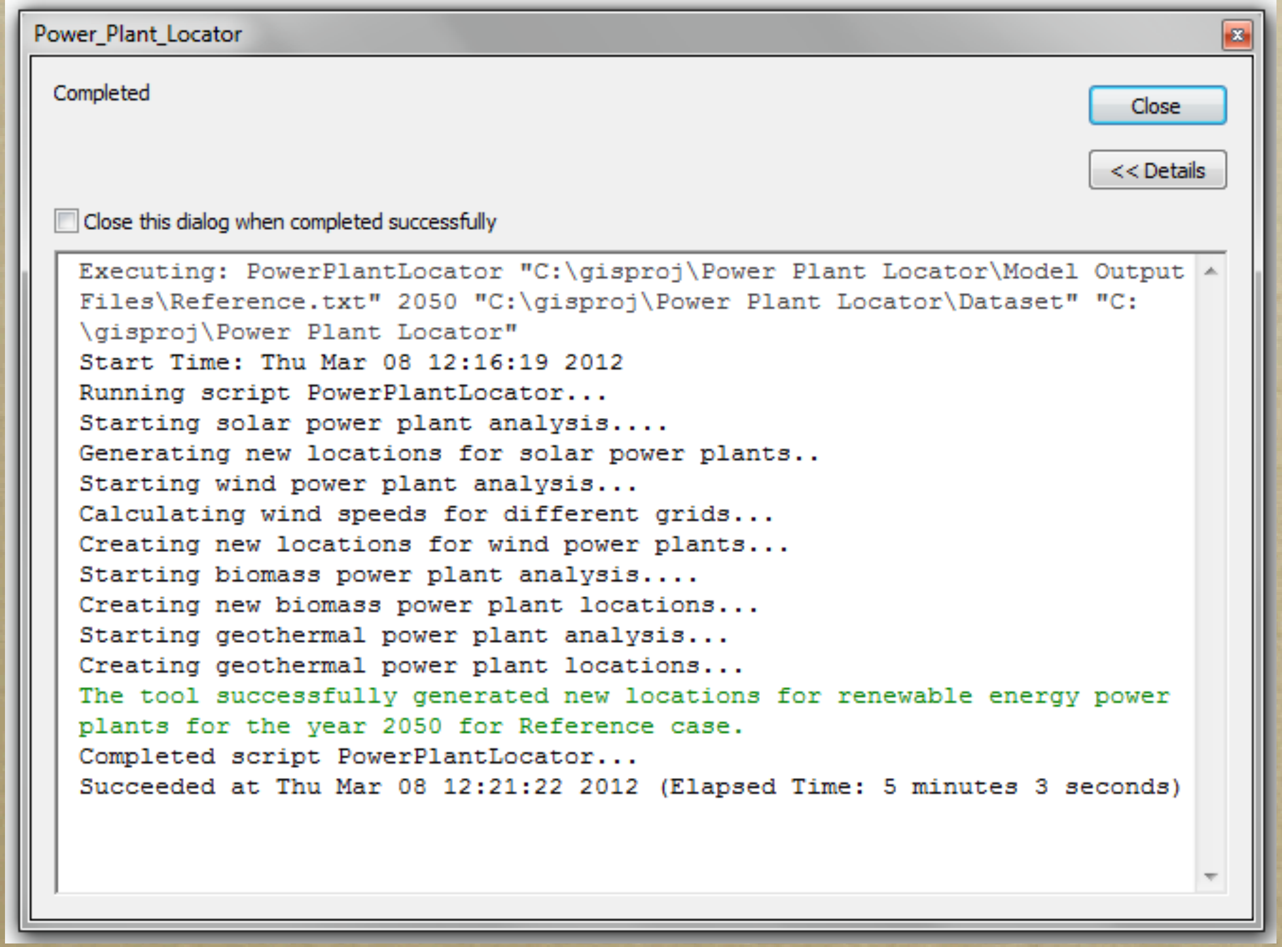
Next steps...

- Different types of power plants, (on-shore and off-shore wind power plants, different types of solar power plants, etc.)
- ‘Power generation’ is only a *tiny* part of the comprehensive model. Incorporating the spatial element of other parts.
- Dynamic integration: Incorporating investment decisions from the spatial output back to the energy model.

Thank You!

(additional sides available!)

Error Handling

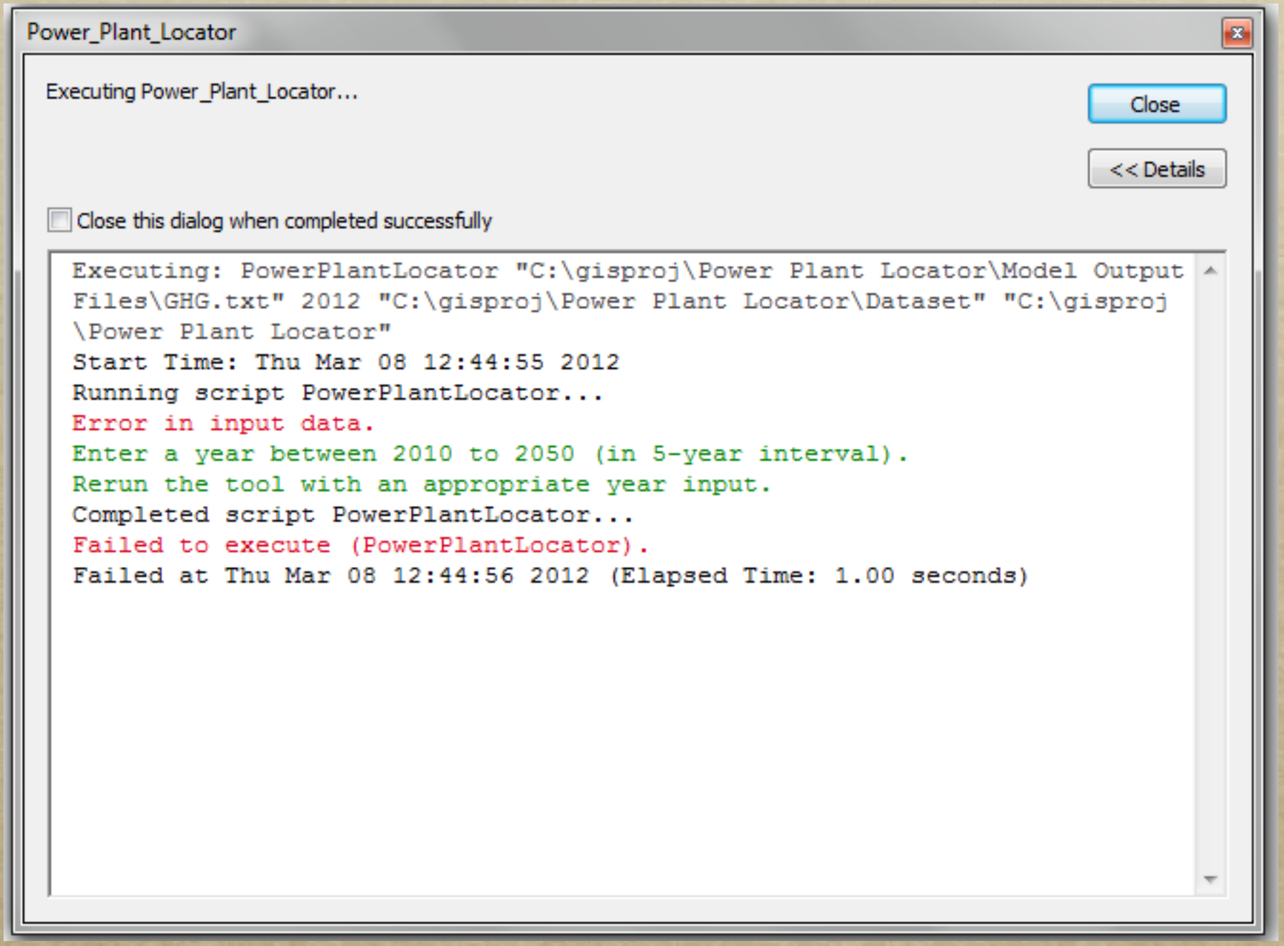


Completed

□ Close this dialog when completed successfully

```
Executing: PowerPlantLocator "C:\gisproj\Power Plant Locator\Model Output
Files\Reference.txt" 2050 "C:\gisproj\Power Plant Locator\Dataset" "C:
\gisproj\Power Plant Locator"
Start Time: Thu Mar 08 12:16:19 2012
Running script PowerPlantLocator...
Starting solar power plant analysis....
Generating new locations for solar power plants..
Starting wind power plant analysis...
Calculating wind speeds for different grids...
Creating new locations for wind power plants...
Starting biomass power plant analysis....
Creating new biomass power plant locations...
Starting geothermal power plant analysis...
Creating geothermal power plant locations...
The tool successfully generated new locations for renewable energy power
plants for the year 2050 for Reference case.
Completed script PowerPlantLocator...
Succeeded at Thu Mar 08 12:21:22 2012 (Elapsed Time: 5 minutes 3 seconds)
```

Proper Year input



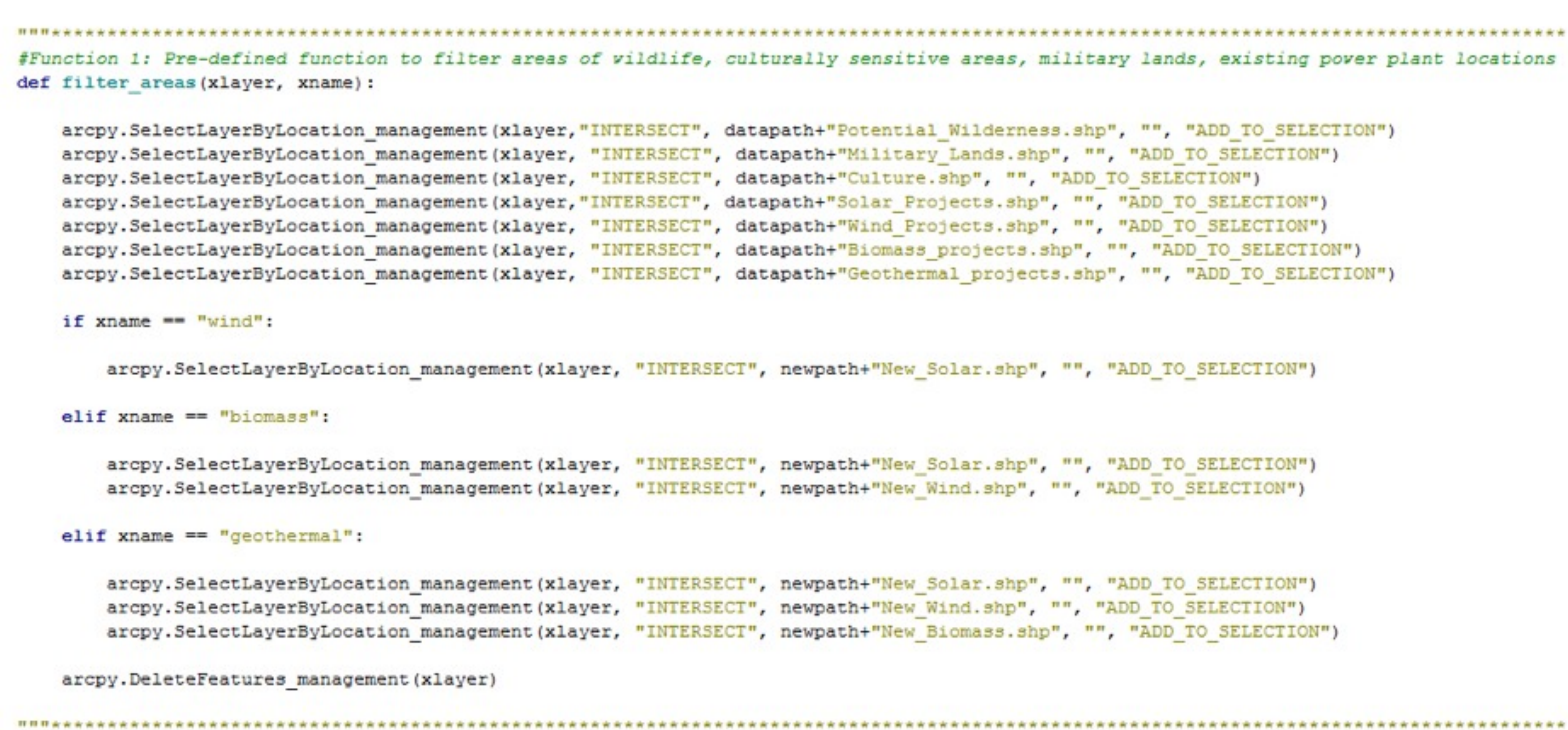
Executing Power_Plant_Locator...

□ Close this dialog when completed successfully

```
Executing: PowerPlantLocator "C:\gisproj\Power Plant Locator\Model Output
Files\GHG.txt" 2012 "C:\gisproj\Power Plant Locator\Dataset" "C:\gisproj
\Power Plant Locator"
Start Time: Thu Mar 08 12:44:55 2012
Running script PowerPlantLocator...
Error in input data.
Enter a year between 2010 to 2050 (in 5-year interval).
Rerun the tool with an appropriate year input.
Completed script PowerPlantLocator...
Failed to execute (PowerPlantLocator).
Failed at Thu Mar 08 12:44:56 2012 (Elapsed Time: 1.00 seconds)
```

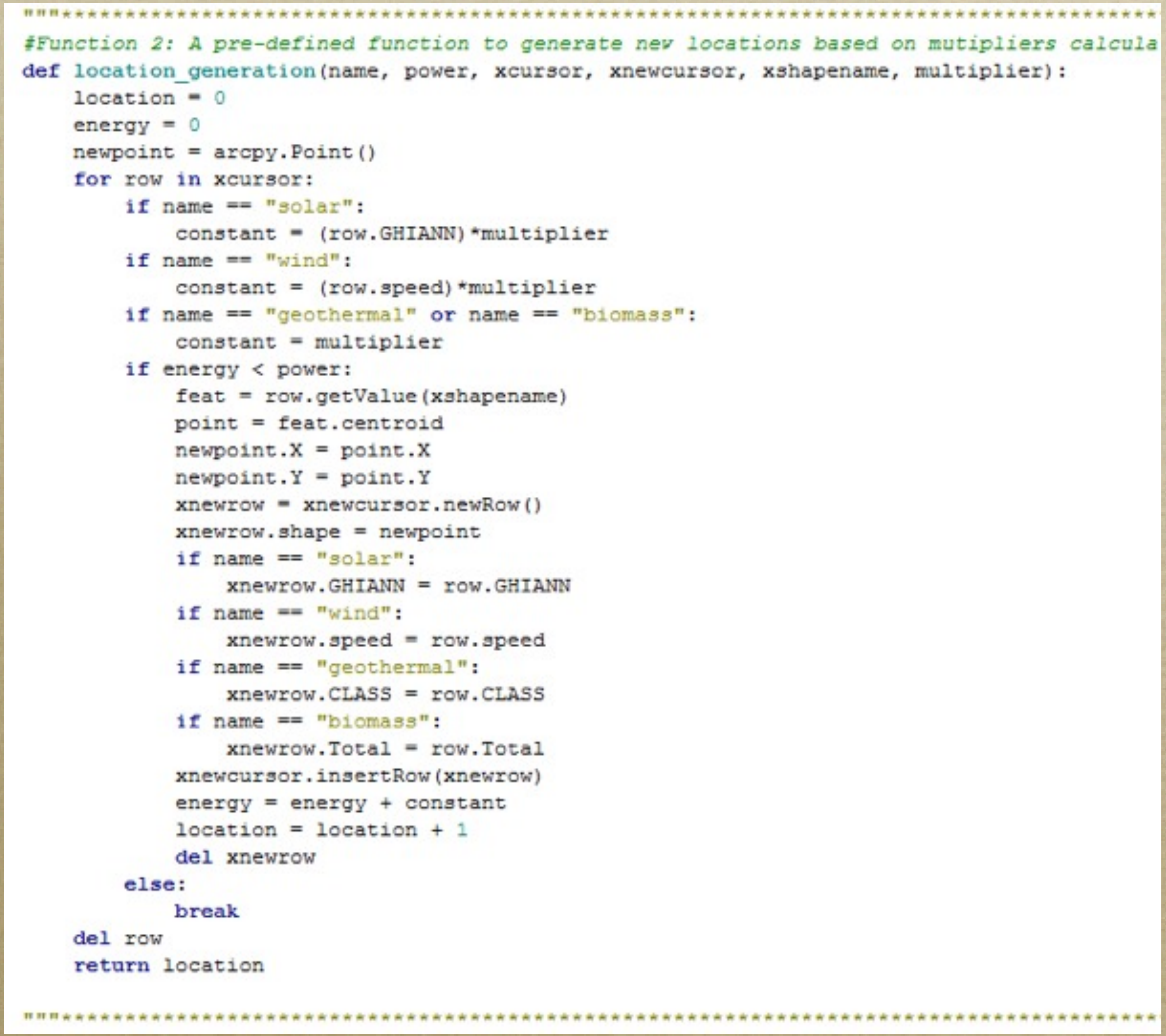
Year input >2050 or <2010, or not in 5-year intervals

Function 1: Filter Areas



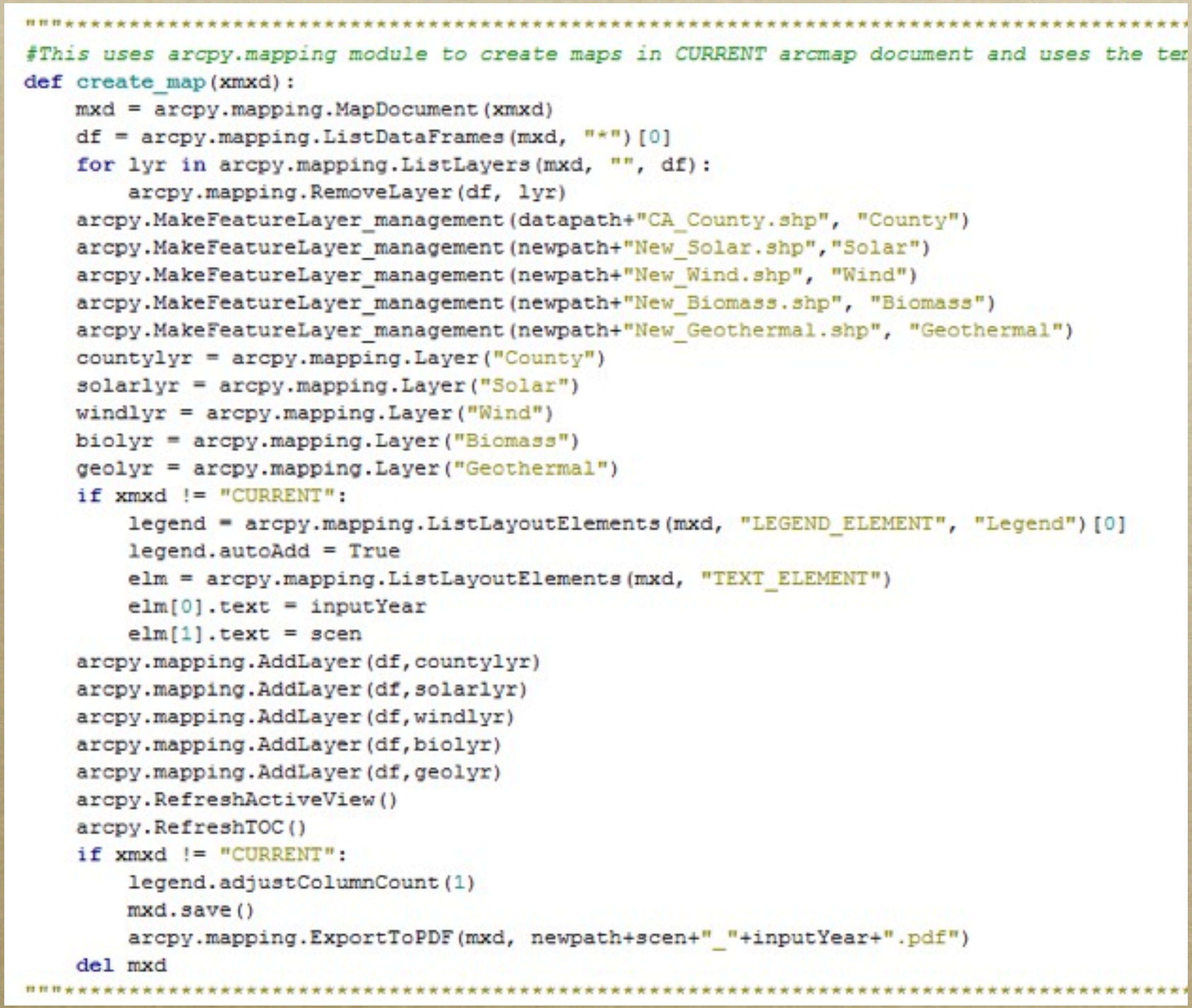
```
"""*******************************************************************************************************************************************
#Function 1: Pre-defined function to filter areas of wildlife, culturally sensitive areas, military lands, existing power plant locations
def filter_areas(xlayer, xname):

    arcpy.SelectLayerByLocation_management(xlayer,"INTERSECT", datapath+"Potential_Wilderness.shp", "", "ADD_TO_SELECTION")
    arcpy.SelectLayerByLocation_management(xlayer, "INTERSECT", datapath+"Military_Lands.shp", "", "ADD_TO_SELECTION")
    arcpy.SelectLayerByLocation_management(xlayer, "INTERSECT", datapath+"Culture.shp", "", "ADD_TO_SELECTION")
    arcpy.SelectLayerByLocation_management(xlayer,"INTERSECT", datapath+"Solar_Projects.shp", "", "ADD_TO_SELECTION")
    arcpy.SelectLayerByLocation_management(xlayer, "INTERSECT", datapath+"Wind_Projects.shp", "", "ADD_TO_SELECTION")
    arcpy.SelectLayerByLocation_management(xlayer, "INTERSECT", datapath+"Biomass_projects.shp", "", "ADD_TO_SELECTION")
    arcpy.SelectLayerByLocation_management(xlayer, "INTERSECT", datapath+"Geothermal_projects.shp", "", "ADD_TO_SELECTION")

    if xname == "wind":

        arcpy.SelectLayerByLocation_management(xlayer, "INTERSECT", newpath+"New_Solar.shp", "", "ADD_TO_SELECTION")

    elif xname == "biomass":

        arcpy.SelectLayerByLocation_management(xlayer, "INTERSECT", newpath+"New_Solar.shp", "", "ADD_TO_SELECTION")
        arcpy.SelectLayerByLocation_management(xlayer, "INTERSECT", newpath+"New_Wind.shp", "", "ADD_TO_SELECTION")

    elif xname == "geothermal":

        arcpy.SelectLayerByLocation_management(xlayer, "INTERSECT", newpath+"New_Solar.shp", "", "ADD_TO_SELECTION")
        arcpy.SelectLayerByLocation_management(xlayer, "INTERSECT", newpath+"New_Wind.shp", "", "ADD_TO_SELECTION")
        arcpy.SelectLayerByLocation_management(xlayer, "INTERSECT", newpath+"New_Biomass.shp", "", "ADD_TO_SELECTION")

    arcpy.DeleteFeatures_management(xlayer)

"""*******************************************************************************************************************************************
```

Function 2: Location Generation



```
"""**************************************************************************************
#Function 2: A pre-defined function to generate new locations based on mutipliers calcula
def location_generation(name, power, xcursor, xnewcursor, xshapename, multiplier):
    location = 0
    energy = 0
    newpoint = arcpy.Point()
    for row in xcursor:
        if name == "solar":
            constant = (row.GHIANN)*multiplier
        if name == "wind":
            constant = (row.speed)*multiplier
        if name == "geothermal" or name == "biomass":
            constant = multiplier
        if energy < power:
            feat = row.getValue(xshapename)
            point = feat.centroid
            newpoint.X = point.X
            newpoint.Y = point.Y
            xnewrow = xnewcursor.newRow()
            xnewrow.shape = newpoint
            if name == "solar":
                xnewrow.GHIANN = row.GHIANN
            if name == "wind":
                xnewrow.speed = row.speed
            if name == "geothermal":
                xnewrow.CLASS = row.CLASS
            if name == "biomass":
                xnewrow.Total = row.Total
            xnewcursor.insertRow(xnewrow)
            energy = energy + constant
            location = location + 1
            del xnewrow
        else:
            break
    del row
    return location

"""**************************************************************************************
```

Function 3: Create Map



```
"""*************************************************************************************
#This uses arcpy.mapping module to create maps in CURRENT arcmap document and uses the ter
def create_map(xmxd):
    mxd = arcpy.mapping.MapDocument(xmxd)
    df = arcpy.mapping.ListDataFrames(mxd, "*")[0]
    for lyr in arcpy.mapping.ListLayers(mxd, "", df):
        arcpy.mapping.RemoveLayer(df, lyr)
    arcpy.MakeFeatureLayer_management(datapath+"CA_County.shp", "County")
    arcpy.MakeFeatureLayer_management(newpath+"New_Solar.shp","Solar")
    arcpy.MakeFeatureLayer_management(newpath+"New_Wind.shp", "Wind")
    arcpy.MakeFeatureLayer_management(newpath+"New_Biomass.shp", "Biomass")
    arcpy.MakeFeatureLayer_management(newpath+"New_Geothermal.shp", "Geothermal")
    countylyr = arcpy.mapping.Layer("County")
    solarlyr = arcpy.mapping.Layer("Solar")
    windlyr = arcpy.mapping.Layer("Wind")
    biolyr = arcpy.mapping.Layer("Biomass")
    geolyr = arcpy.mapping.Layer("Geothermal")
    if xmxd != "CURRENT":
        legend = arcpy.mapping.ListLayoutElements(mxd, "LEGEND_ELEMENT", "Legend")[0]
        legend.autoAdd = True
        elm = arcpy.mapping.ListLayoutElements(mxd, "TEXT_ELEMENT")
        elm[0].text = inputYear
        elm[1].text = scen
    arcpy.mapping.AddLayer(df,countylyr)
    arcpy.mapping.AddLayer(df,solarlyr)
    arcpy.mapping.AddLayer(df,windlyr)
    arcpy.mapping.AddLayer(df,biolyr)
    arcpy.mapping.AddLayer(df,geolyr)
    arcpy.RefreshActiveView()
    arcpy.RefreshTOC()
    if xmxd != "CURRENT":
        legend.adjustColumnCount(1)
        mxd.save()
        arcpy.mapping.ExportToPDF(mxd, newpath+scen+"_"+inputYear+".pdf")
    del mxd
"""*************************************************************************************
```