Guidelines on Building a Shiny Application

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Learning Objectives

- Build an interactive web application
- Plot an interactive map with custom pop-up tables
- Compare the extent of `energy insecurity` across the U.S.
  - `Energy insecurity` refers to the inability of a household to meet basic energy needs, which includes the following conditions:
    * Reducing or forgoing basic necessities in order to pay energy bills
    * Keeping one's home at unhealthy temperatures
    * Receiving disconnection notice from energy providers
    * Being unable to use A/C or heating equipment in the home, due to
      · High costs of repair
      · Failure to pay utility bills

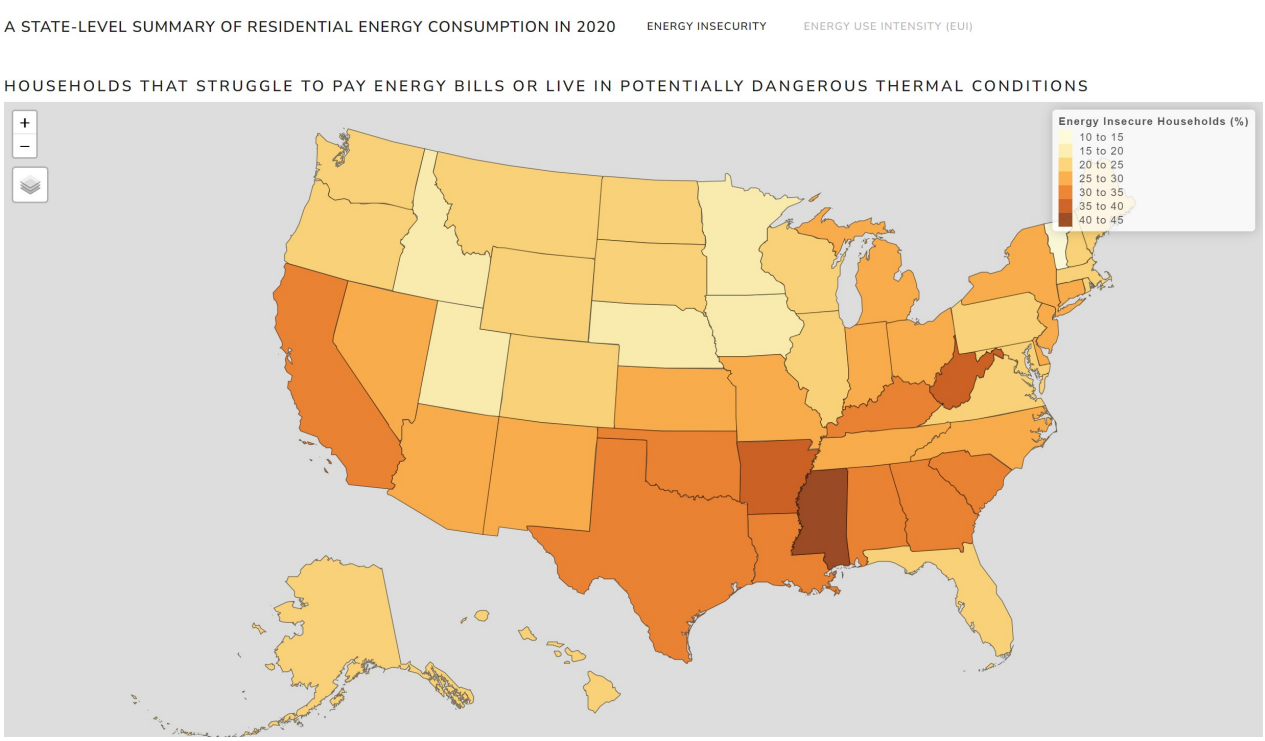
- Examine state-level differences in annual household energy consumption, expressed in terms of the size of the housing unit
  - Compare `Energy Use Intensity (EUI; Btu/square foot)`, which is an indication of energy efficiency of the home
- Transform and merge data of various formats (`shp.` and `csv.` data types)
  - Create user-defined functions to write clean and efficient blocs of code

Instructions

In this tutorial, we will build a Shiny web application that visualizes findings from the 2020 Residential Energy Consumption Survey (RECS). The app will display 2 maps:

1. One that summarizes the extent of household energy insecurity across U.S. states; and
2. Another that compares the average energy use intensity of U.S. homes.

The final dashboard will look like the following:

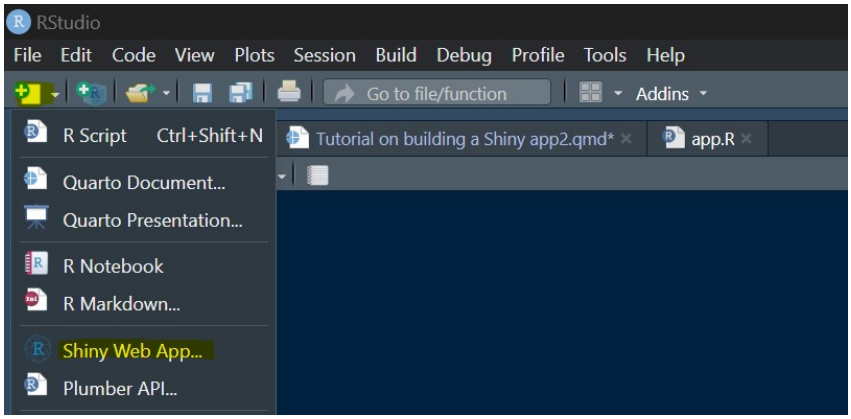


The *complete* R script for building a Shiny app can be found here.

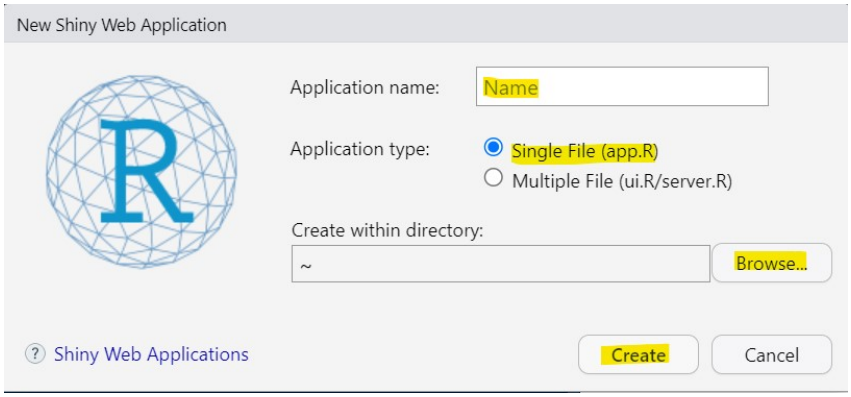
I. Getting Started: Loading Shiny Apps & Data Processing

1. Create a new shiny web application in RStudio

- Click on '*new file*' > '*shiny web app*'



- Fill out the '*Application name*' and select the directory in which to save the file.



Note: The file name should be saved as `app.R`.

2. Install and load packages

```
# p_load() function of the pacman package installs & loads packages simultaneously
pacman::p_load(tidyverse, # for data wrangling
               shiny, shinydashboard, shinythemes, bslib, rsconnect, # for shiny app
               sf, tigris, tmap) # for spatial mapping
```

3. Read in and merge the datasets

- Define a function that:
  - Loads the following datasets

    - Two state-level summaries of the 2020 Residential Energy Consumption Survey (RECS)
        - energy_insecurity.csv, which provides data on the number of energy insecure households for each state; and
        - energy_consumption.csv, which includes data on annual household energy consumption (per square foot)
    - A geospatial data of U.S. states
  - Transforms the spatial data
    - Rotate, scale, and transpose Alaska and Hawaii to locate them closer to the continental United States
    - Project the map according to an *Albers equal-area conic reference system*, to preserve the correct proportion of the states
  - Merges spatial data with the RECS, by *state name*
    - Convert the names of each state to upper case, for consistency across datasets
    - Perform a left join, using the *state name* variables as key:
        - `STATE` variable for the `RECS` dataframe
        - `NAME` variable for the `US` geospatial dataframe

- Store the merged data as `energy_insecurity` and `energy_consumption`, respectively

```
##### I. Create a user defined function that wrangles the data
merge_the_data <- function(file_name) {

### 1) Read in the RECS summary data
# Define the path directory
  directory <-
    "https://raw.githubusercontent.com/quinnei/Residential-Energy-Consumption-2020/main/RECS-Shiny-App/1_Dataset/"
# Specify the location of the csv file
  file_path <- paste0(directory, file_name, ".csv")
# Read the csv dataset
  RECS <- read.csv(file_path)

### 2) Read in the geospatial data of the US, using the tigris package
  US <- states(cb = TRUE, year = 2020) %>%
# Position Alaska & Hawaii below the continental US
    shift_geometry(position = "below") %>%
# For a conic representation of the U.S.
    sf::st_transform("+proj=aea +lat_1=29.5 +lat_2=45.5 +lat_0=37.5 +lon_0=-96")
# Capitalize the state names
  US$NAME <- toupper(US$NAME)

### 3) Join the 2 datasets, by the state variable
  merged_data <- left_join(RECS, US, by = c("STATE" = "NAME"))
# Make sure that the merged dataframe is recognized as a spatial object
  st_geometry(merged_data) <- merged_data$geometry


  return(merged_data)
}



##### II. Call the function and store the merged, spatial dataset
energy_insecurity <- merge_the_data("energy_insecurity")
energy_consumption <- merge_the_data("energy_consumption")
```

II. Data Visualization: An Interactive Map of the U.S.

1. Define a custom function that generates an interactive map

- Use the `tmap` package for visualization
- The function takes in 4 arguments:
  - dataset;
  - main variable of interest, which to indicate in varying degrees of colors;
  - title of the legend; and
  - pop-up labels, for displaying supplementary information
- Delineate state boundaries in black and apply a line width of 0.5
- Fill in the state geometries, using the default yellow-orange color scheme; Set the transparency of the colors to 0.85
- Remove the external borders of the map, which comes as a default
- Place the legend on the top right-hand corner, to prevent it from overlapping with the map
- Make sure that the map is represented according to the *Albers equal-area conic reference system*

```
##### III. Define a function that plots an interactive map

create_map <- function(data, colored_variable, legend_title, popup_labels) {
  tm_shape(data) +
    tm_borders(col = 'black', alpha = 0.5) + # Black outlines for representing the states
    tm_fill(col = colored_variable, title = legend_title,
            popup.vars = popup_labels, # Add popup with relevant info
            id = "STATE", # The first piece of info to display in the popup
            alpha = 0.85) + # Set the transparency of the colors
    tm_layout(frame = FALSE, # Remove the black frame that surrounds the map
              legend.outside = TRUE, # Move the legend
              legend.title.size = 1, legend.text.size = 0.7) +
# Plot the interactive map in the original CRS (in conic form)
    tm_view(projection = 0) + tm_basemap(NULL)
}
```

2. Customize the layout of the map and store the map object

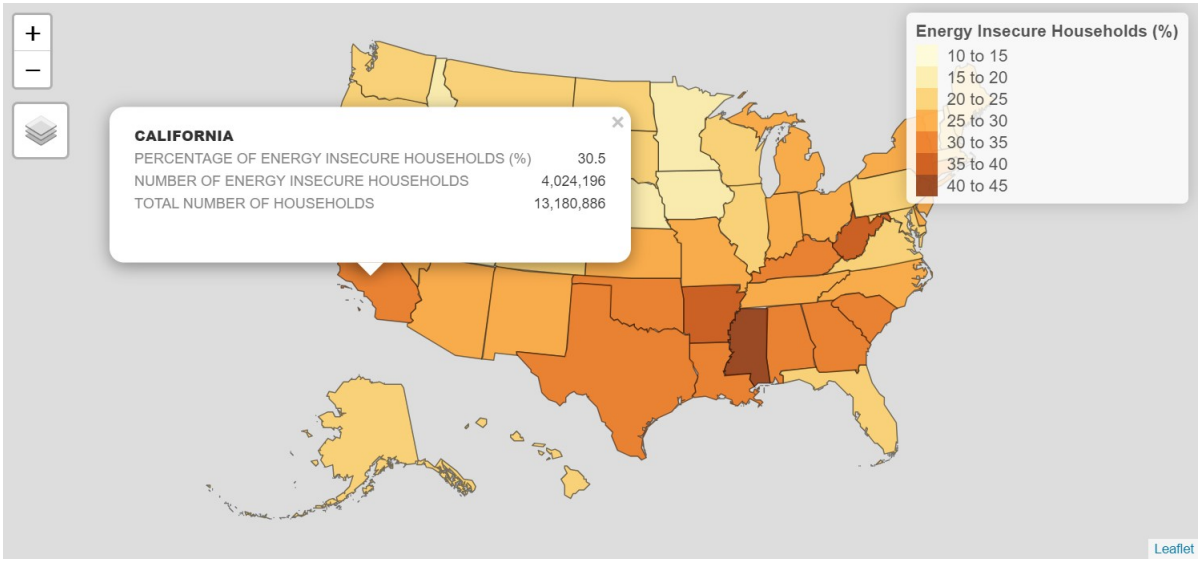
- Create a pair of interactive maps based on the 1) `energy_insecurity` and 2) `energy_consumption` dataframe
  - Store the output as `map_energy_insecurity` and `map_energy_consumption`
- Apply the following layout to each output:

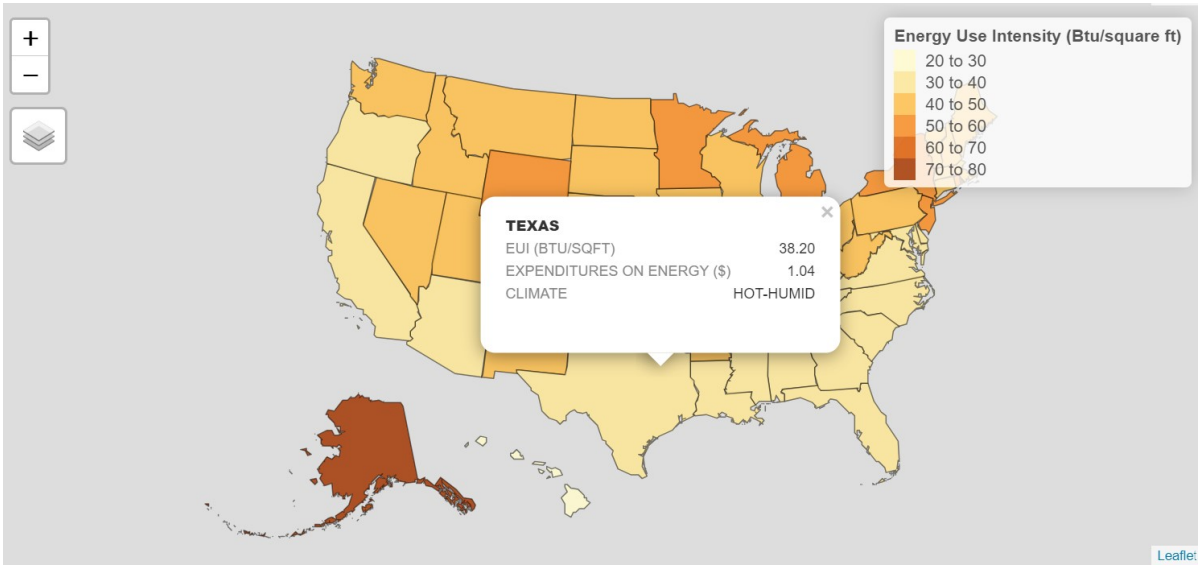
	Energy Insecurity	Energy Use Intensity
Variable used to fill in state geometries	`PERCENTAGE`	`ENERGY_CONSUMPTION_PER_SQFT`
Legend title	`Energy Insecure Households (%)`	`Energy Use Intensity (Btu/square ft)`
Info to display in the pop-up table and their respective variable names	• PERCENTAGE OF ENERGY INSECURE HOUSEHOLDS (%) - `PERCENTAGE` • NUMBER OF ENERGY INSECURE HOUSEHOLDS - `NUM_ENERGY_INSECURE_HOUSEHOLDS` • TOTAL NUMBER OF HOUSEHOLDS - `TOTAL_HOUSEHOLDS`	• EUI (BTU/SQFT) - `ENERGY_CONSUMPTION_PER_SQFT` • EXPENDITURES ON ENERGY ($) - `ENERGY_EXPENDITURE_PER_SQFT` • CLIMATE - `CLIMATE`

```
##### IV. Create an interactive map of 1) energy insecurity 2) Energy Use Intensity (EUI)

map_energy_insecurity <- create_map(
  energy_insecurity, 'PERCENTAGE', "Energy Insecure Households (%)",
# Indicate % and absolute values of energy insecurity & total number of households in each state
  c("PERCENTAGE OF ENERGY INSECURE HOUSEHOLDS (%)" = "PERCENTAGE",
    "NUMBER OF ENERGY INSECURE HOUSEHOLDS" = "NUM_ENERGY_INSECURE_HOUSEHOLDS",
    "TOTAL NUMBER OF HOUSEHOLDS" = "TOTAL_HOUSEHOLDS"))


map_energy_consumption <- create_map(
  energy_consumption, 'ENERGY_CONSUMPTION_PER_SQFT', "Energy Use Intensity (Btu/square ft)",
# For each state, indicate EUI, total average expenditures on energy, and climate region
  c("EUI (BTU/SQFT)" = "ENERGY_CONSUMPTION_PER_SQFT",
    "EXPENDITURES ON ENERGY ($)" = "ENERGY_EXPENDITURE_PER_SQFT",
    "CLIMATE" = "CLIMATE"))
```





III. Setting up the Shiny Dashboard

Note that ***Steps III-2*** to ***III-5*** are about designing the user interface (`ui`), whereas ***III-6*** relates to creating the `server` logic.

1. Create the main skeleton of the Shiny application

```
##### V. Create a user interface that defines the visual elements of the app
ui <- fluidPage()

##### VI. Create a server, which consists of an 1) input and 2) output
##### Tells the server how to generate outputs from the inputs provided
server <- function(input, output){}

##### VII. Run the Shiny app
shinyApp(ui = ui, server = server)
```

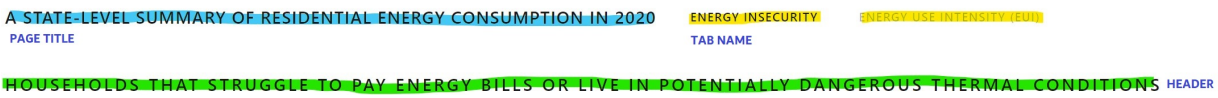
2. Apply a ready-made template to the Shiny app

- Select any of the themes provided by the `bslib` package
  - Run `bootswatch_themes()` to check out the full list of themes available

```
##### V. Create a user interface that defines the visual elements of the app
ui <- fluidPage(
##### 1) Apply a minimalist theme
  theme = bs_theme(bootswatch = "lux")
)
```

3. Add a page title and 2 tab panels for displaying the interactive map

The application should look like the following:



- Create a navigation bar at the top of the page
- Add the title of the web page: `A STATE-LEVEL SUMMARY OF RESIDENTIAL ENERGY CONSUMPTION IN 2020`
- Create 2 tabs, which will display an interactive map of 1) `energy insecurity` and 2) `energy use intensity`
  - Assign names to each tab; Introduce the topic/main theme of the visualized output

	Energy Insecurity	Energy Use Intensity
Tab name	`ENERGY INSECURITY`	`ENERGY USE INTENSITY (EUI)`
Header	`HOUSEHOLDS THAT STRUGGLE TO PAY ENERGY BILLS OR LIVE IN POTENTIALLY DANGEROUS THERMAL CONDITIONS`	`ANNUAL HOUSEHOLD ENERGY CONSUMPTION (PER SQUARE FOOTAGE)`
Output ID	`energy_insecurity_map`	`energy_consumption_map`
Output size	`width = "100%", height = "865px"`	`width = "100%", height = "865px"`

- For a preview of the Shiny app, click on '*Run app*' on the top right-hand corner of the source editor.

```
##### V. Create a user interface that defines the visual elements of the app
ui <- fluidPage(
##### 1) Apply a minimalist theme
  theme = bs_theme(bootswatch = "lux"),

##### 2) Create a navigation bar at the top of the page
  navbarPage(
# 2-1) Specify the title of the web page
    title = "A STATE-LEVEL SUMMARY OF RESIDENTIAL ENERGY CONSUMPTION IN 2020",

# 2-2) Create 2 main tabs
# 2-2-a) title of tab 1
    tabPanel("ENERGY INSECURITY"),

# 2-2-a') title of tab 2
    tabPanel("ENERGY USE INTENSITY (EUI)")
  )
)
```

4. Display a header for each landing page

The header will be displayed above the interactive map, underneath every tab.

- Apply a `h4` HTML style heading to the header
  - Tags that define HTML headings range from `h1` to `h6`
  - `h1` defines the most important heading and is the largest in size.
  - `h6` defines the least important heading and is the smallest in size

```
##### V. Create a user interface that defines the visual elements of the app
ui <- fluidPage(
##### 1) Apply a minimalist theme
  theme = bs_theme(bootswatch = "lux"),

##### 2) Create a navigation bar at the top of the page
  navbarPage(
# 2-1) Specify the title of the web page
    title = "A STATE-LEVEL SUMMARY OF RESIDENTIAL ENERGY CONSUMPTION IN 2020",

# 2-2) Create 2 main tabs
# 2-2-a) title of tab 1
    tabPanel("ENERGY INSECURITY",
# 2-2-b) header for the landing page
             h4("HOUSEHOLDS THAT STRUGGLE TO PAY ENERGY BILLS OR LIVE IN POTENTIALLY DANGEROUS THERMAL CONDITIONS")),


# 2-2-a') title of tab 2
    tabPanel("ENERGY USE INTENSITY (EUI)",
# 2-2-b') header for the landing page
             h4("ANNUAL HOUSEHOLD ENERGY CONSUMPTION (PER SQUARE FOOTAGE)")
    )
  )
)
```

5. Place the map within each tab and adjust the size of the output

- Instruct Shiny to display 2 outputs: the interactive maps to be defined in ***Step III-6***
  - Tell Shiny *where* to display the map object by listing `tmapOutput(outputId)` within `ui`
    - Nest the map object under each tab, using `tabPanel(..., tmapOutput(outputId))`
- Set the width of the output to `100%` and height to `865px` , using `tmapOutput(outputId, width = ..., height = ...)`

```
##### V. Create a user interface that defines the visual elements of the app
ui <- fluidPage(
##### 1) Apply a minimalist theme
  theme = bs_theme(bootswatch = "lux"),

##### 2) Create a navigation bar at the top of the page
  navbarPage(
# 2-1) Specify the title of the web page
    title = "A STATE-LEVEL SUMMARY OF RESIDENTIAL ENERGY CONSUMPTION IN 2020",

# 2-2) Create 2 main tabs
# 2-2-a) title of tab 1
    tabPanel("ENERGY INSECURITY",
# 2-2-b) title of the landing page
             h4("HOUSEHOLDS THAT STRUGGLE TO PAY ENERGY BILLS OR LIVE IN POTENTIALLY DANGEROUS THERMAL CONDITIONS"),
# 2-2-c) Define the size of the map
             tmapOutput("energy_insecurity_map", width = "100%", height = "865px")
    ),


# 2-2-a') title of tab 2
    tabPanel("ENERGY USE INTENSITY (EUI)",
# 2-2-b') title of the landing page
             h4("ANNUAL HOUSEHOLD ENERGY CONSUMPTION (PER SQUARE FOOTAGE)"),
# 2-2-c') Define the size of the map
             tmapOutput("energy_consumption_map", width = "100%", height = "865px")
    )
  )
)
```

6. Render the map object within the *server*

- Render the map object defined in ***Step II-2*** (i.e. `map_energy_insecurity` and `map_energy_consumption`)
- Toggle on the interactive mode
  - The map can be plotted either as a static image or an interactive, zoomable output, using the `"plot"` or `"view"` mode
- Create a list of outputs (i.e.`energy_insecurity_map` and `energy_consumption_map`) inside the `server`, to make these outputs visible
  - ***Note:*** The *output names* in both the `server` (i.e. `output$name`) and the `ui` (i.e. `tmapOutput("name")`) should be identical to each another
    - `output$energy_insecurity_map` in the `server` *should match* the `tmapOutput("energy_insecurity_map")` in the `ui`
    - `output$energy_consumption_map` in the `server` *should match* the `tmapOutput("energy_consumption_map")` in the `ui`

```
##### VI. Create a server, which consists of input and output
server <- function(input, output) {
##### 1) Generate the 'energy_insecurity_map' output
  output$energy_insecurity_map <- renderTmap({
# 1-a) Turn on interactive feature of the map
    tmap_mode("view")
# 1-b) Return the output that was defined in Part I.
    map_energy_insecurity
  })

##### 2) Generate the 'energy_consumption_map' output
  output$energy_consumption_map <- renderTmap({
# 2-a) Turn on interactive feature of the map
    tmap_mode("view")
# 2-b) Return the output that was defined in Part I.
    map_energy_consumption
  })

}
```

7. Test the application

- Click on each tab and check whether the map has been rendered successfully
- Make sure that the information displayed in the pop-up table is without error

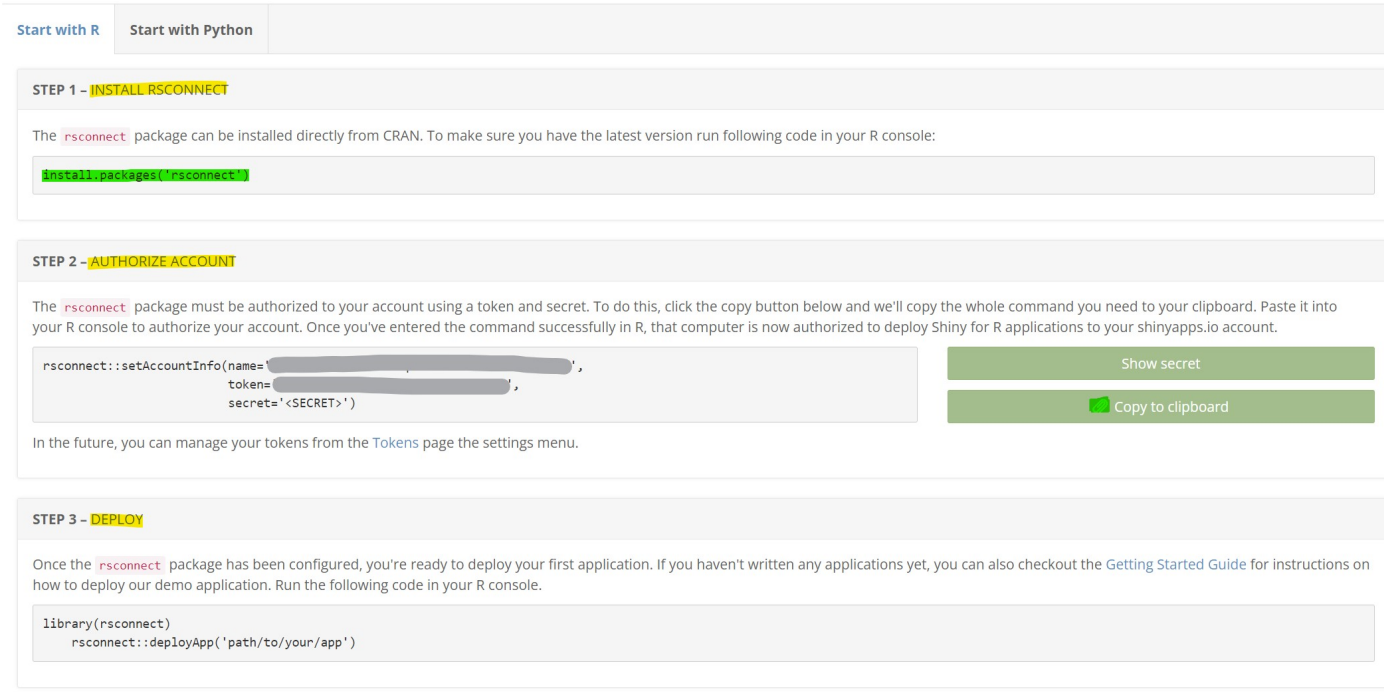
IV. Publishing the App on the Cloud

Subscribers of shinyapps.io can host their web applications for free, without having to set up a Shiny Server from scratch. Under the free plan, users can deploy up to 5 applications, which supports a monthly usage of up to 25 active hours.

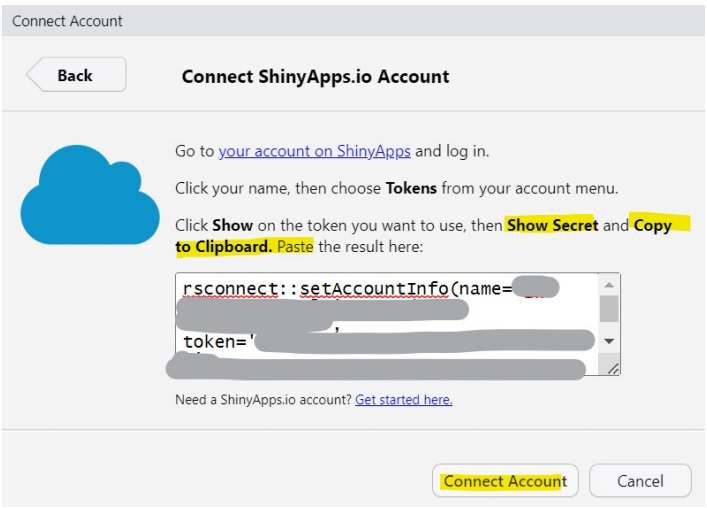
1. Click on '*Publish the application or document*' on the top right-hand corner of the source editor

2. Connect RStudio to shinyapps.io

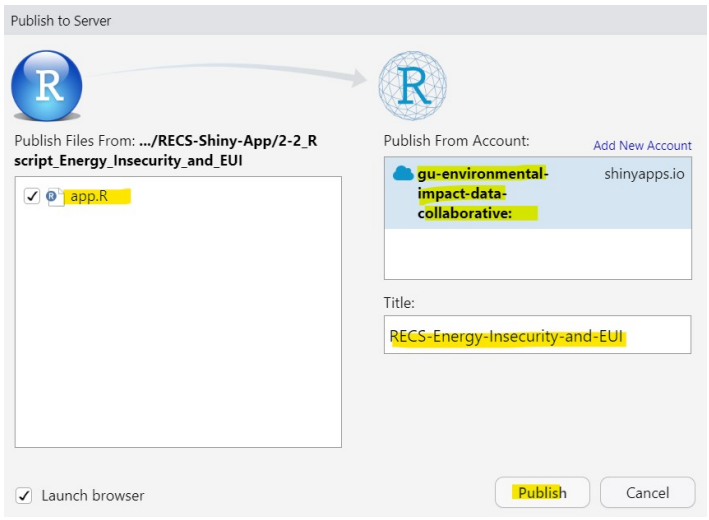
- Sign in/Sign up for a free account at shinyapps.io
- (*For new subscribers only*) Authorize the shinyapps.io account
  - Copy the token by clicking on '*Show secret*' > '*Copy to clipboard*'
    New users can skip the installation of `rsconnect`, as it has already been done in ***Step I-2***



– Paste the token in the space provided. Then proceed to '*Connect Account*'



- Select 1) the `app.R` file, 2) your shinyapps.io account, and 3) provide a title for the Shiny app. Then click '*Publish*'


Publish to Server
Publish Files From: .../RECS-Shiny-App/2-2_R script_Energy_Insecurity_and_EUI
app.R
Publish From Account:
Add New Account
gu-environmental-impact-data-collaborative:
shinyapps.io
Title:
RECS-Energy-Insecurity-and-EUI
Launch browser
Publish
Cancel