Data Visualization

Joerg Evermann

Faculty of Business Administration
Memorial University of Newfoundland
jevermann@mun.ca

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Legal Stuff

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Why Visualize?

”A Picture is Worth 1000 Words”

- Humans are good at visual pattern recognition, but
  - Humans also identify patterns where there are none!
  - It’s easy to mislead or deceive with visualization (others and oneself!)

Why Visualize?

Visual Discovery: Sense Making

- Exploration, confirmation or verification
- Iterative, dynamic

Declarative Visualization: Storytelling

- Explanation
- Affirming, convincing
- Presenting, explaining
- Decision support
- Static

Operational Visualization: Monitoring

- Supervision, alarms
- Operational decision making

Purpose of Visualization

- Simplify, summarize & abstract
- Compare
- Identify trends, patterns & relationships
- Gain insights

Visualization Process

1. Define objective and target audience
2. Acquire data
   - Identify sources
3. Parse data
   - Convert into appropriate format
4. Filter data
   - Select relevant information
5. Mine data
   - Apply statistical or data mining strategies for trends, correlations, etc.
6. Represent findings
   - Select a visualization type
7. Refine representation
   - Enhance for clarity and information content
8. Interact with representation
   - Provide user-controllable tools

Honesty in Visualization

General Guidelines

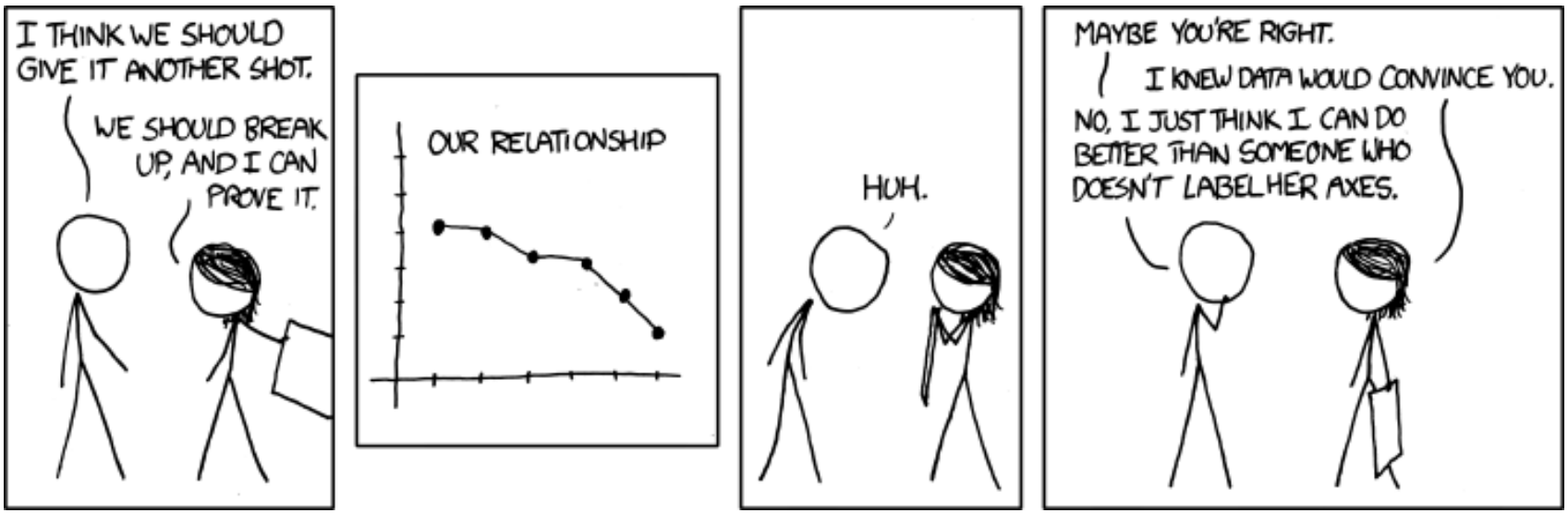
- Do not deceive your target audience
- Do not diminish or hide relationships or trends
- Do not exaggerate relationships or trends
- Do not confuse or obfuscate

Honesty in Visualization

Specific ”no-nos”

- Graph unrelated data to suggest non-existent relationships
- Scale multiple vertical axes to suggest correlations
- Truncate axes to hide or exaggerate trend
- Plot cumulative growth to hide trend
- Use maps for non-geographic data
- Use incomplete data (”cherry-picking”)
- Use invalid data

Label your Axes (XKCD)



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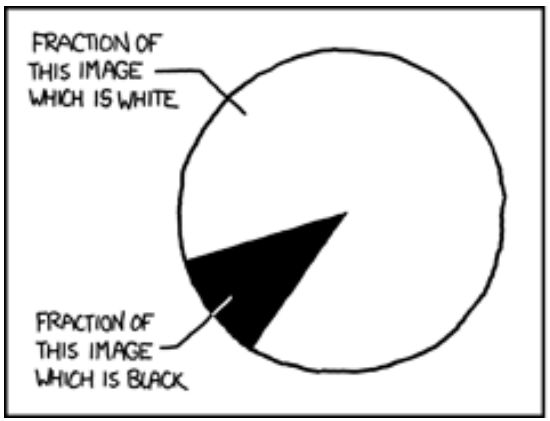
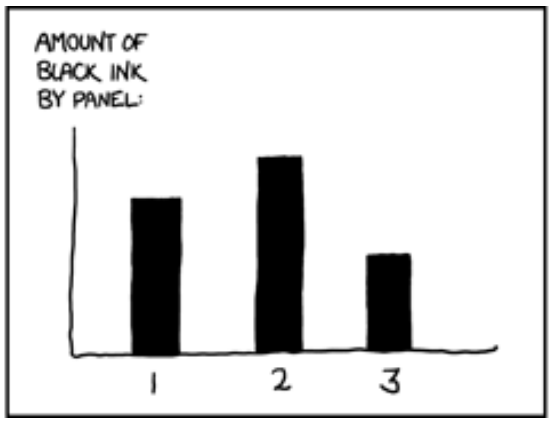
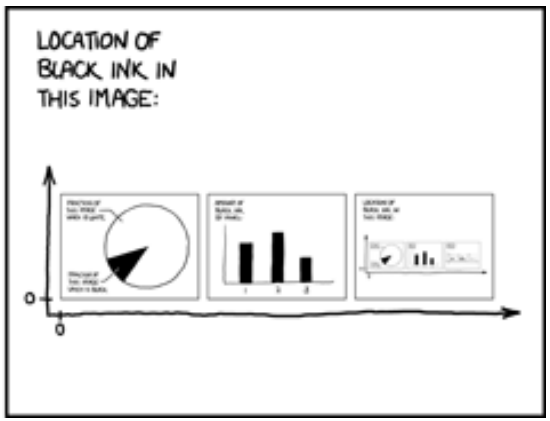
Use Meaningful Data (XKCD)







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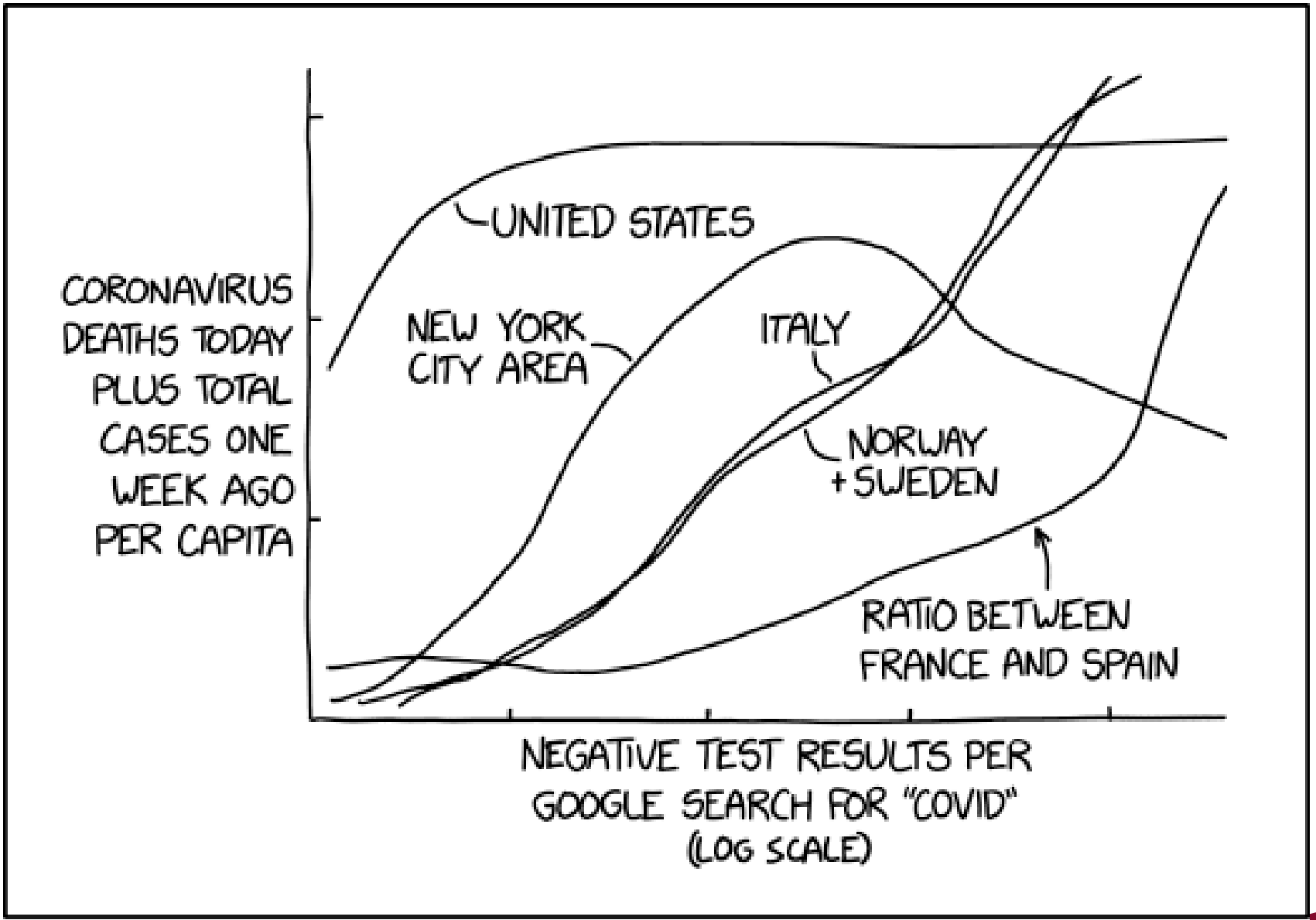
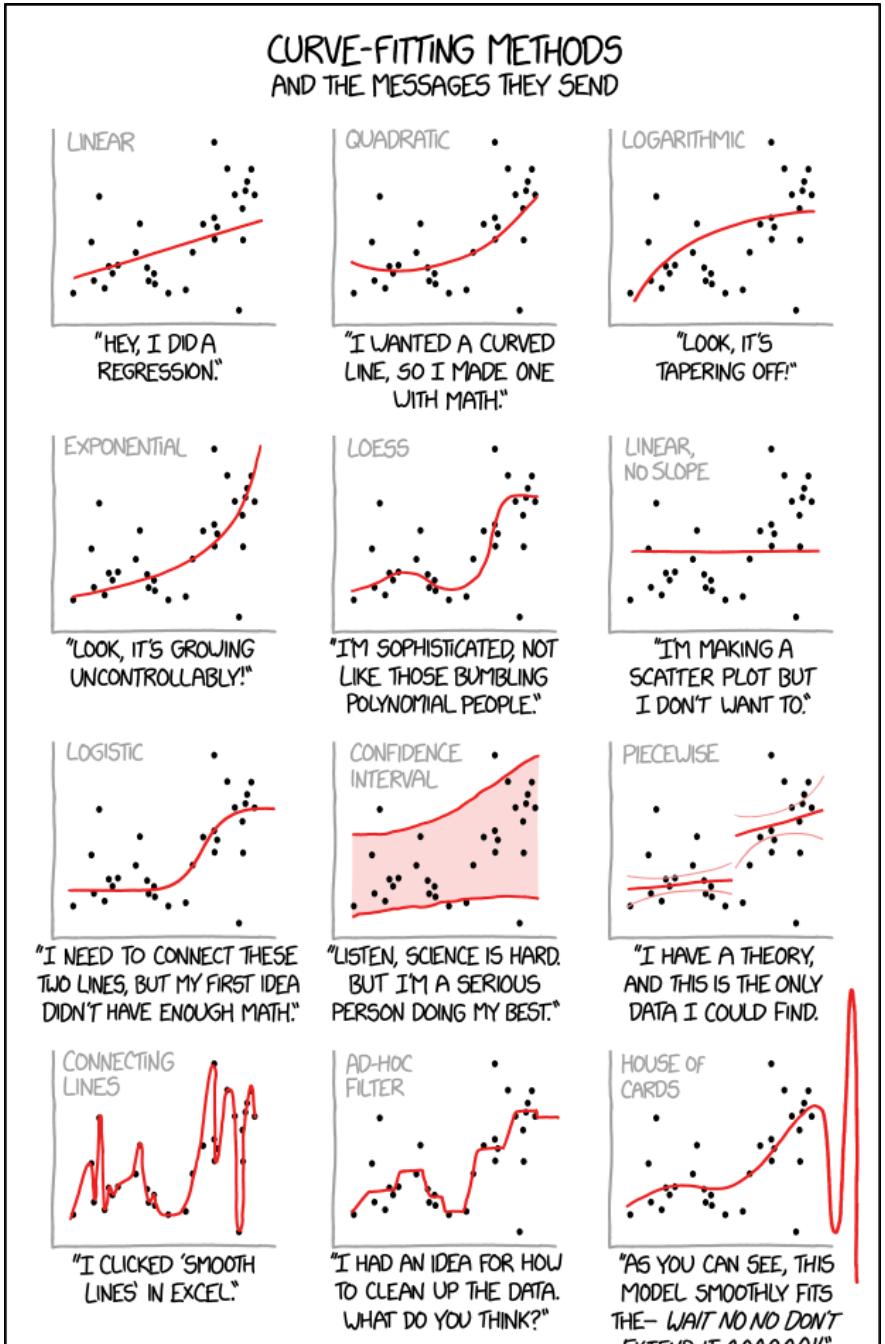
Use Related Data (XKCD)



I'M A HUGE FAN OF WEIRD GRAPHS, BUT EVEN I ADMIT SOME OF THESE CORONAVIRUS CHARTS ARE LESS THAN HELPFUL.

Do Not Mislead (XKCD)



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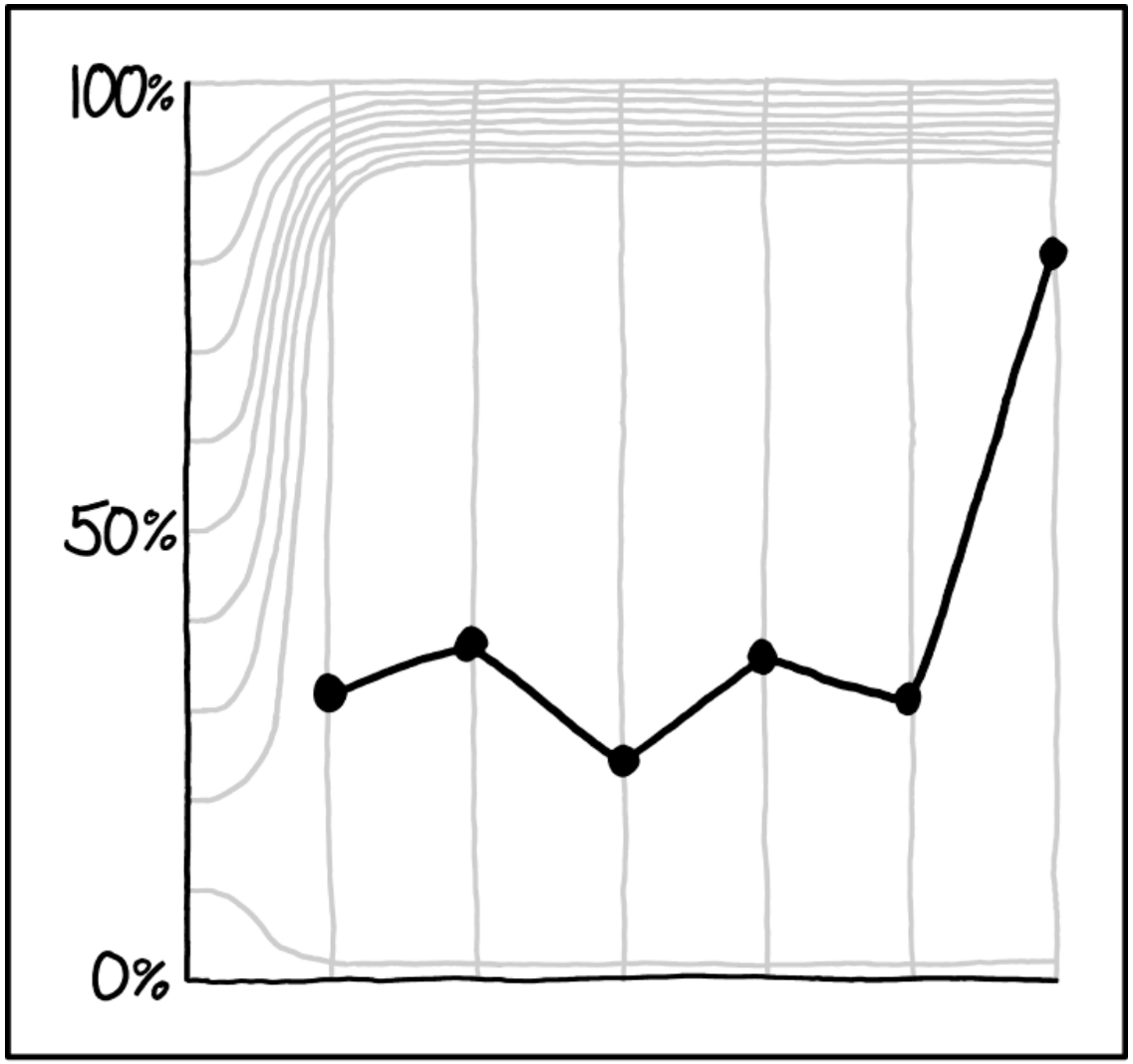
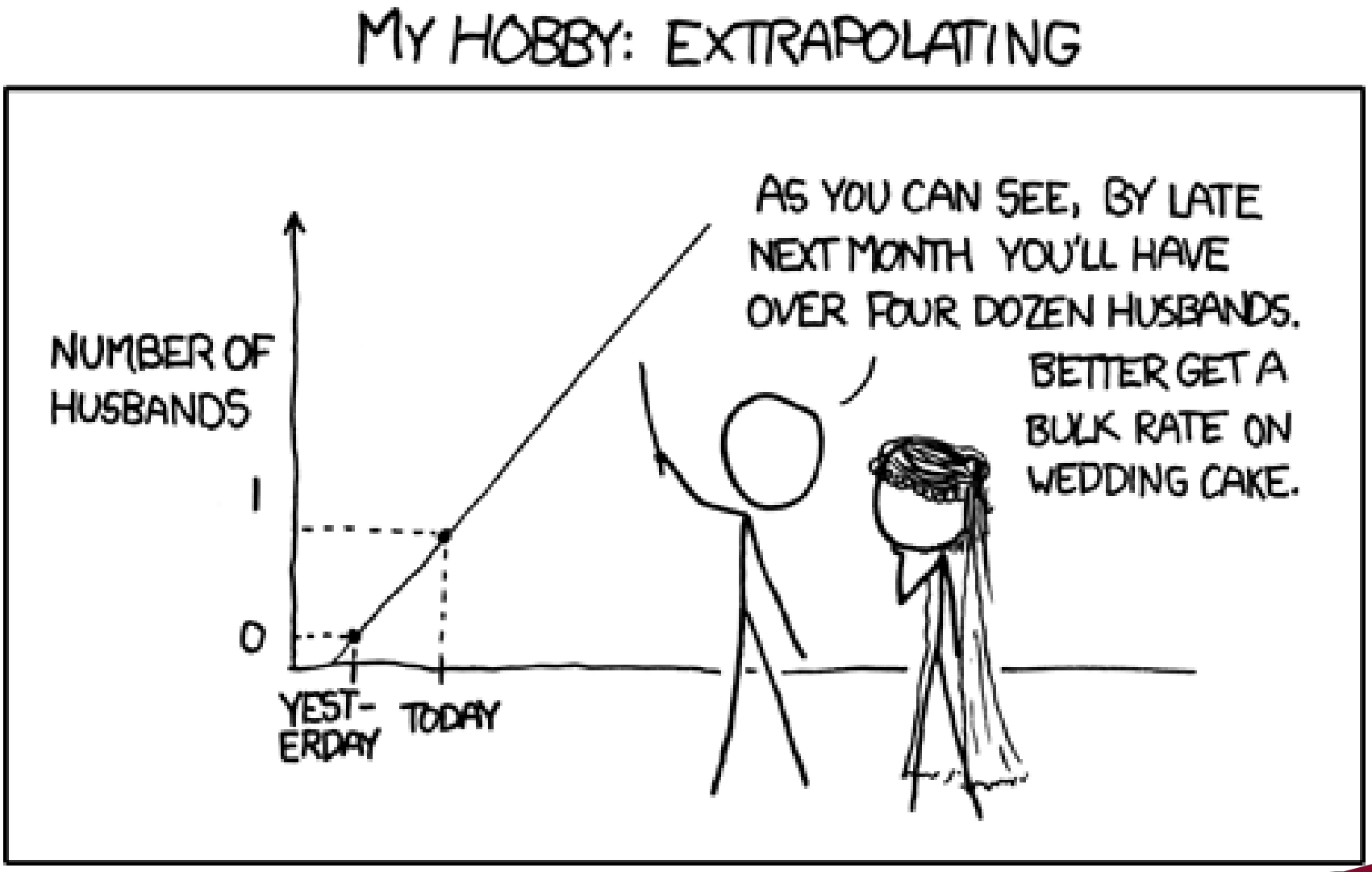
Choose Your Axes Meaningfully

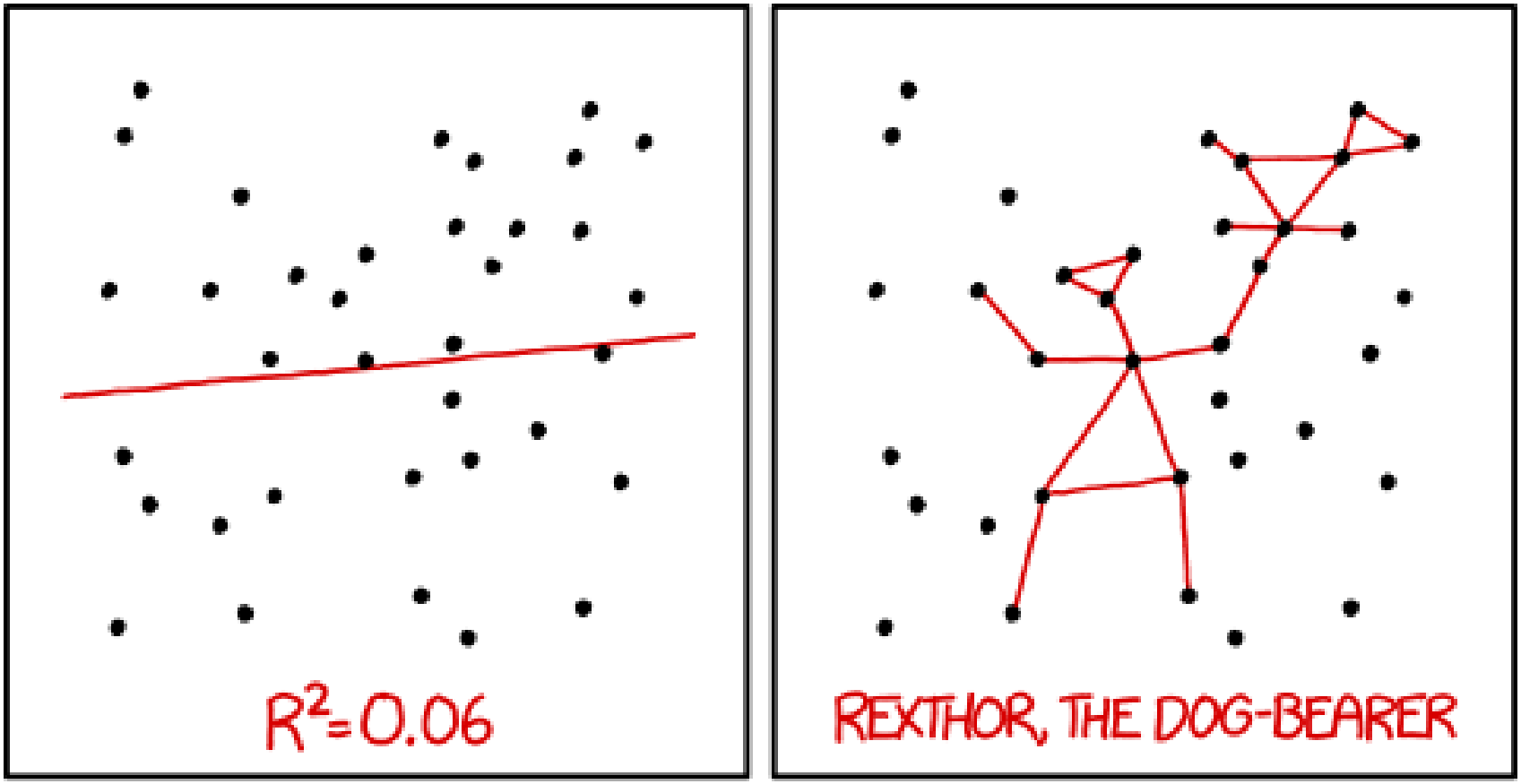


PEOPLE HAVE WISED UP TO THE "CAREFULLY CHOSEN Y-AXIS RANGE" TRICK, SO WE MISLEADING GRAPH MAKERS HAVE HAD TO GET CREATIVE.

Be Careful When Extrapolating (XKCD)

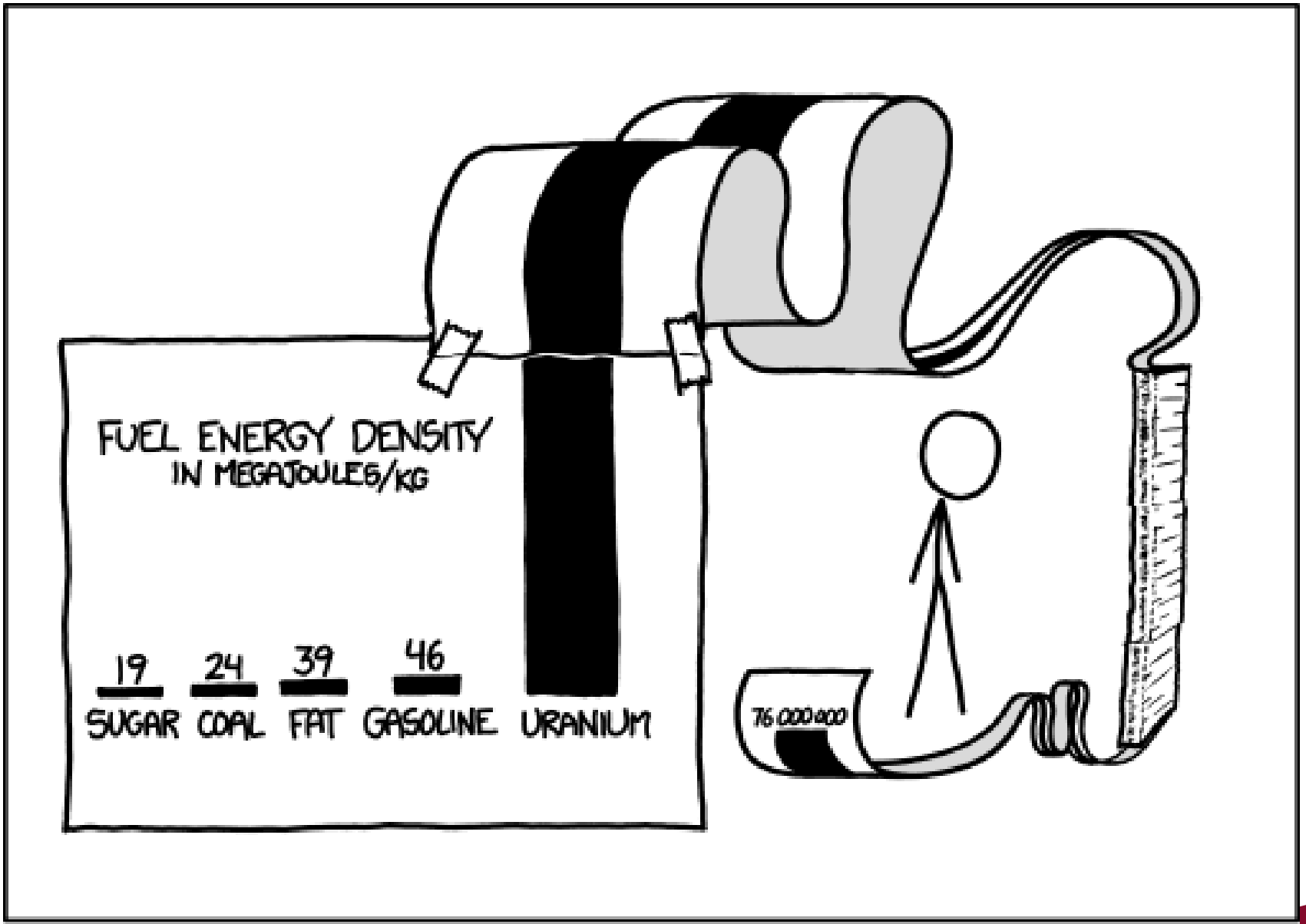


Verify Trends (XKCD)



I DON'T TRUST LINEAR REGRESSIONS WHEN IT'S HARDER TO GUESS THE DIRECTION OF THE CORRELATION FROM THE SCATTER PLOT THAN TO FIND NEW CONSTELLATIONS ON IT.

Use Appropriate Scales (XKCD)



SCIENCE TIP: LOG SCALES ARE FOR QUITTERS WHO CAN'T FIND ENOUGH PAPER TO MAKE THEIR POINT *PROPERLY.*

Don’t Lose Your Point

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Special Types of Data and Visual Analytics

- Streaming data
  - Continually changing
  - Limited buffers/windows
- Spatial, geographic, map data
  - Geo aware, irregular map boundaries, image overlays
- Network data
  - Vertices and vertex types, edges and edge types
- Text data
  - Unstructured text, e.g. from social media or web sites

Plot Elements

Map Data to Plot Elements

- X, Y axis
- Colour (point, line, fill)
- Transparency (”alpha”)
  - Be aware of print versus screen or color vision deficiency
- Pattern (fill)
- Size, Weight/Width (point, line)
- Shape, Style (pint, line)

Other Plot Elements

- Title, sub-title, captions
- Axis titles, axis labels and ”ticks”
- Legend(s)

Colour Palettes

Desirable Characteristics

- Colourful (range of values)
- Perceptually uniform (even perceptual distances)
- Robust to colourblindness (CVD)
- Pretty

Typical of Colour Palettes

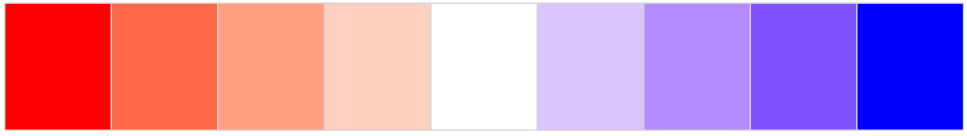
- **Monochrome/Sequential**, i.e. light to dark within a single colour
- **Divergent**, i.e. from one colour to another via white
- **Spectral**, uses a large number of colours
- **Bivariate**, e.g. combination or RGB and CMY

Colour palettes may be continuous, discrete, or categorical

Diverging

Sequential

Diverging



Spectral

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CVD (Colour Vision Deficiency)

- Monochromatism
- Protanopia (missing ”S-cone”, blue)
- Deuteranopia (missing ”M-cone”, green)
- Tritanopia (missing ”L-cone”, red)

1 in 12 men have CVD
1 in 200 women have CVD
2.6 million Canadians are colour blind

Original

MUN Faculty of Education Class Room

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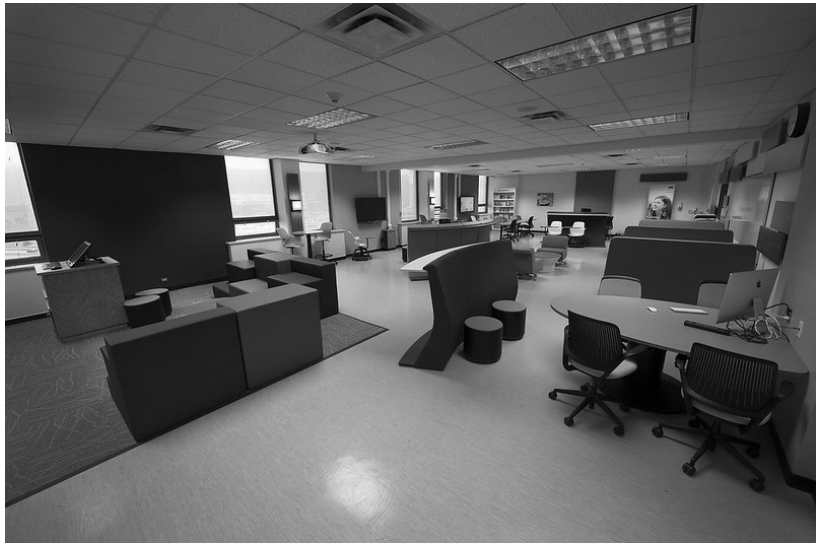
Simulated Colour Vision Deficiencies



Monochromatism

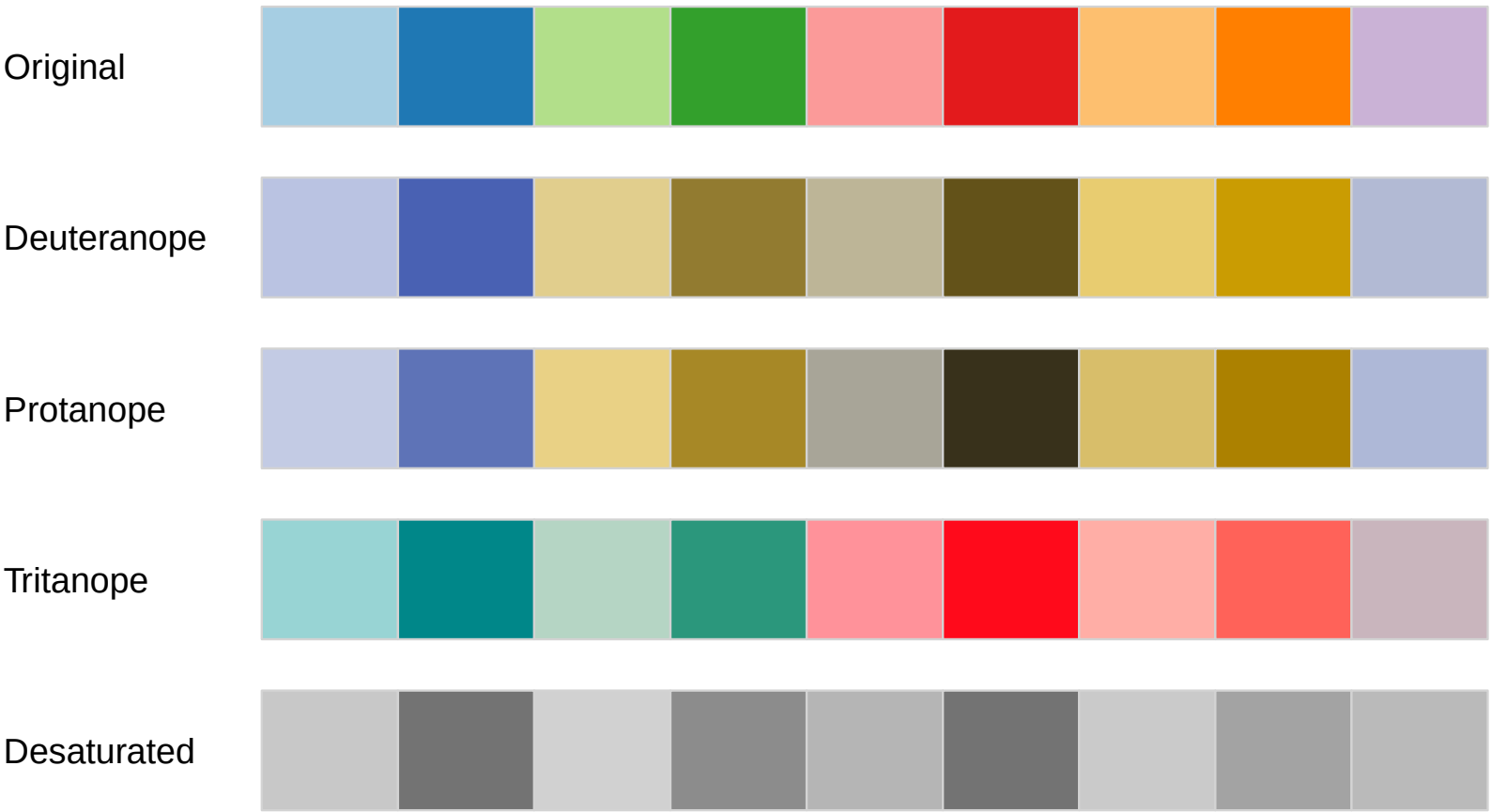
Protanopia

Deuteranopia

Tritanopia

Example: Colourbrewer Palette ”Paired”

Brewer Paired



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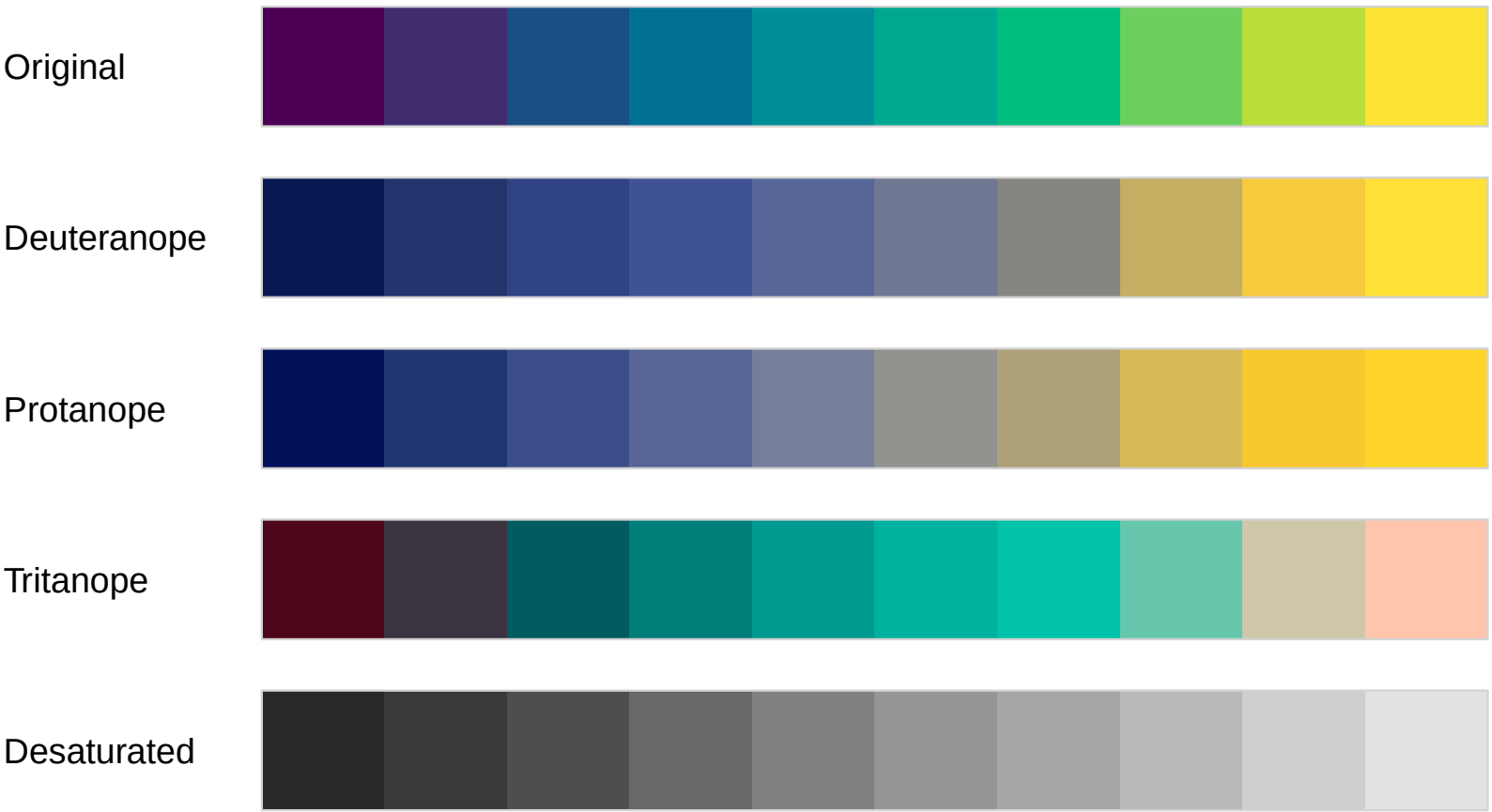
Viridis Colour Palette

Viridis Palette



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Plots for One Variable

Continuous

- **Area**: Degree of change over time, or relationship of parts to aggregate
- **Density, Dot, Frequency, Histogram**: Show frequency distribution of data

Discrete

- **Bar**: Connections among individual things, compare items of different groups
- **Pie**: Relationships of parts to aggregate

Plots for Two Variables

Both Continuous

- **Point**: Connections among numeric values, show multiple groups of data
- **Lines, Local Regression**: Relationships/correlations among multiple data series or over time
- **Text** / **Label**: Frequency of labels in content/document

One Discrete, One Continuous

- **Column**: Correlations among things or information changes over time
- **Box, Dot, Violin**: Compare distributions between many groups, display spread and skew of data

Plots for Two Variables, cont'd

Both Discrete

- **Points/Counts**: Magnitude of counts
- **Jitter**: Plots of data points

Distributions

- **Bin2D, Density2D, Hex**: Shows frequency of values over two continuous variables

Plots for Three Variables

Continuous

- **Contour, Raster and Tile**: Shows relationships among three data series

Visualizing Errors and Uncertainty

Purpose

- Give a general idea of how precise a value is, or how far a value might be from the true value
- Used to augment a given visualization

Common Visualization Styles

- Crossbar
- Errorbar
- Range (line, point)

Selected Graphics Libraries and Frameworks

R

- GGPlot (and related libraries such as GGPattern)
- Plotly for R
- GGVis (for Dashboards)
- Shiny (for Dashboards)

Python

- Matplotlib
- Seaborn
- Plotnine (”GGPlot for python”)
- Plotly (Express, GO, Dash)
- Shiny (for Dashboards)

Web & JS

- D3, ChartJS, GoogleCharts

Example Dataset 1 (”Contracts”)

- Government of Canada, Open Government Portal
- Proactive Publication – Contracts – Contracts over $10,000
- Last updated Sep 26, 2023
- https://open.canada.ca/data/en/dataset/d8f85d91-7dec-4fd1-8055-483b77225d8b/resource/fac950c0-00d5-4ec1-a4d3-9cbebf98a305

Column	Data Type
contract_date	Date
contract_value	Numeric
commodity_type	Discrete[1]
country_of_vendor	Discrete
province_of_vendor	Discrete
number_of_bids	Numeric
solicitation_procedure	Discrete

[1] Construction, Goods, Services

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Data Preparation

```
d.clean <- read.csv('contracts.cleaned.csv')

d.clean$contract_date <- as.Date(d.clean$contract_date)
d.clean$contract_period_start <- as.Date(d.clean$contract_period_start)
d.clean$economic_object_code <- as.factor(d.clean$economic_object_code)
d.clean$commodity_type <- as.factor(d.clean$commodity_type)
d.clean$commodity_code <- as.factor(d.clean$commodity_code)
d.clean$country_of_vendor <- as.factor(d.clean$country_of_vendor)
d.clean$solicitation_procedure <- as.factor(d.clean$solicitation_procedure)
d.clean$limited_tendering_reason <- as.factor(d.clean$limited_tendering_reason)
d.clean$trade_agreement_exceptions <- as.factor(d.clean$trade_agreement_exceptions)
d.clean$award_criteria <- as.factor(d.clean$award_criteria)

d.clean <- d.clean %>% mutate(vendor_province = case_when(
    str_starts(vendor_postal_code, 'A') ~ 'NL',
    str_starts(vendor_postal_code, 'B') ~ 'NS',
    str_starts(vendor_postal_code, 'C') ~ 'PE',
    str_starts(vendor_postal_code, 'E') ~ 'NB',
    str_starts(vendor_postal_code, 'G|J') ~ 'QC',
    str_starts(vendor_postal_code, 'L|M|N|K|P') ~ 'ON',
    str_starts(vendor_postal_code, 'R') ~ 'MB',
    str_starts(vendor_postal_code, 'S') ~ 'SK',
    str_starts(vendor_postal_code, 'T') ~ 'AB',
    str_starts(vendor_postal_code, 'V') ~ 'BC',
    str_starts(vendor_postal_code, 'X') ~ 'NT',
    str_starts(vendor_postal_code, 'Y') ~ 'YK',
    TRUE ~ 'UNKWN'))
d.clean$vendor_province <- as.factor(d.clean$vendor_province)
```

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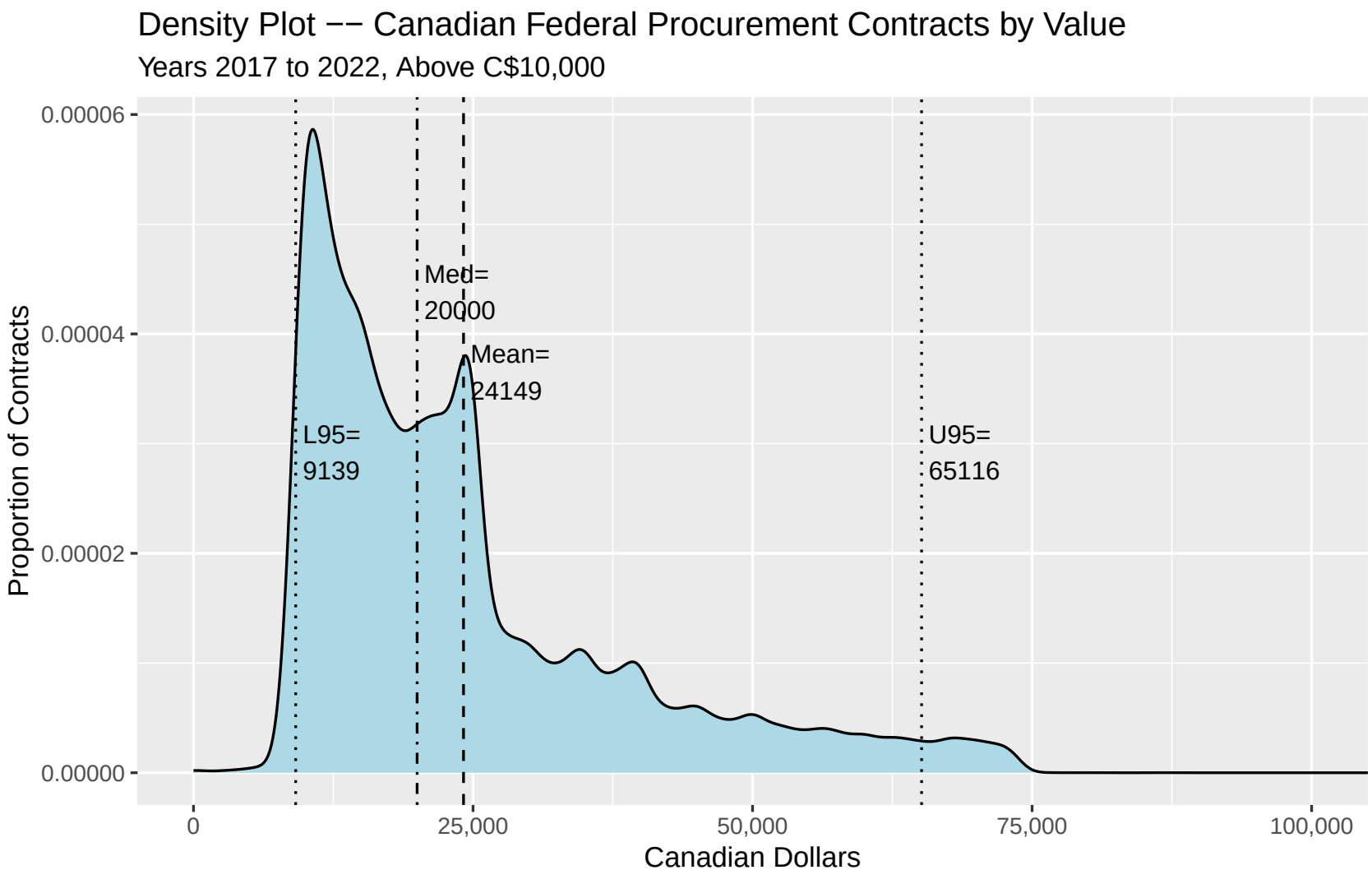
Density Chart – 1 Variable, 1 Series



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Density Chart – 1 Variable, 1 Series

```
mean_v <- d.clean %>%
   filter(original_value < quantile(original_value, .90)) %>%
   filter(contract_value < quantile(contract_value, .90)) %>%
   pivot_longer(  c(original_value, contract_value),
                  names_to="value_type",
                  values_to="value") %>%
   summarize(
       mean_v = mean(value),
       median_v = median(value),
       lower95=quantile(value, .025),
       upper95=quantile(value, .975),
       maxdensity = max(density(value)$y))
```

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Density Chart – 1 Variable, 1 Series

```
d.clean %>%
   filter(original_value < quantile(original_value, .90)) %>%
   filter(contract_value < quantile(contract_value, .90)) %>%
   pivot_longer(  c(original_value, contract_value),
                  names_to="value_type",
                  values_to="value") %>%
   ggplot(aes(value)) +
     geom_density(kernel='gaussian', n=4096, fill='lightblue') +
     scale_x_continuous(labels=scales::comma) +
     scale_y_continuous(labels=scales::comma) +
     labs(
         x = 'Canadian Dollars',
         y = 'Proportion of Contracts',
         title='Density Plot -- Canadian Federal Procurement Contracts
         subtitle='Years 2017 to 2022, Above C$10,000',
         caption='Lower and Upper 95 percentile, median and mean') +
     coord_cartesian(xlim=c(0, 100000)) +
```

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Density Chart — 1 Variable, 1 Series

```
geom_vline(data=mean_v, aes(xintercept=mean_v), linetype='dashed') +
geom_vline(data=mean_v, aes(xintercept=median_v), linetype='dotdash')
geom_vline(data=mean_v, aes(xintercept=lower95), linetype='dotted') +
geom_vline(data=mean_v, aes(xintercept=upper95), linetype='dotted') +
annotate('text', label = paste(' L95=\n ', round(mean_v$lower95), sep
  x = mean_v$lower95, y = mean_v$maxdensity/2, size=3.5, hjust=0) +
annotate('text', label = paste(' Med=\n ', round(mean_v$median_v), se
  x = mean_v$median_v, y = mean_v$maxdensity*3/4, size=3.5, hjust=0)
annotate('text', label = paste(' Mean=\n ', round(mean_v$mean_v), sep
  x = mean_v$mean_v, y = mean_v$maxdensity*5/8, size=3.5, hjust=0) +
annotate('text', label = paste(' U95=\n ', round(mean_v$upper95), sep
  x = mean_v$upper95, y = mean_v$maxdensity/2, size=3.5, hjust=0)
```

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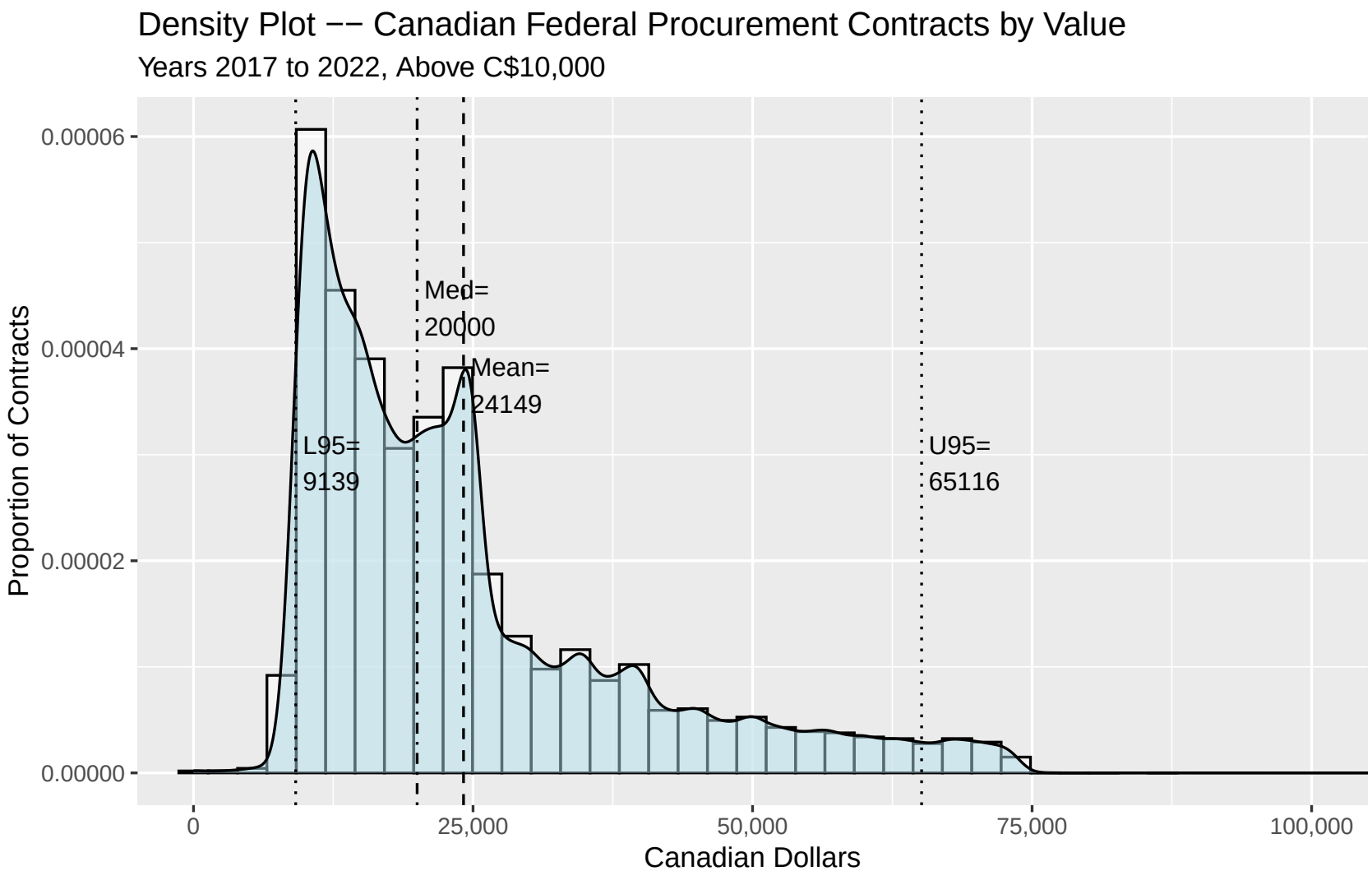
Histogram – 1 Variable, 1 Series



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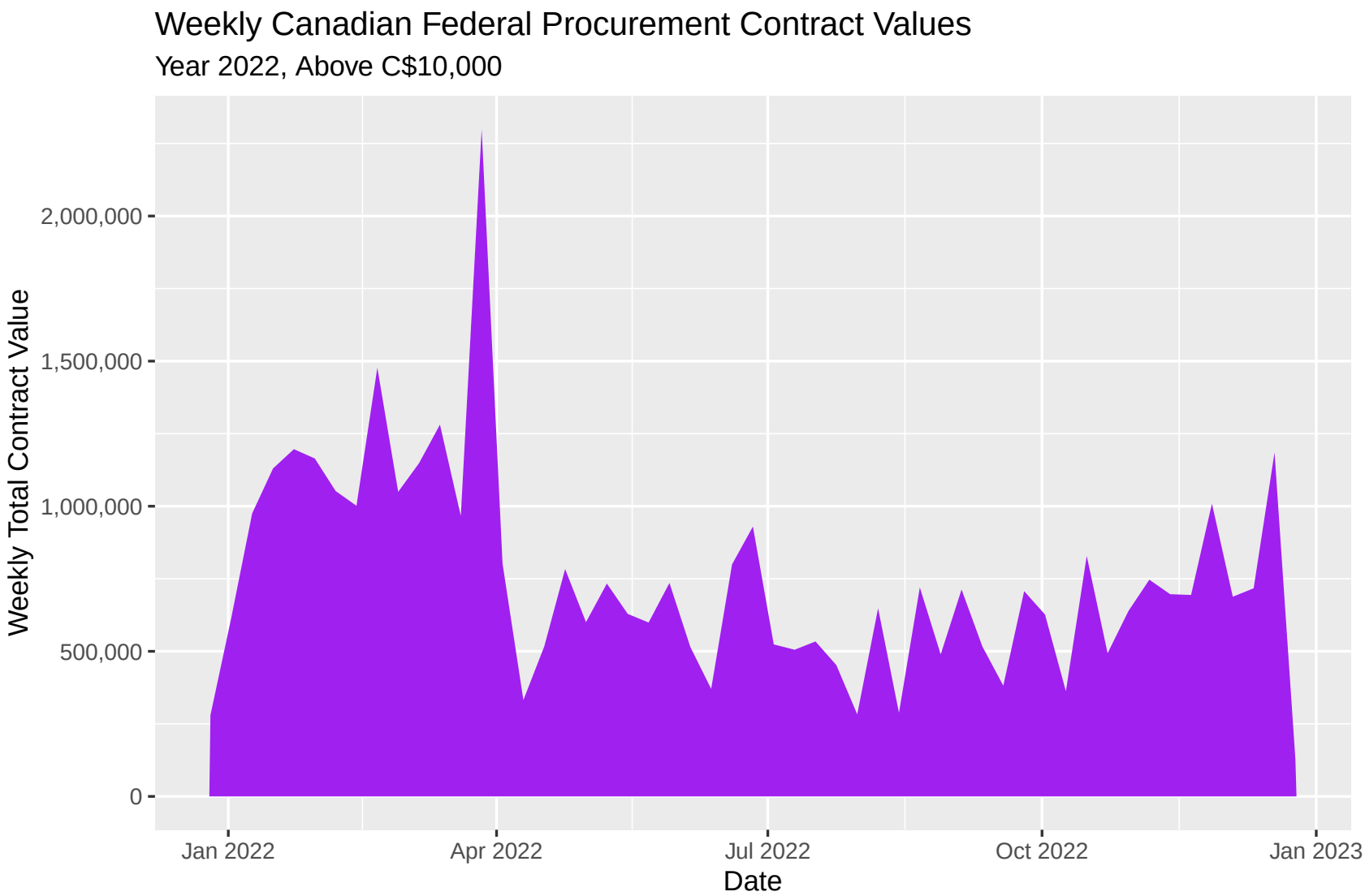
Histogram – 1 Variable, 1 Series

```
...

ggplot(aes(value)) +
 geom_histogram(
          aes(y=..density..),
          bins=50,
          fill='white',
          color='black',
          alpha=0.5) +

...
```

Area Chart – 1 Variable, 1 Series



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Area Chart – 1 Variable, 1 Series

```
d.clean %>%
   filter(original_value < quantile(original_value, .90)) %>%
   filter(contract_value < quantile(contract_value, .90)) %>%
   filter(contract_date >= '2022-01-01') %>%
   filter(contract_date <= '2022-12-31') %>%
   mutate(commodity_type=case_when(
                commodity_type=='C' ~ 'Construction',
                commodity_type=='G' ~ 'Goods',
                commodity_type=='S' ~ 'Services')) %>%
   mutate(contract_quarter = floor_date(contract_date, 'week')) %>%
   group_by(contract_quarter) %>%
   summarize(daily_value = sum(contract_value)) %>%
   ungroup() %>%
```

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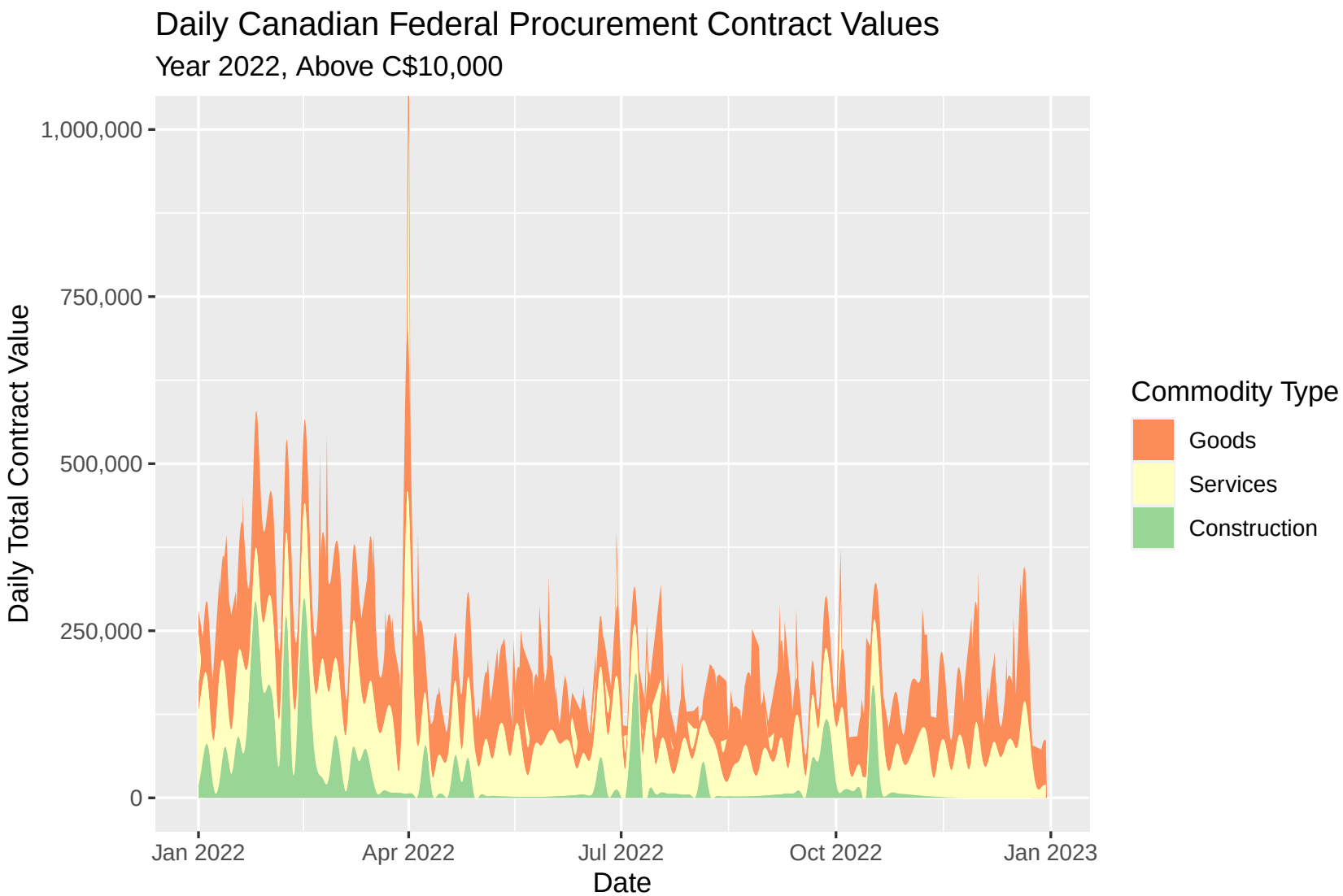
Area Chart – 1 Variable, 1 Series

```
ggplot(aes(contract_quarter, daily_value)) +
 geom_area(fill='purple') +
 scale_y_continuous(labels=scales::comma) +
 labs( x = 'Date',
       y = 'Weekly Total Contract Value',
       title='Weekly Canadian Federal Procurement Contract Values',
       subtitle='Year 2022, Above C$10,000')
```

Area Chart – 1 Variable, 3 Series



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Area Chart – 1 Variable, 3 Series

```
...

ggplot(aes( contract_date,
            daily_value,
            fill=reorder(commodity_type, -daily_value))) +
 geom_area() +
 geom_stream(type='ridge', bw=0.2) +
 scale_fill_brewer(palette="Spectral") +

...
```

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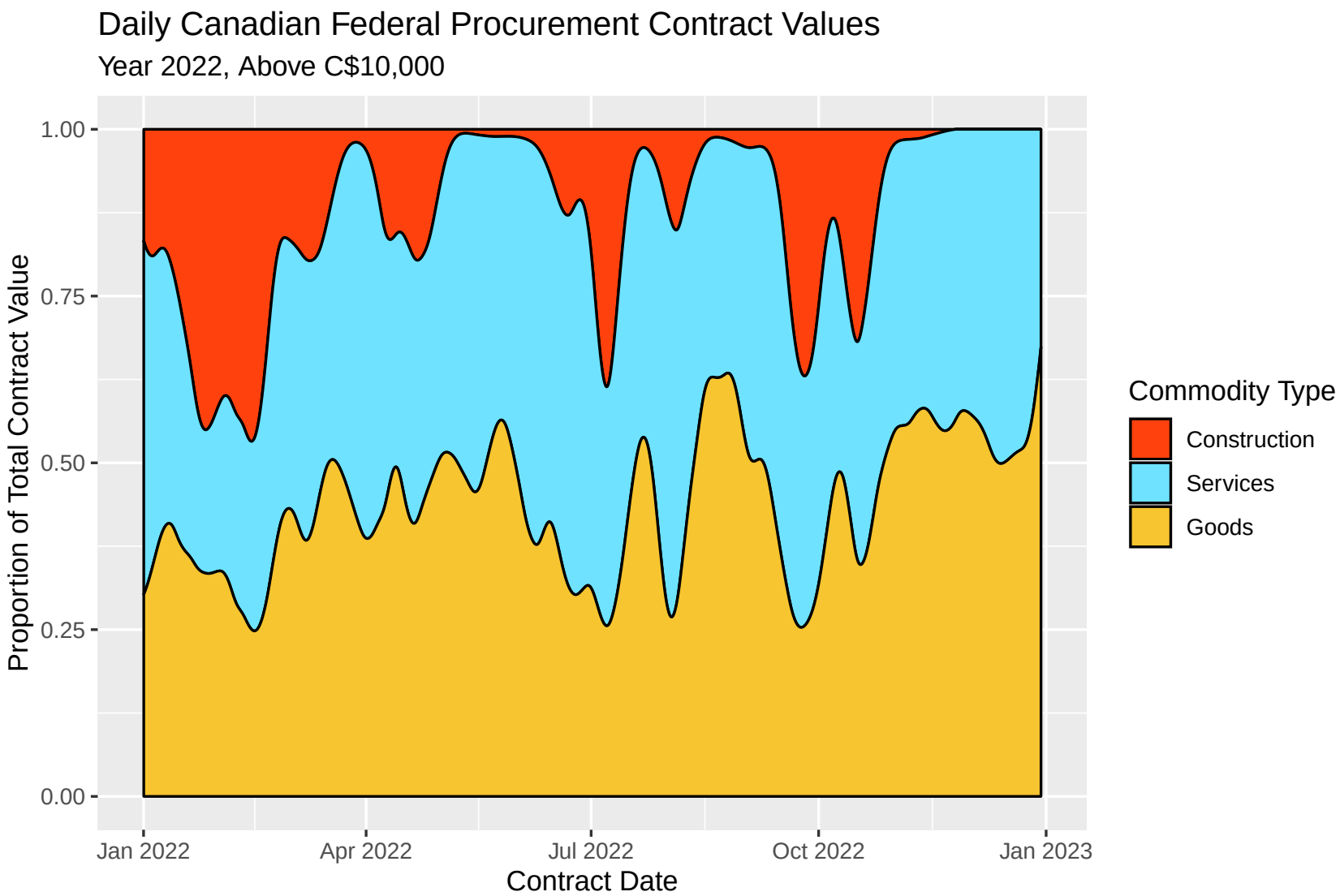
Area Chart (Stacked, Smoothed) – 1 Variable, 3 Series



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Area Chart (Stacked, Smoothed) – 1 Variable, 3 Series

```
...

ggplot(aes(
    x=contract_date,
    y=daily_value,
    fill=reorder(commodity_type, daily_value))) +
 geom_area(position="fill", alpha=0.5) +
 geom_stream(type = "proportional", bw=0.5, color='black') +

...
```

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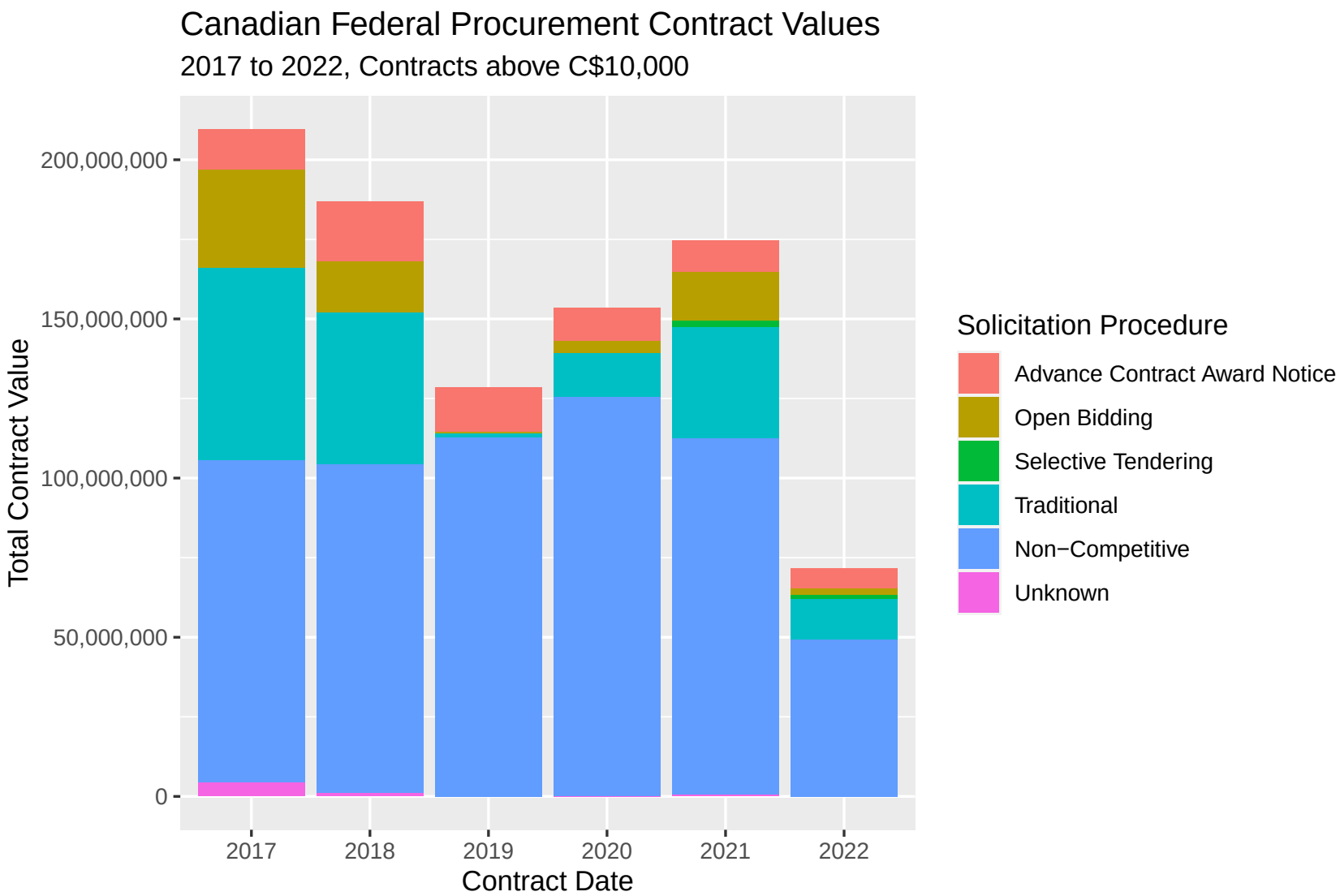
Column Chart – 2 Variables, 3 Series



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Column Chart – 2 Variables, 3 Series

```
d.clean %>%
   filter(original_value < quantile(original_value, .95)) %>%
   filter(contract_value < quantile(contract_value, .95)) %>%
   mutate(year=substr(contract_date, 1, 4)) %>%
   filter(contract_date >= '2017-01-01') %>%
   filter(contract_date <= '2022-12-31') %>%
   group_by(solicitation_procedure, year) %>%
   summarize(totalvalue = sum(contract_value)) %>%
   ungroup() %>%
   ggplot(aes(year, totalvalue, fill=solicitation_procedure)) +
      geom_col() +
      scale_fill_brewer(palette="Paired") +
      scale_fill_discrete(
         labels=c("Advance Contract Award Notice", "Open Bidding",
                  "Selective Tendering", "Traditional",
                  "Non-Competitive", "Unknown")) +
      scale_y_continuous(labels=scales::comma) +
      labs(x = 'Contract Date', y = 'Annual Total Contract Value', fil
```

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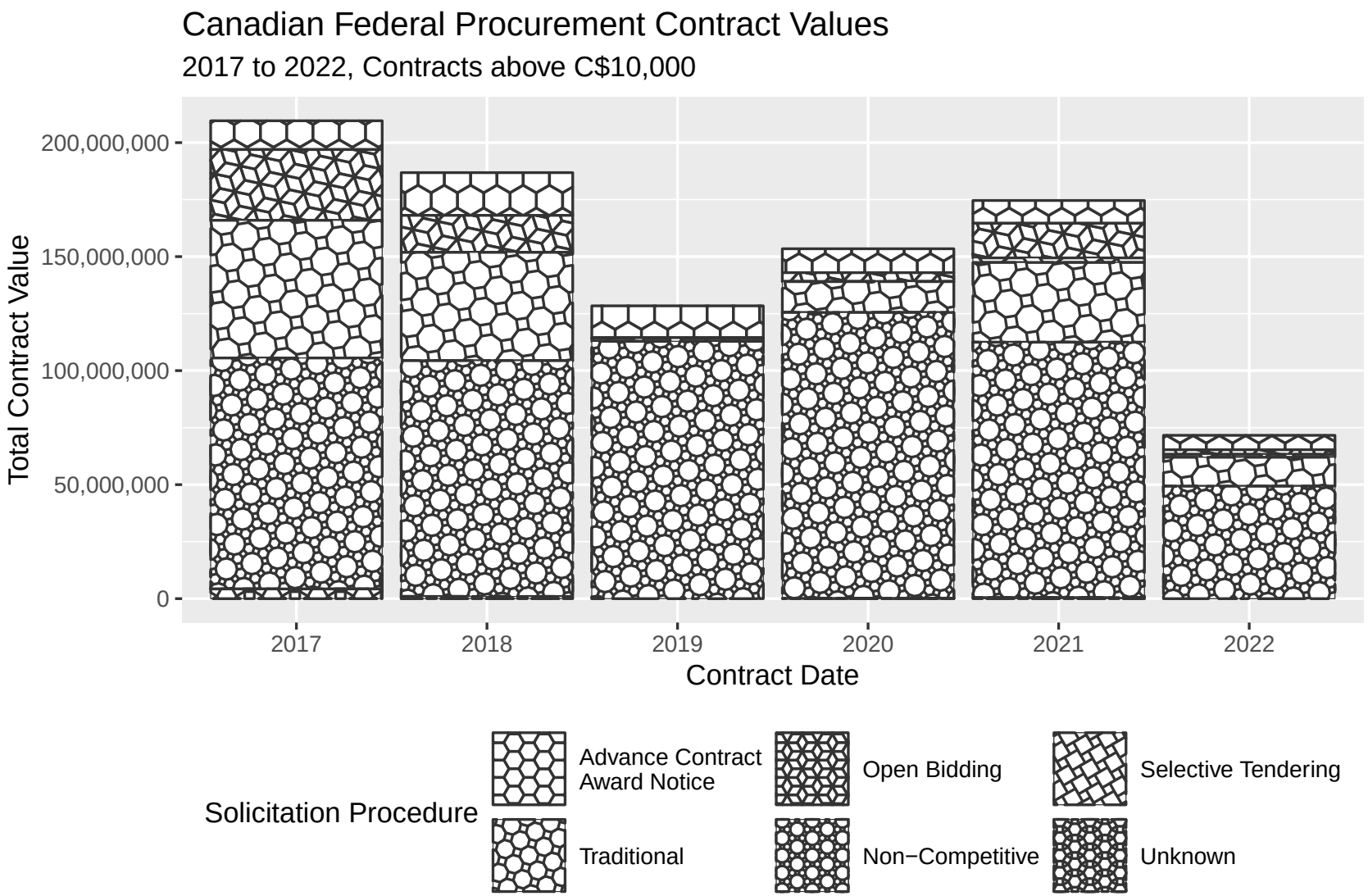
Column Chart (Pattern) – 2 Variables, 6 Series



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Column Chart (Pattern) – 2 Variables, 6 Series

```
ggplot(aes(year, totalvalue, pattern_angle=solicitation_procedure)) +
  geom_col_pattern( aes(pattern_type=solicitation_procedure),
                    pattern_fill='white',
                    pattern='polygon_tiling',
                    pattern_scale=0.5,
                    pattern_key_scale_factor=0.4) +
  scale_pattern_type_manual(
      values = c('hexagonal', 'rhombille', 'pythagorean',
                 'truncated_square', 'rhombitrihexagonal',
                 'truncated_trihexagonal'),
      labels=c("Advance Contract\nAward Notice",
               "Open Bidding", "Selective Tendering",
               "Traditional", "Non-Competitive", "Unknown")) +
  scale_y_continuous(labels=scales::comma) +
  labs(x = 'Contract Date', y = 'Annual Total Contract Value',
       pattern_type='Solicitation Procedure',
       title='Canadian Federal Procurement Contract Values',
       subtitle='2017 to 2022, Contracts above C$10,000') +
```

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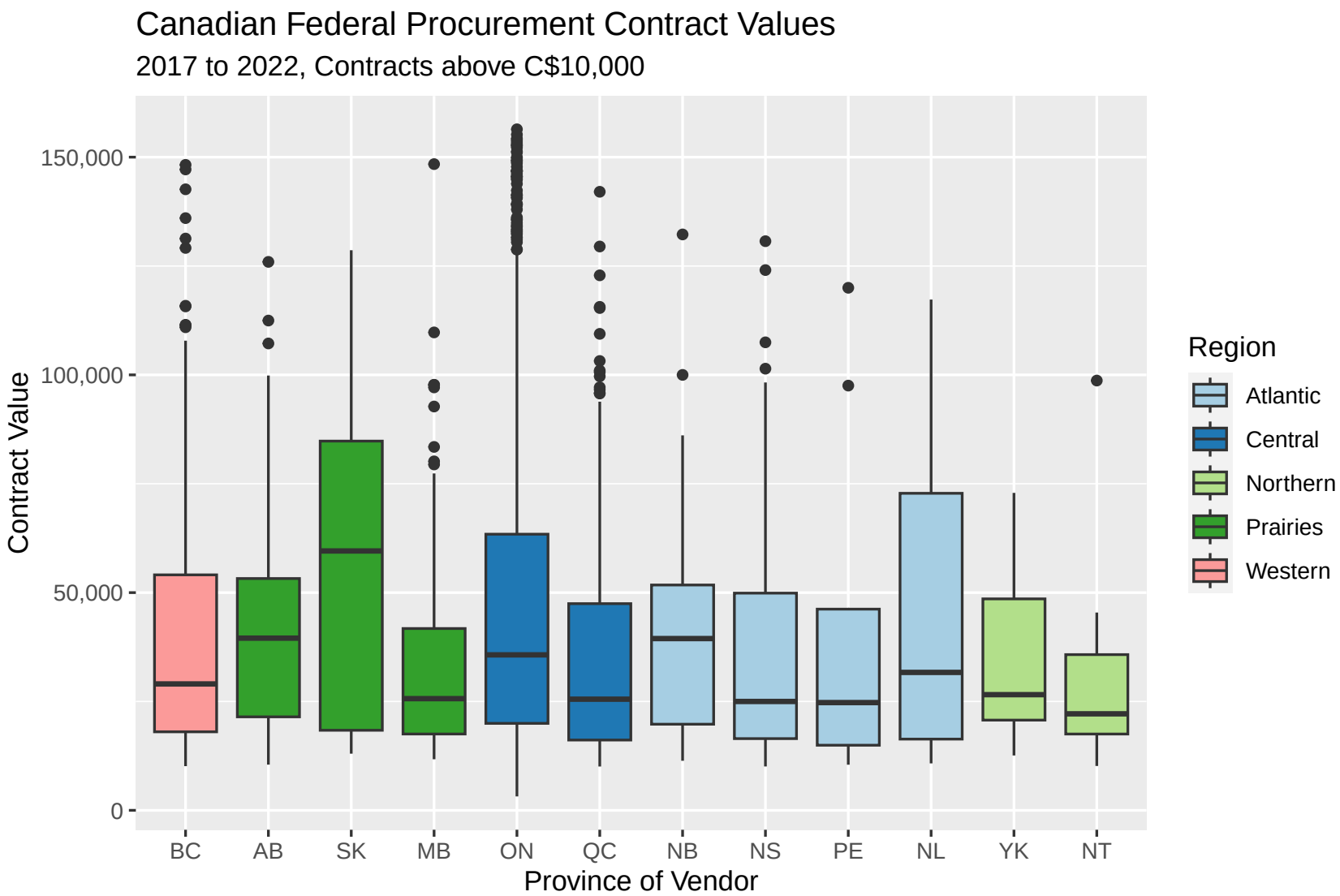
Column Chart (Pattern) – 2 Variables, 6 Series

```
guides(pattern_angle=FALSE, pattern_type=guide_legend(nrow=1)) +
guides(pattern_type=guide_legend(
           nrow=2,byrow=TRUE,
           legend.position='bottom',
           keyheight=unit(1, 'cm'),
       keywidth=unit(1, 'cm'))) +
theme(legend.key.size=unit(1, 'cm'), legend.position='bottom')
```

Box Plot – 2 Variables, 5 Series



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Box Plot – 2 Variables, 5 Series

```
d.clean %>%
   mutate(region = case_when(
        vendor_province %in% c('NL', 'NS', 'PE', 'NB') ~ 'Atlantic',
        vendor_province %in% c('YK', 'NT') ~ 'Northern',
        vendor_province %in% c('AB', 'SK', 'MB') ~ 'Prairies',
        vendor_province %in% c('QC', 'ON') ~ 'Central',
        vendor_province %in% c('BC') ~ 'Western')) %>%
   mutate(vendor_province = factor(vendor_province,
        levels=c('BC', 'AB', 'SK', 'MB', 'ON', 'QC', 'NB',
                 'NS', 'PE', 'NL', 'YK', 'NT'), ordered=TRUE)) %>%
   ggplot(aes(vendor_province, contract_value, fill=region)) +
      geom_boxplot() +
      scale_fill_brewer(palette="Paired") +
      scale_y_continuous(labels=scales::comma) +
      labs(x = 'Province of Vendor',
           y = 'Contract Value',
           fill='Region',
           title='Canadian Federal Procurement Contract Values',
           subtitle='2017 to 2022, Contracts above C$10,000')
```

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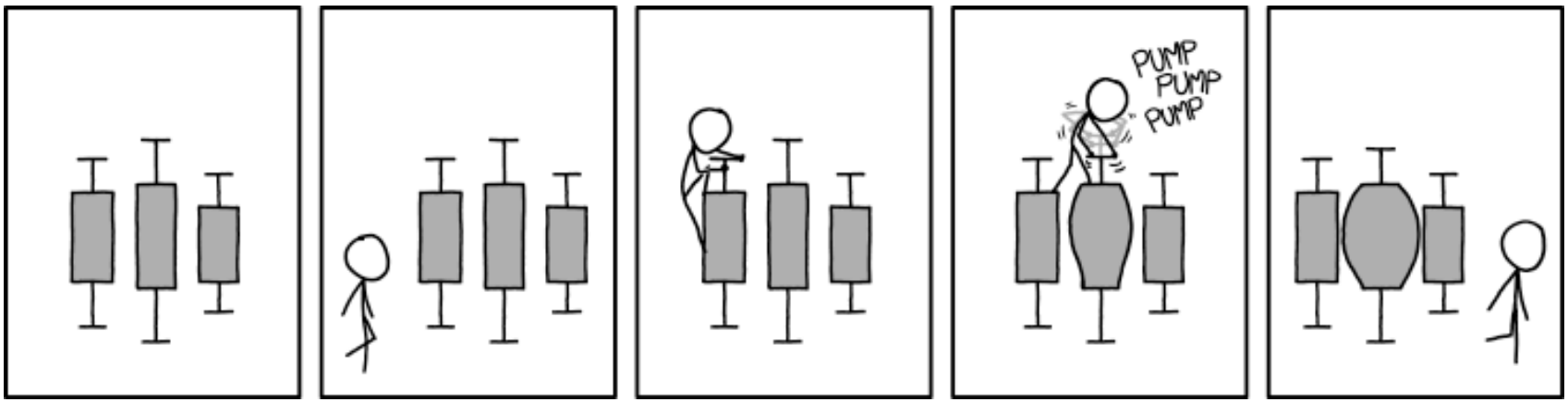
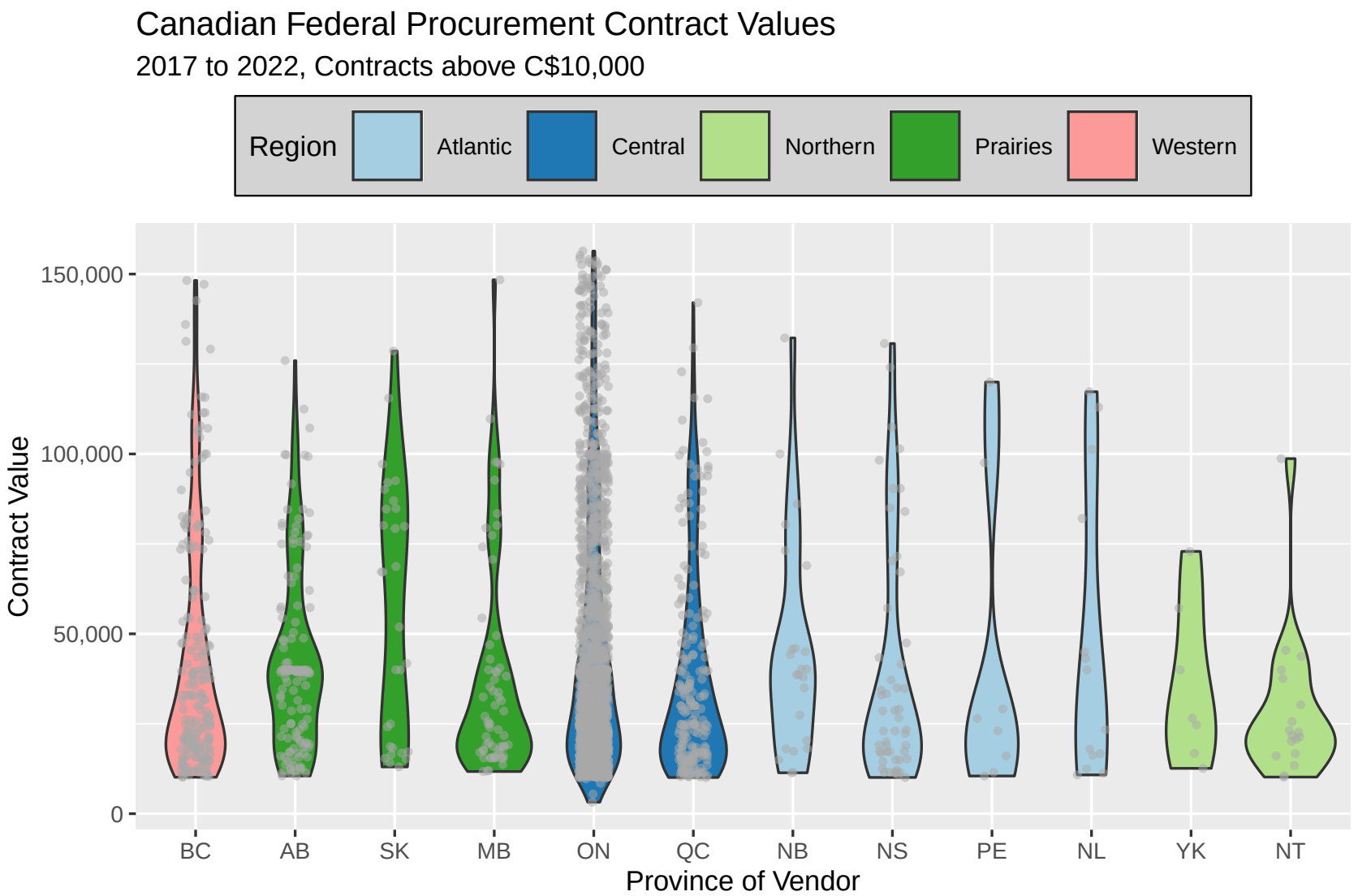
Boxplot (XKCD)



Violin Plot (with Jitter) – 2 Variables, 5 Series



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Violin Plot (with Jitter) – 2 Variables, 5 Series

```
...

ggplot(aes(vendor_province, contract_value, fill=region)) +
  geom_violin() +
  scale_fill_brewer(palette="Paired") +
  scale_y_continuous(labels=scales::comma) +
  labs(x = 'Province of Vendor',
       y = 'Contract Value',
       fill='Region',
       title='Canadian Federal Procurement Contract Values',
       subtitle='2017 to 2022, Contracts above C$10,000') +
  geom_jitter(width=0.15, color='darkgrey',
              size=1, fill=NA, alpha=0.5) +
  theme(legend.position='top',
        legend.background=element_blank(),
        legend.box.background=
            element_rect(color='black', fill='lightgrey'),
            legend.key.size=unit(1, 'cm'))
...
```

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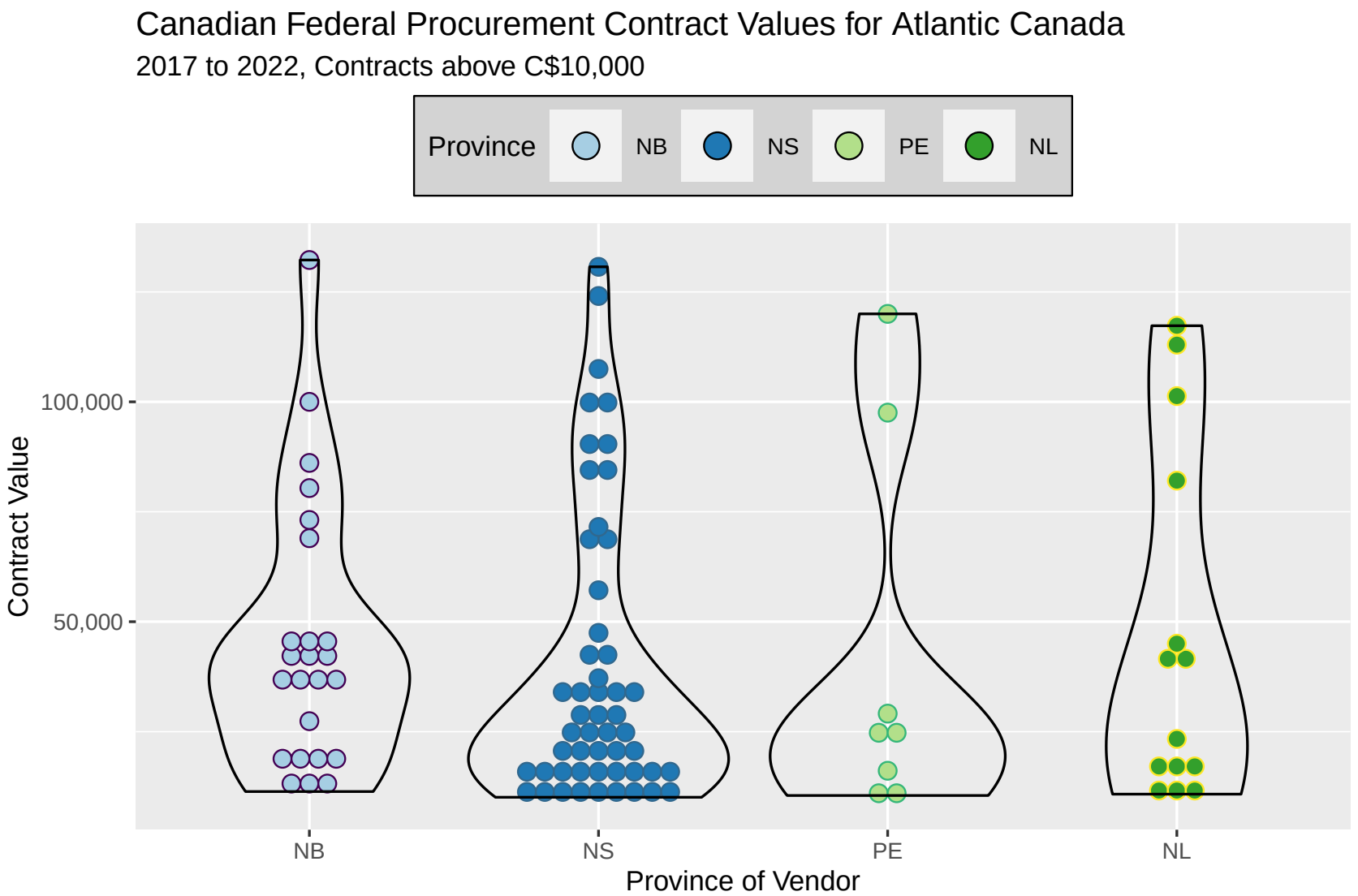
Dot Plot (with Violin) – 2 Variables



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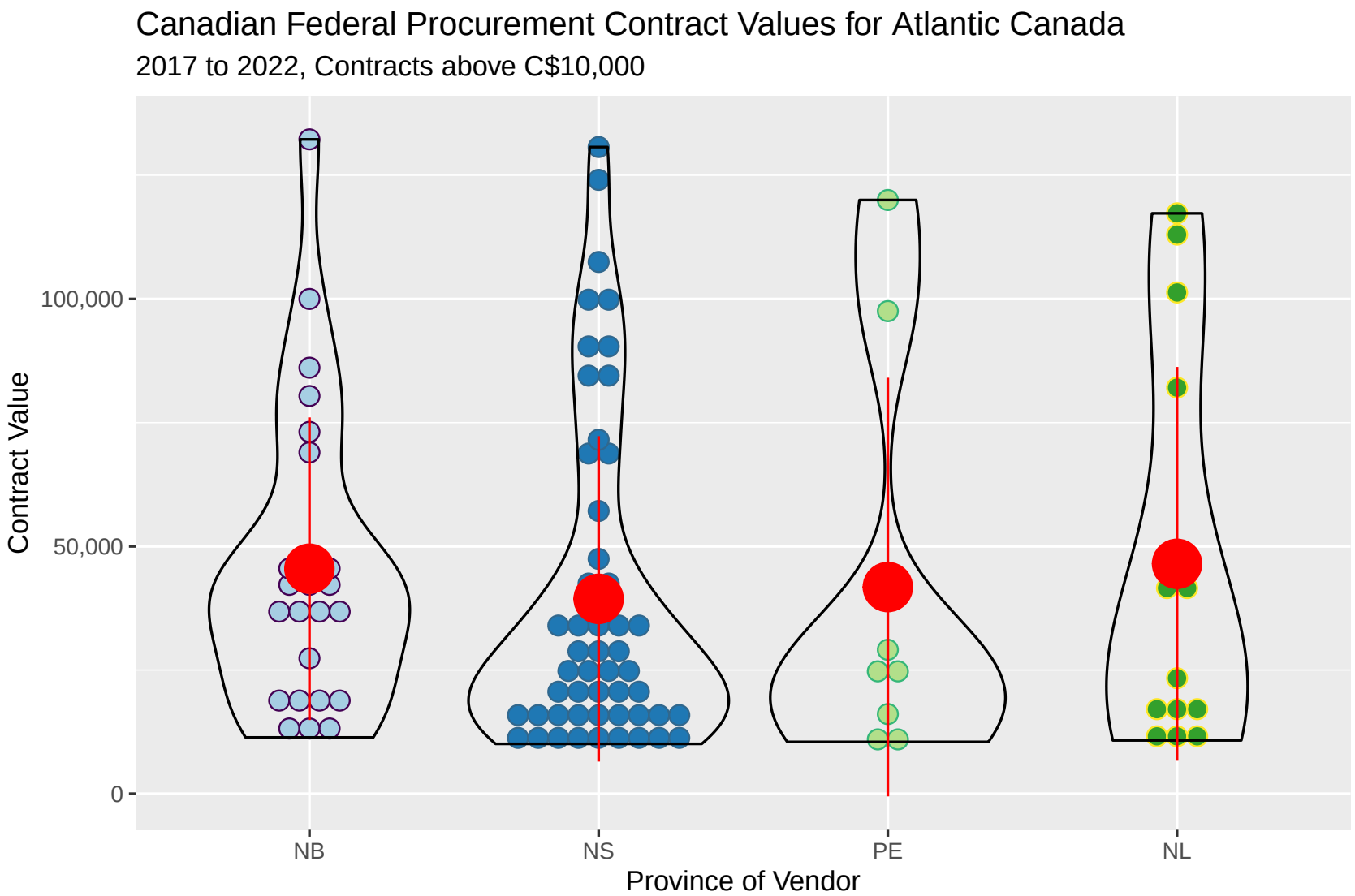
Box Plot – 2 Variables, 5 Series

```
...

ggplot(aes(x=vendor_province, y=contract_value,
           color=vendor_province, fill=vendor_province)) +
  geom_dotplot(binaxis='y', stackdir='center', dotsize=1) +
  geom_violin(color='black', fill=NA) +
  scale_fill_brewer(palette="Paired")

...
```

Dot Plot (with Summaries) – 2 Variables



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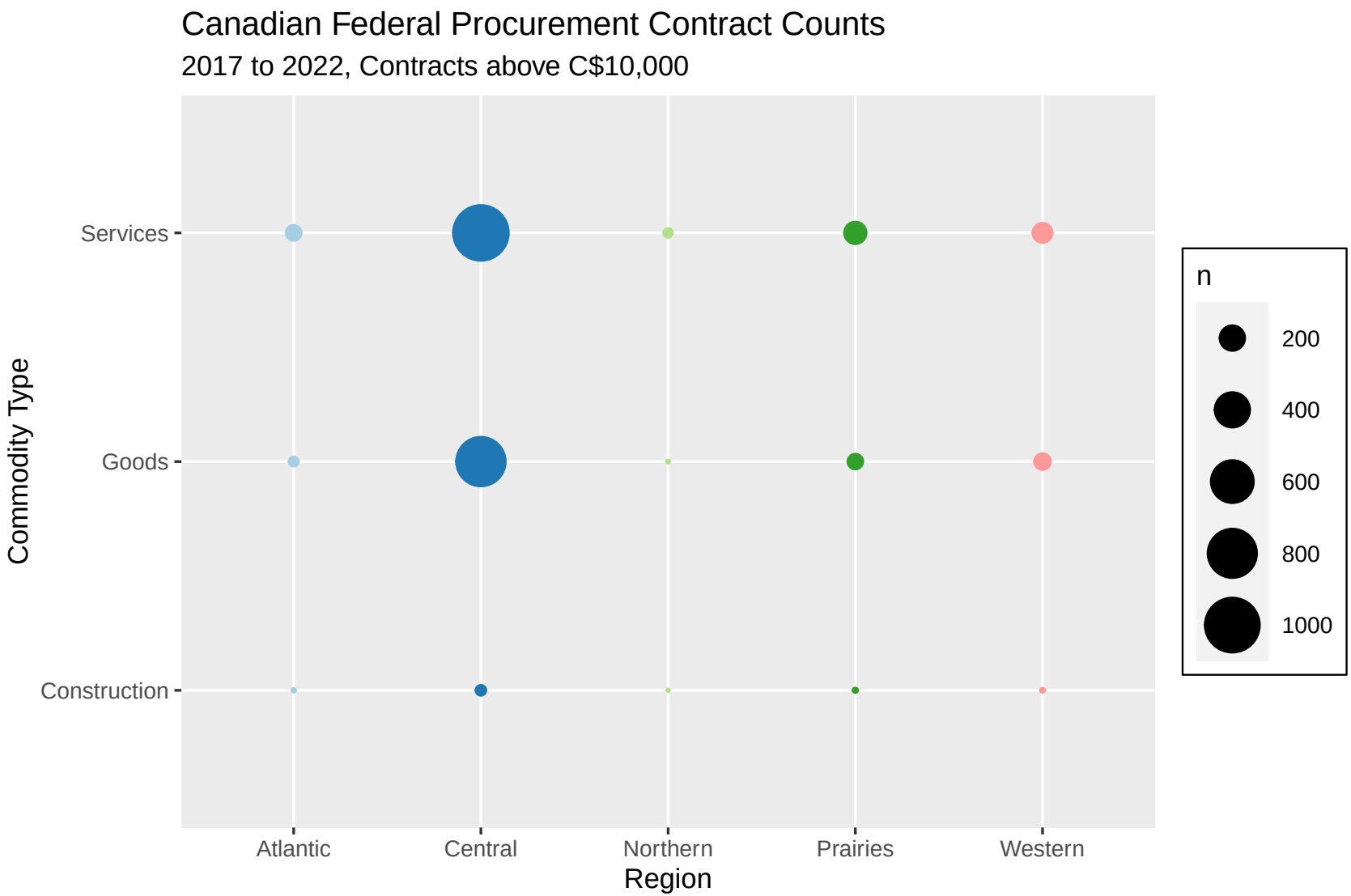
Dot Plot (with Summaries) – 2 Variables

```
...

ggplot(aes(x=vendor_province, y=contract_value,
           color=vendor_province, fill=vendor_province)) +
  geom_dotplot(binaxis='y', stackdir='center', dotsize=1) +
  geom_violin(color='black', fill=NA) +
  stat_summary(fun.data=mean_sdl,
               fun.args=list(mult=1),
               size=2, color='red',
               geom="pointrange")

...
```

Count Plot – 2 Discrete Variables



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Count Plot – 2 Discrete Variables

```
...

ggplot(aes(region, commodity_type)) +
  geom_count(aes(color=region))+
  scale_size_area(max_size=10, n.breaks=6) +
  scale_color_brewer(palette="Paired") +
  scale_y_discrete(labels=c('Construction', 'Goods', 'Services')) +
  guides(color=FALSE) +
  labs(x = 'Region', y = 'Commodity Type'
       title='Canadian Federal Procurement Contract Counts',
       subtitle='2017 to 2022, Contracts above C$10,000') +
 theme(legend.background=element_blank(),
       legend.box.background=element_rect(color='black', fill=NA),
       legend.key.size=unit(1, 'cm'))

...
```

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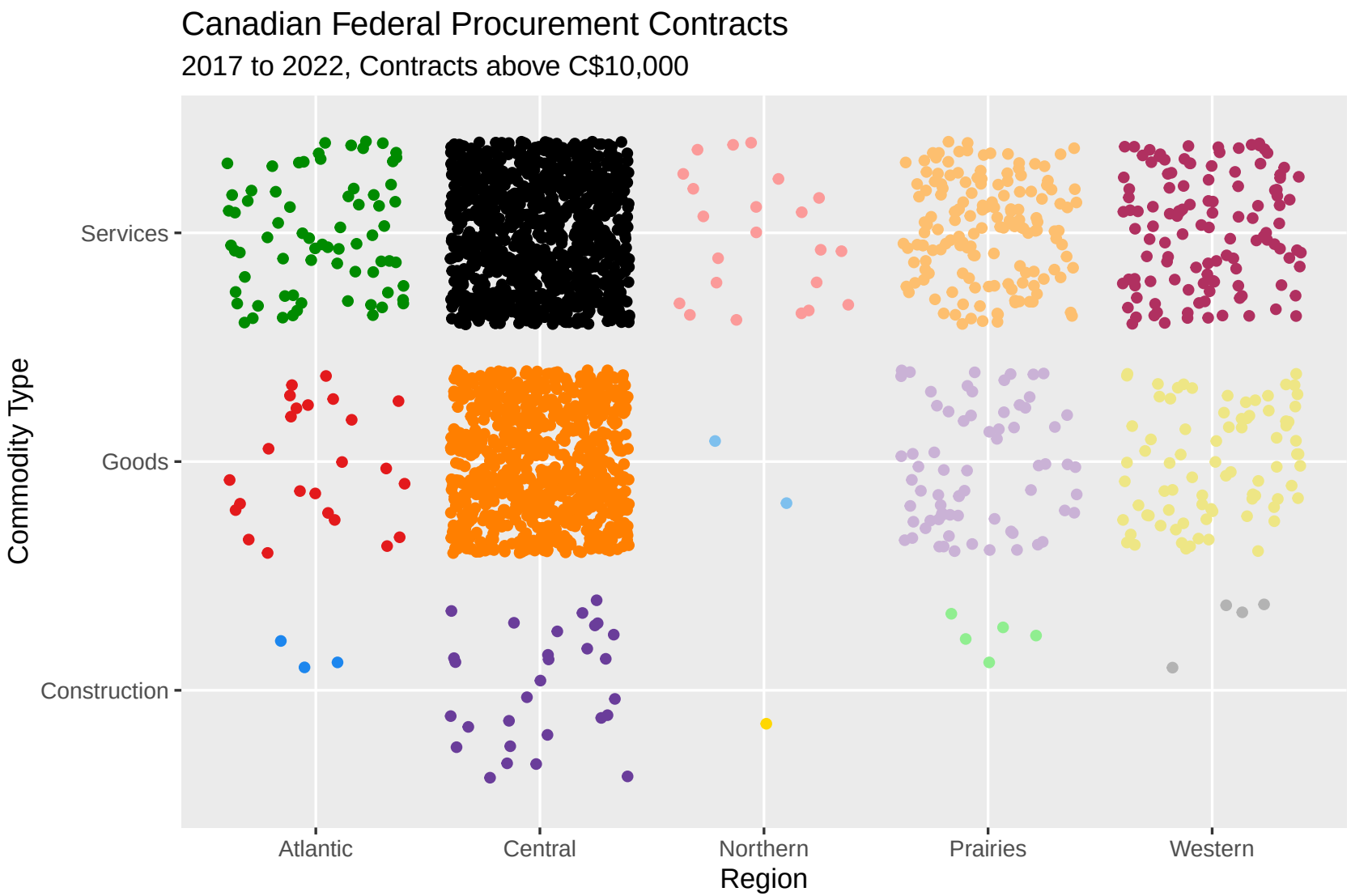
Jitter Plot – 2 Discrete Variables



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Jitter Plot – 2 Discrete Variables

```
...

ggplot(aes(region, commodity_type)) +
  geom_jitter(aes(color=paste(region, commodity_type))) +
  scale_color_manual(values=c25) +
  scale_y_discrete(labels=c('Construction', 'Goods', 'Services')) +
  guides(color=FALSE) +
  labs(x = 'Region', y = 'Commodity Type',
       title='Canadian Federal Procurement Contracts',
       subtitle='2017 to 2022, Contracts above C$10,000')

...
```

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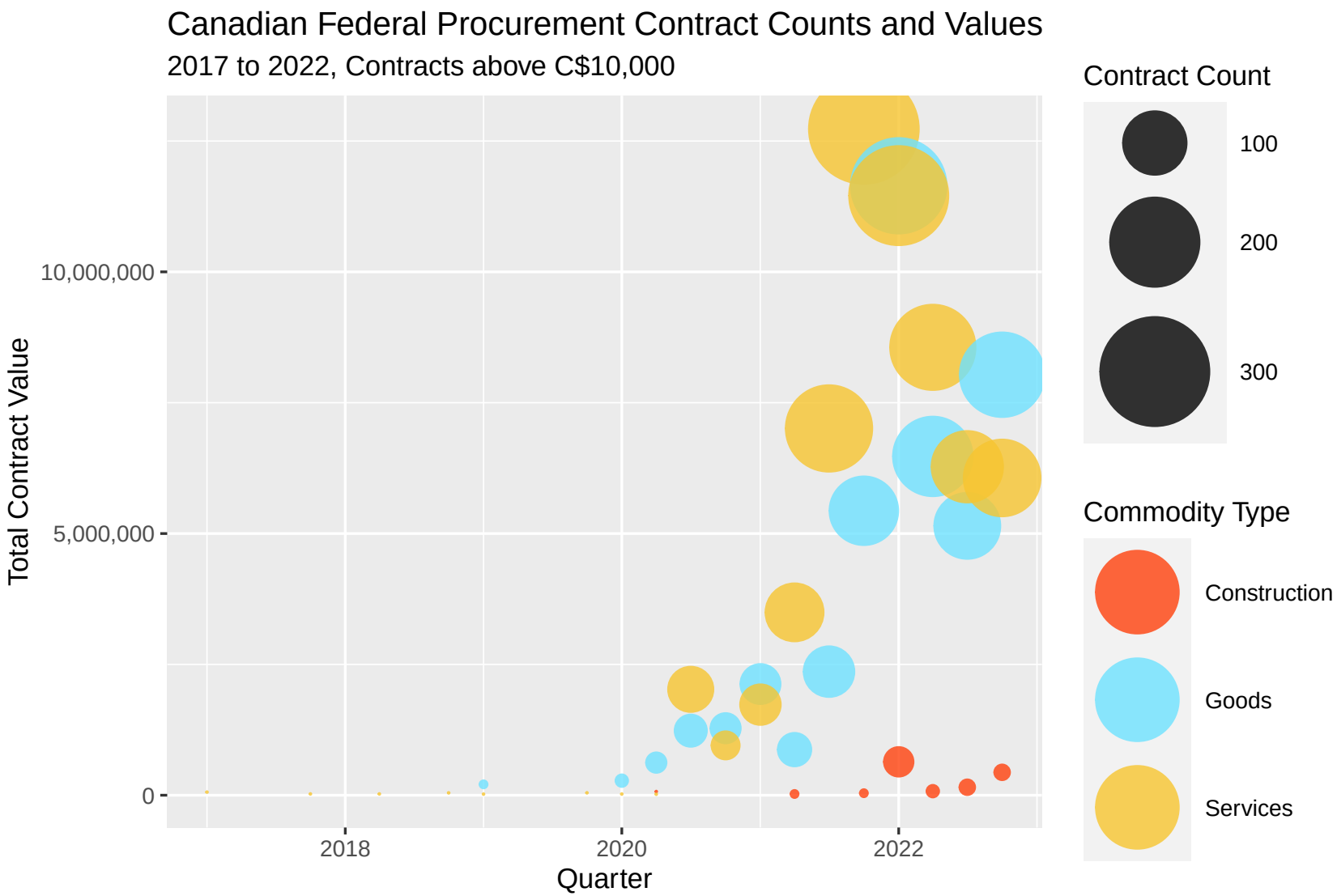
Point Plot – Multiple Variables



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Point Plot – Multiple Variables

```
d.clean %>% ... %>%
   mutate(contract_quarter = floor_date(contract_date, 'quarter')) %>%
   group_by(contract_quarter, commodity_type) %>%
   summarize(totalcount = n(), totalvalue=sum(contract_value)) %>%
   ungroup() %>%
   ggplot(aes(contract_quarter, totalvalue,
              color=commodity_type, size=totalcount)) +
      geom_point(alpha=0.8) +
      scale_size_continuous(range=c(0, 20)) +
      scale_color_tron(labels=c('Construction', 'Goods', 'Services')) +
      scale_y_continuous(labels=scales::comma) +
          guides(color=guide_legend(override.aes = list(size=15))) +
      labs(x = 'Quarter',
           y = 'Quarterly Total Contract Value',
           color='Commodity Type',
           size='Contract Count',
           title='Quraterly Canadian Federal Procurement Contract Coun
           subtitle='2017 to 2022, Contracts above C$10,000')
```

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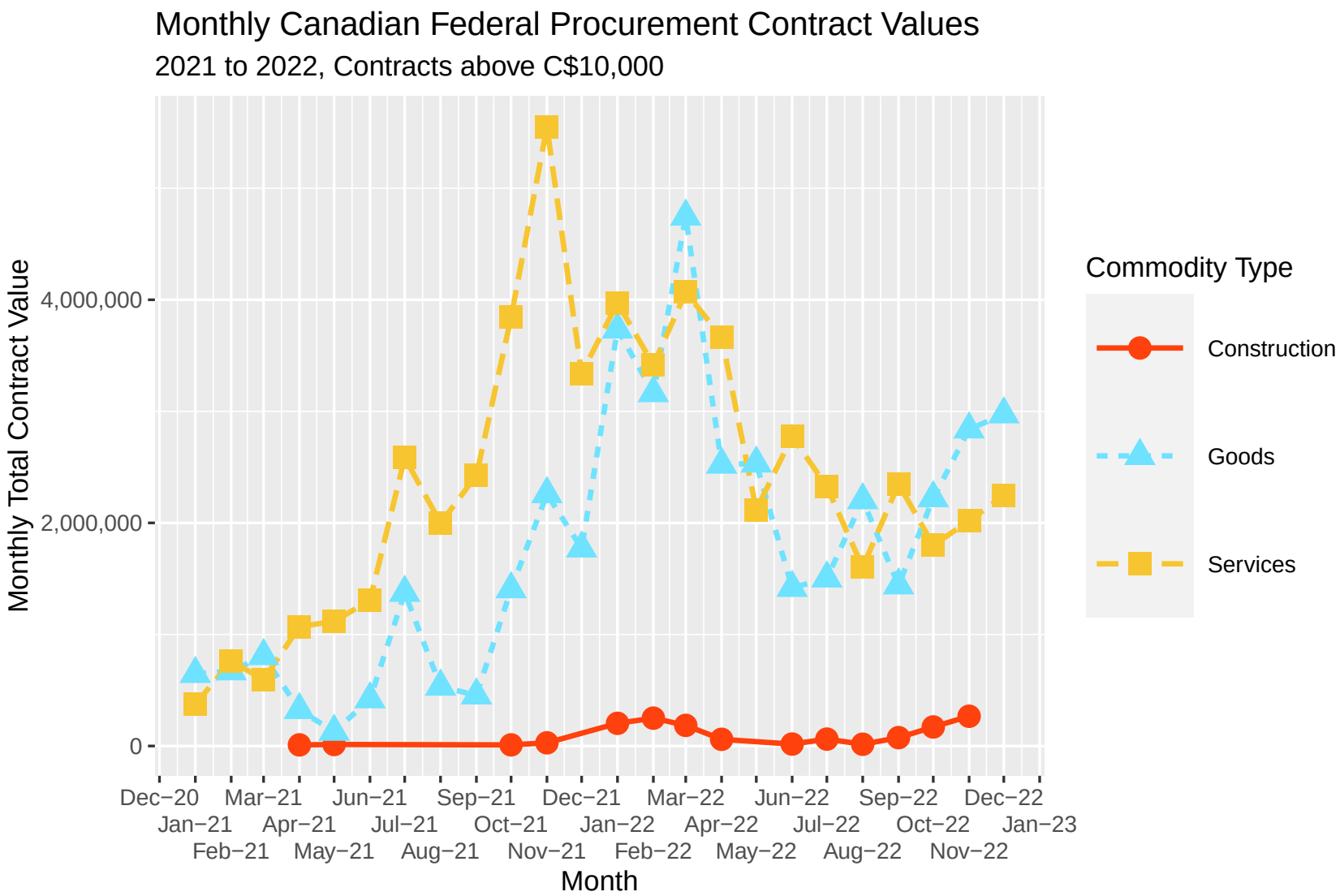
Line Plot – 2 Variables, 3 Series



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Line Plot – 2 Variables, 3 Series

```
...
ggplot(aes(contract_quarter, totalvalue,
           color=commodity_type,
           shape=commodity_type,
           linetype=commodity_type)) +
  geom_line(size=1) +
  geom_point(size=4) +
  scale_color_tron(labels=c('Construction', 'Goods', 'Services')) +
  scale_linetype(labels=c('Construction', 'Goods', 'Services')) +
  scale_shape(labels=c('Construction', 'Goods', 'Services')) +
  scale_y_continuous(labels=scales::comma) +
  scale_x_date(date_breaks = "months" ,
               date_labels = "%b-%y",
               guide = guide_axis(n.dodge=3)) +
  labs(x = 'Month',
       y = 'Monthly Total Contract Value',
       color='Commodity Type',
       shape='Commodity Type',
       linetype='Commodity Type',
       title='Monthly Canadian Federal Procurement Contract Values',
       subtitle='2021 to 2022, Contracts above C$10,000') +
  theme(legend.key.size=unit(1.5, 'cm'))

...
```

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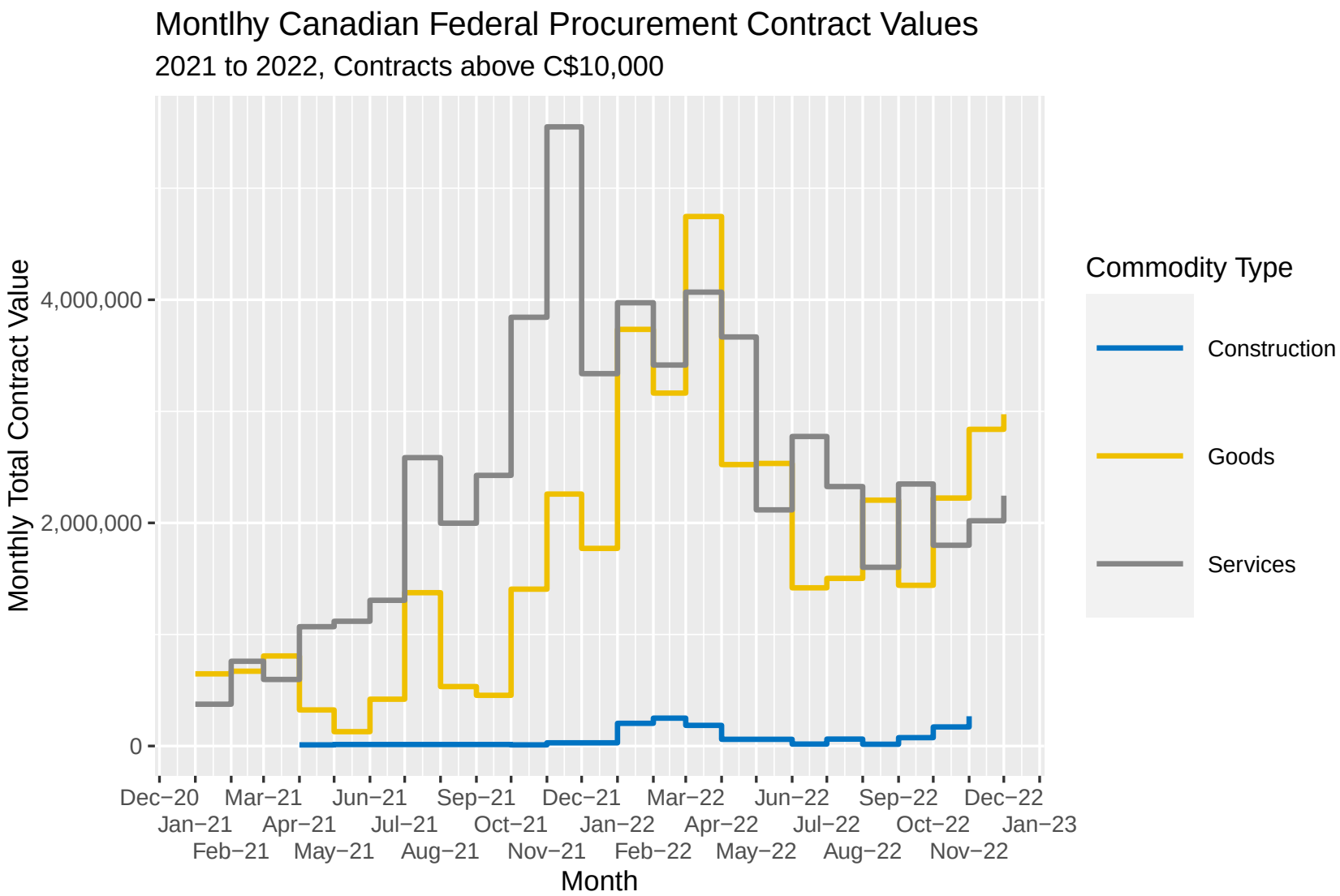
Step Plot – 2 Variables, 3 Series



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Step Plot – 2 Variables, 3 Series

```
...

ggplot(aes(contract_quarter, totalvalue, color=commodity_type)) +
  geom_step(size=1) +
  scale_color_jco(labels=c('Construction', 'Goods', 'Services')) +
  scale_linetype(labels=c('Construction', 'Goods', 'Services')) +
  scale_y_continuous(labels=scales::comma) +
  scale_x_date(date_breaks = "months" ,
               date_labels = "%b-%y",
               guide = guide_axis(n.dodge=3)) +
  labs(x = 'Month',
       y = 'Monthly Total Contract Value',
       color='Commodity Type',
       title='Montlhy Canadian Federal Procurement Contract Values',
       subtitle='2021 to 2022, Contracts above C$10,000') +
  theme(legend.key.size=unit(1.5, 'cm'))

...
```

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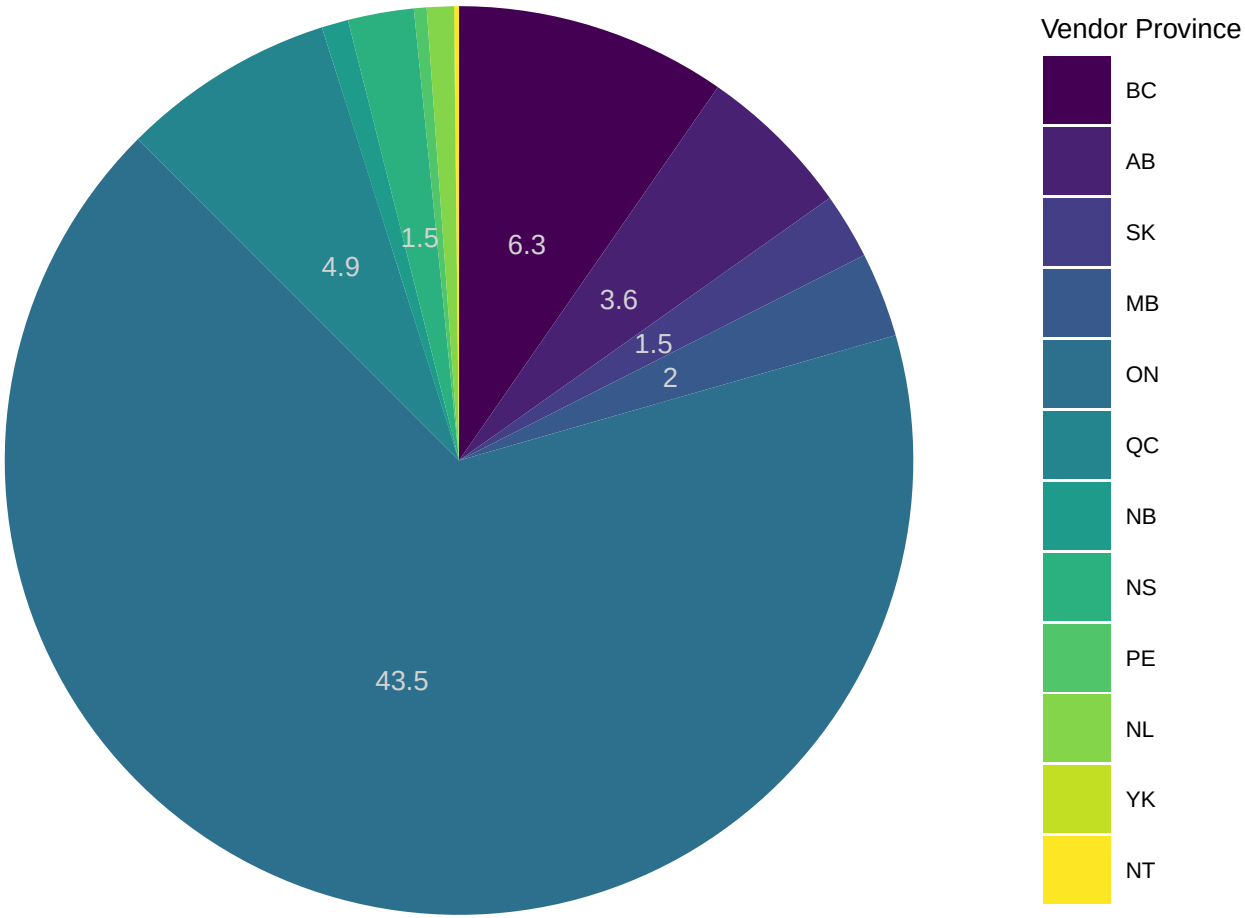
Pie Chart – 1 Variable

Canadian Federal Procurement Contract Values

2022, Millions of C$, Contracts above C$10,000



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Pie Chart – 1 Variable

```
d.clean %>% .... %>%
   group_by(vendor_province) %>%
   summarize(totalvalue=sum(contract_value)) %>%
   ungroup() %>%
   ggplot(aes(x='', y=totalvalue, fill=vendor_province)) +
     geom_bar(stat='identity', width=1) +
     coord_polar('y', direction=-1, start=0) +
     geom_text(aes(label=ifelse(totalvalue > 1000000,
                                round(totalvalue/1000000, digits=1),
                                '')),
                   color='lightgrey',
                   position = position_stack(vjust=0.5)) +
      scale_y_continuous(labels=NULL) +
      scale_color_brewer(palette="Paired") +
      labs(x = '', y = '',
           fill='Vendor Province',
           title='Canadian Federal Procurement Contract Values',
           subtitle='2022, Millions of C$, Contracts above C$10,000')
      theme(legend.key.size=unit(1, 'cm')) +
      theme_void()
```

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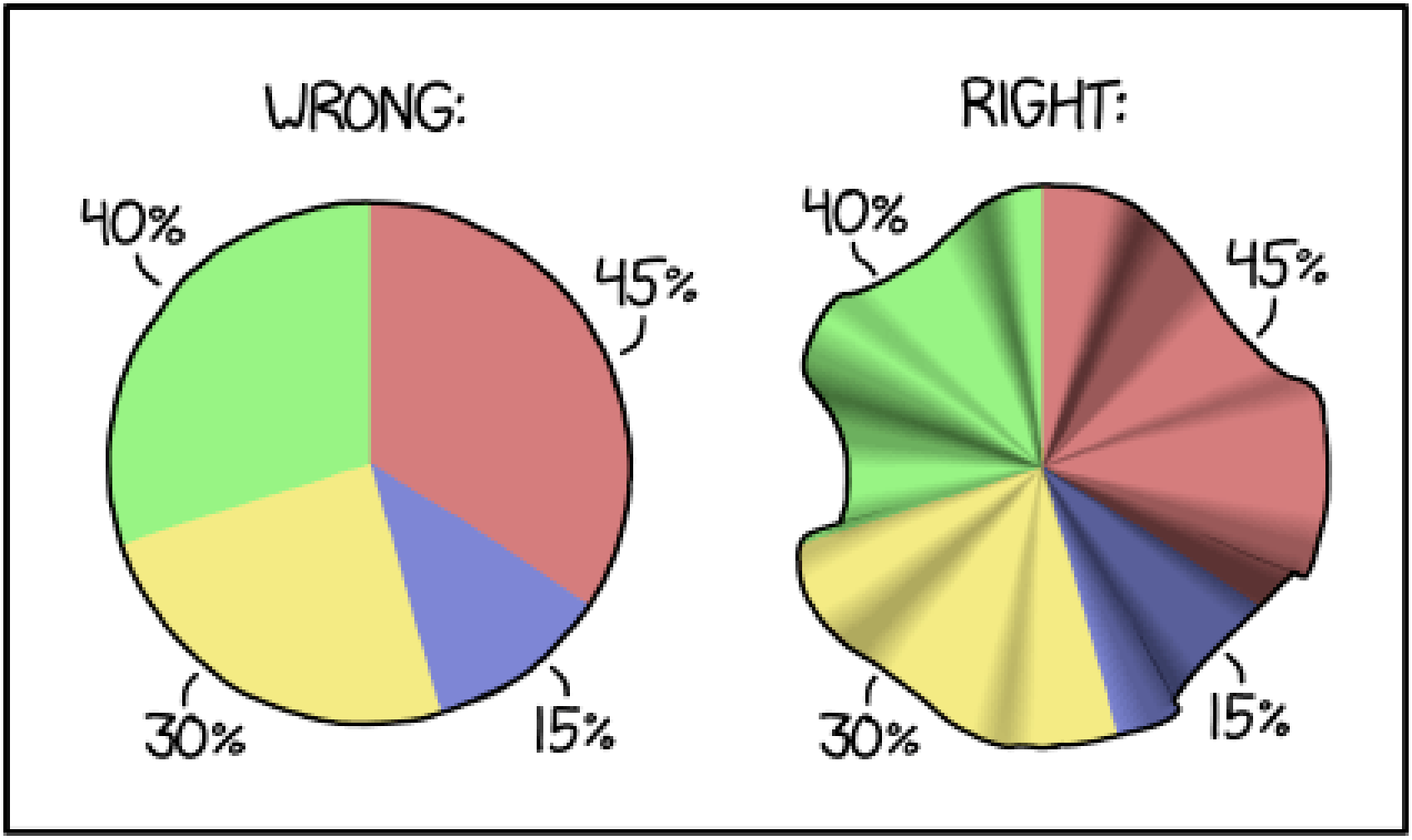
Pie Charts Done Well (XKCD)

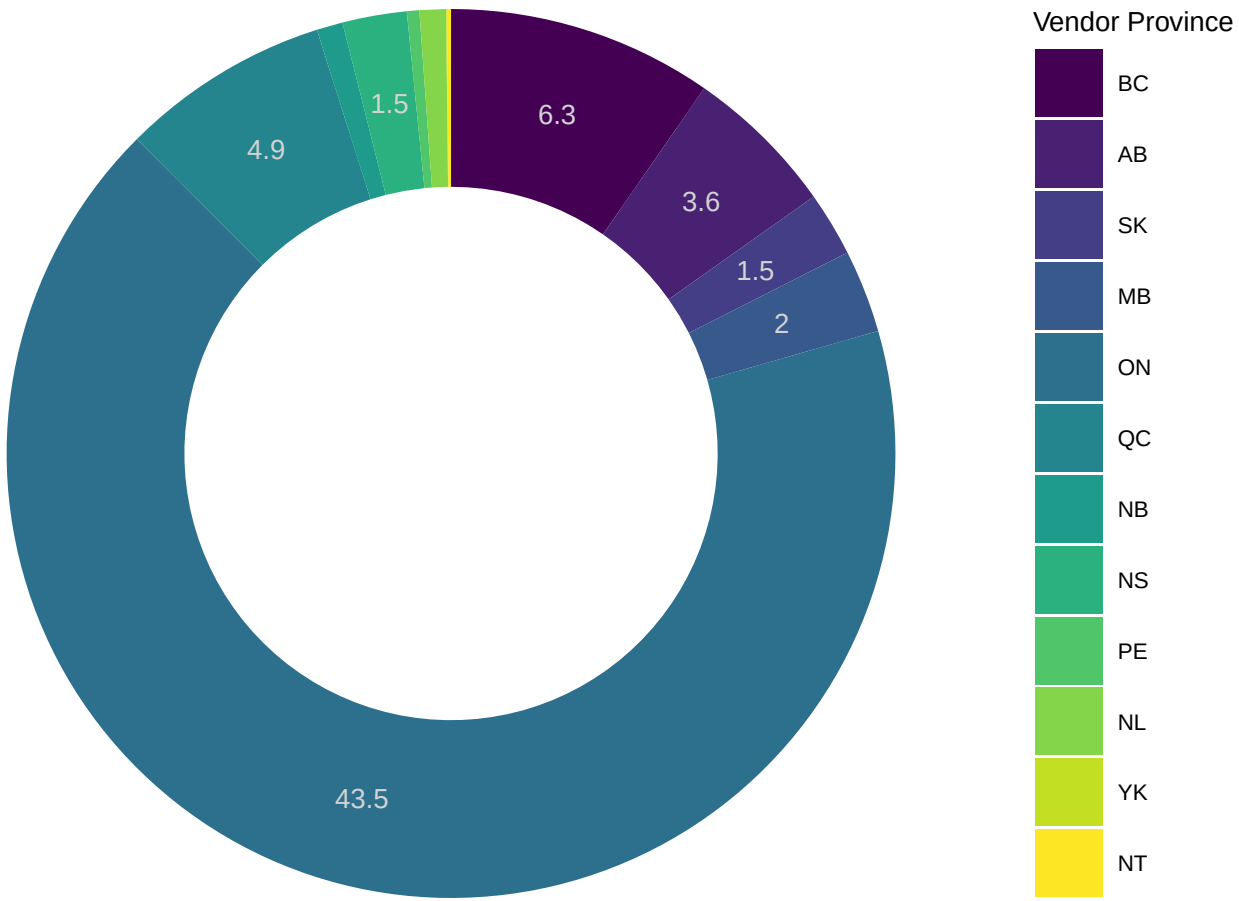


HOW TO MAKE A PIE CHART IF YOUR PERCENTAGES DON'T ADD UP TO 100

Donut Chart – 1 Variable

Canadian Federal Procurement Contract Values

2022, Millions of C$, Contracts above C$10,000



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Donut Chart – 1 Variable

```
holesize <- 2

...
ggplot(aes(x=holesize, y=totalvalue, fill=vendor_province)) +
  geom_col() +
  coord_polar('y', direction=-1, start=0) +
  xlim(c(0.2, holesize+0.5)) +
  geom_text(aes(label=ifelse(totalvalue > 1000000,
                             round(totalvalue/1000000, digits=1),
                             '')),
                color='lightgrey',
                position = position_stack(vjust=0.5)) +

...
```

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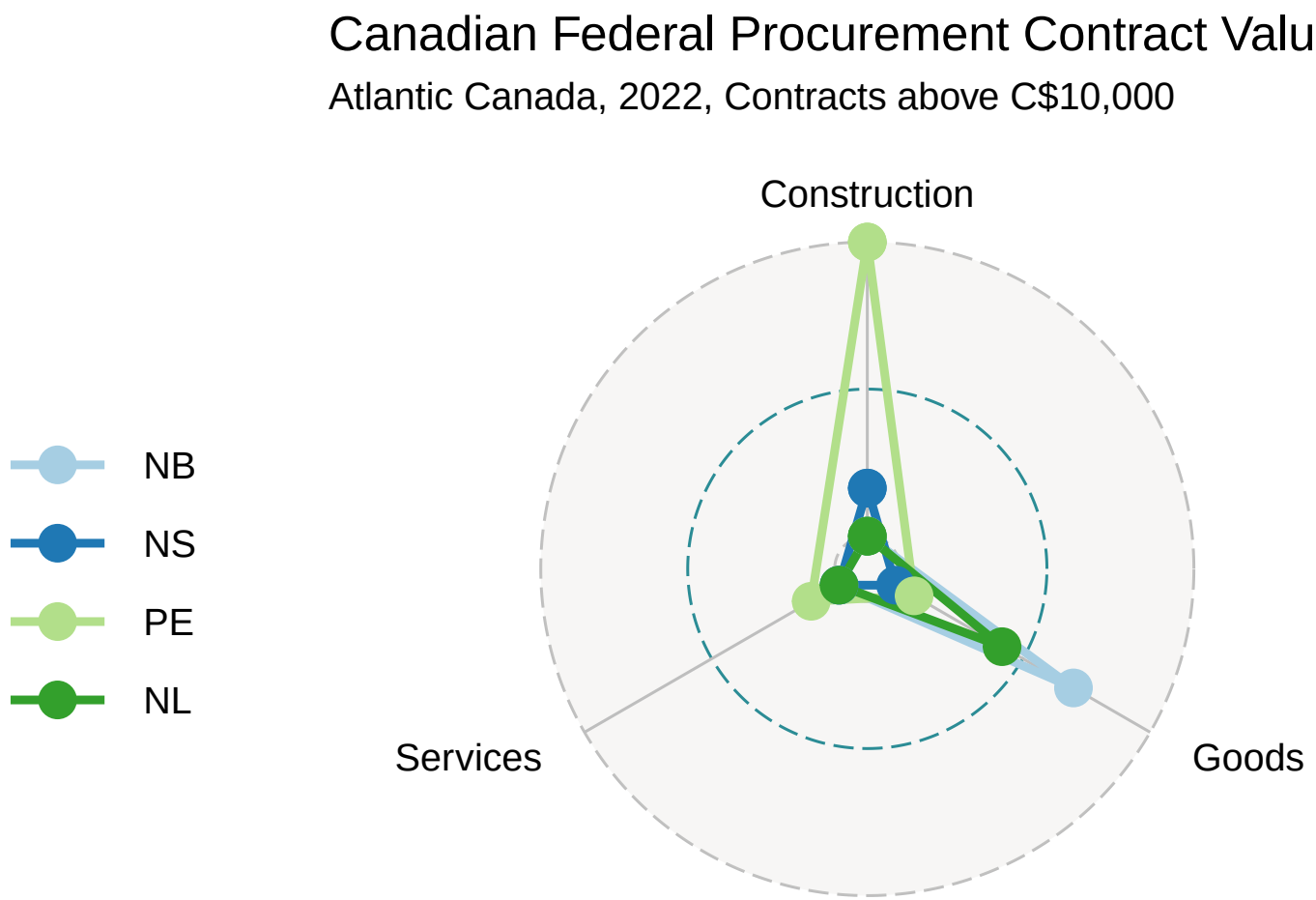
Radar Plot – 3 Variables



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Radar Plot – 3 Variables

```
d.clean %>%  ... %>%
   filter(vendor_province %in% c('NL', 'PE', 'NB', 'NS')) %>%
   group_by(vendor_province, commodity_type) %>%
   summarize(totalvalue=sum(contract_value)/1000000) %>%
   ungroup() %>%
   pivot_wider(names_from='commodity_type', values_from=totalvalue) %>
   replace_na(list(C=0, G=0, S=0)) %>%
   select(vendor_province, 'C', 'G', 'S') %>%
   mutate_at(vars(-vendor_province), rescale) %>%
   relocate(vendor_province, .before=1) %>%
   ggradar(axis.labels=c('Construction', 'Goods', 'Services'),
           values.radar='') +
      scale_color_brewer(palette="Paired") +
      labs(x = '', y = '',  fill='Vendor Province',
           title='Canadian Federal Procurement Contract Values',
           subtitle='Atlantic Canada, 2022, Contracts above C$10,000')
      theme(plot.title=element_text(size=18),
            plot.subtitle=element_text(size=14))
```

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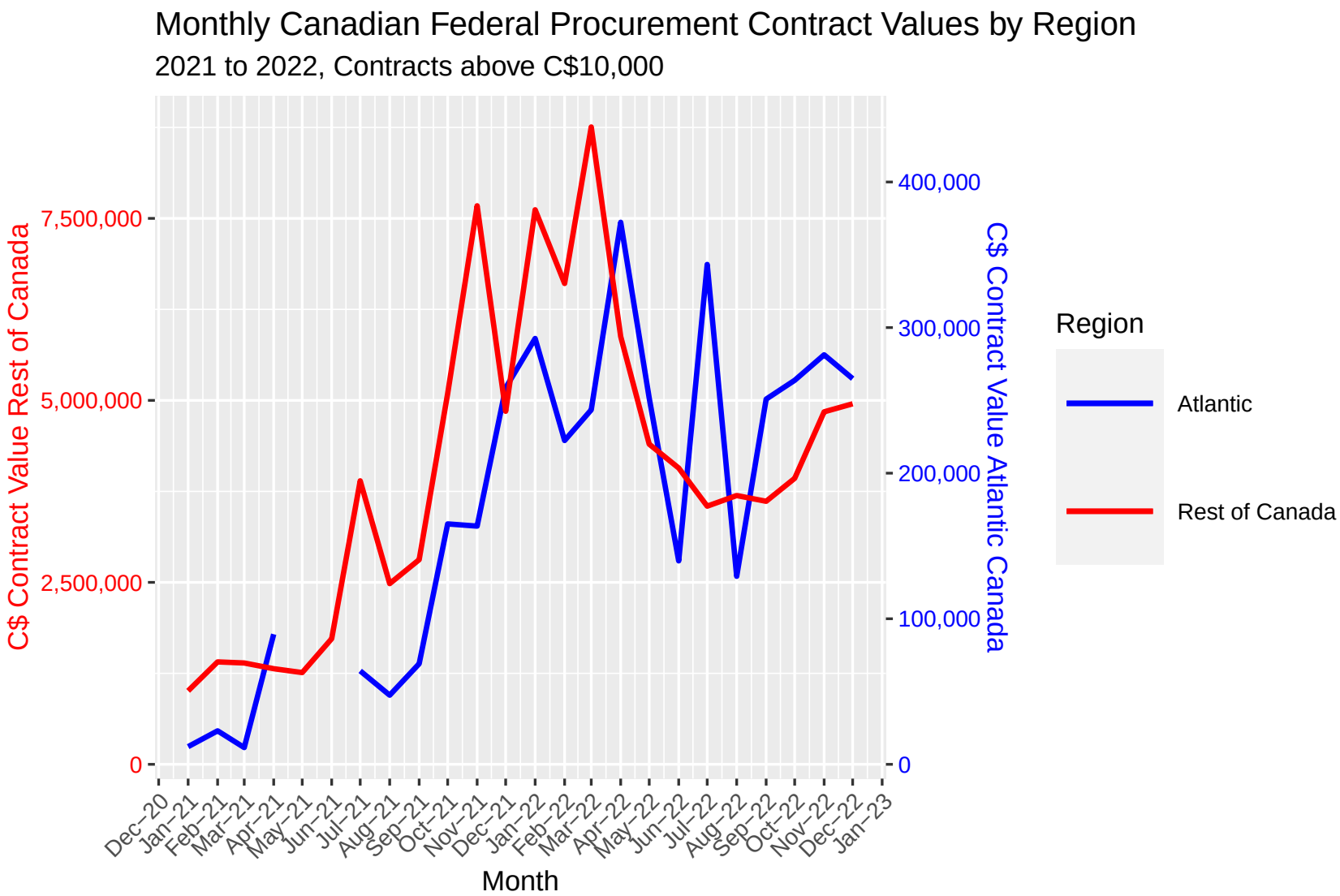
Multiple Axes – 2 Variables, 3 Series



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Multiple Axes – 2 Variables, 3 Series

```
ggplot(aes(x=contract_quarter)) +
  scale_color_manual(
      name='Region',
      values=c('Rest of Canada' = 'red', 'Atlantic' = 'blue')) +
  geom_line(aes(y=Atlantic2, color='Atlantic'), size=1) +
  geom_line(aes(y=Rest, color='Rest of Canada'), size=1) +
  scale_y_continuous(
      labels=scales::comma,
      name="C$ Contract Value Rest of Canada",
      sec.axis=sec_axis(~./20,
                        labels=scales::comma,
                        name="C$ Contract Value Atlantic Canada")) +
  scale_x_date(date_breaks = "months" , date_labels = "%b-%y") +
  labs(x = 'Month', y = 'Total Contract Value', color='Region',
       title='Monthly Canadian Federal Procurement Contract Values by
       subtitle='2021 to 2022, Contracts above C$10,000') +
  theme(legend.key.size=unit(1.5, 'cm'),
        axis.text.x = element_text(angle=45, hjust=1),
        axis.text.y.left = element_text(color='red'),
        axis.text.y.right = element_text(color='blue'),
        axis.title.y.left = element_text(color='red'),
        axis.title.y.right=element_text(color='blue'))
```

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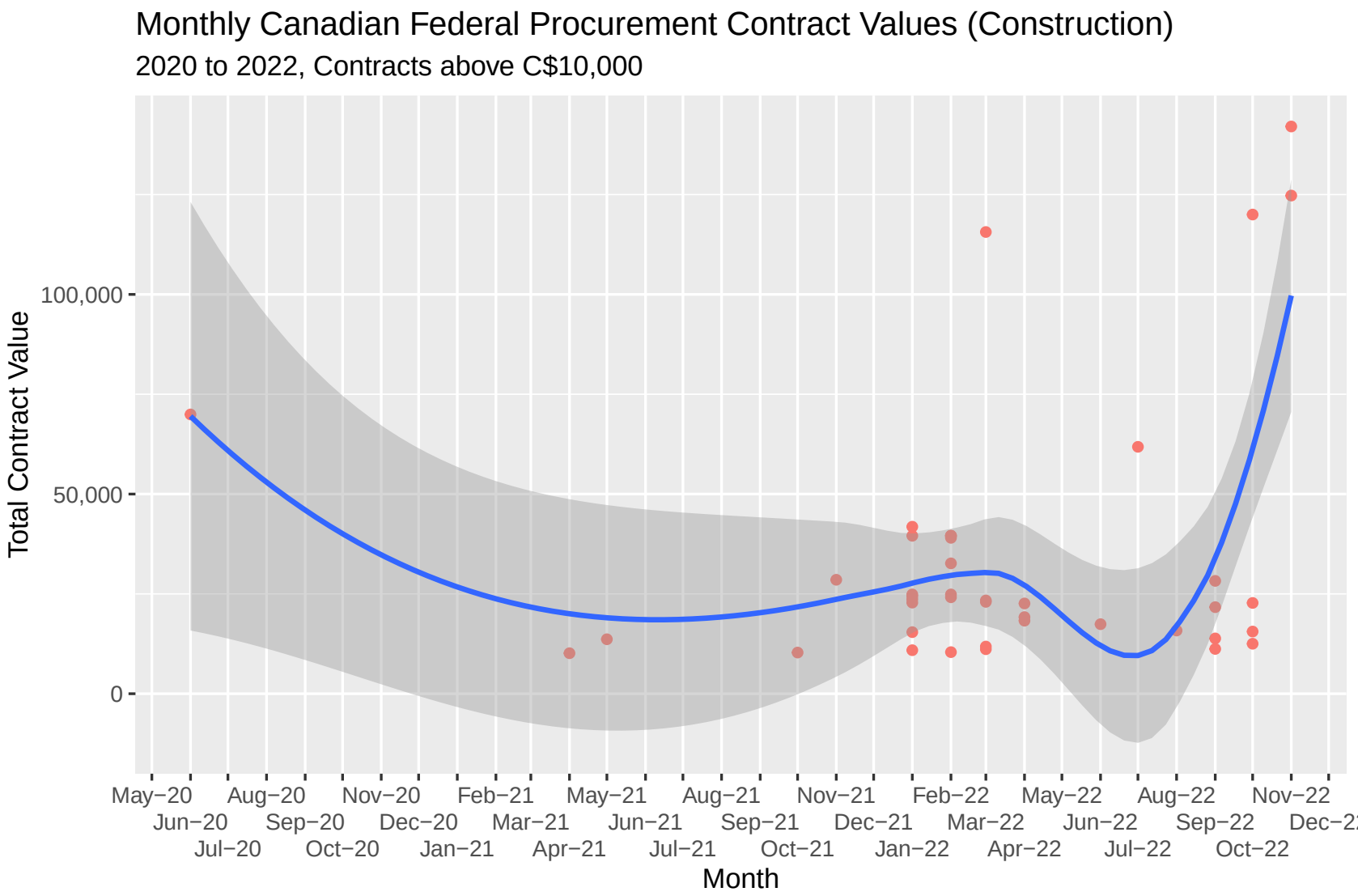
Smoothing (Local Regression) – 2 Variables



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Smoothing (Local Regression) – 2 Variables

```
d.clean %>% ... %>%
   mutate(contract_week = floor_date(contract_date, 'month')) %>%
   filter(commodity_type=='C') %>%
   ggplot(aes(contract_week, contract_value)) +
     geom_point(aes(color=commodity_type)) +
     geom_smooth() +
     guides(color=FALSE) +
       scale_y_continuous(labels=scales::comma) +
       scale_x_date(date_breaks = "months" ,
                    minor_breaks=NULL,
                    date_labels = "%b-%y",
                    guide = guide_axis(n.dodge=3)) +
       labs(x = 'Month', y = 'Total Contract Value',
           title='Monthly Canadian Federal Procurement Contract Values
           subtitle='2020 to 2022, Contracts above C$10,000')
```

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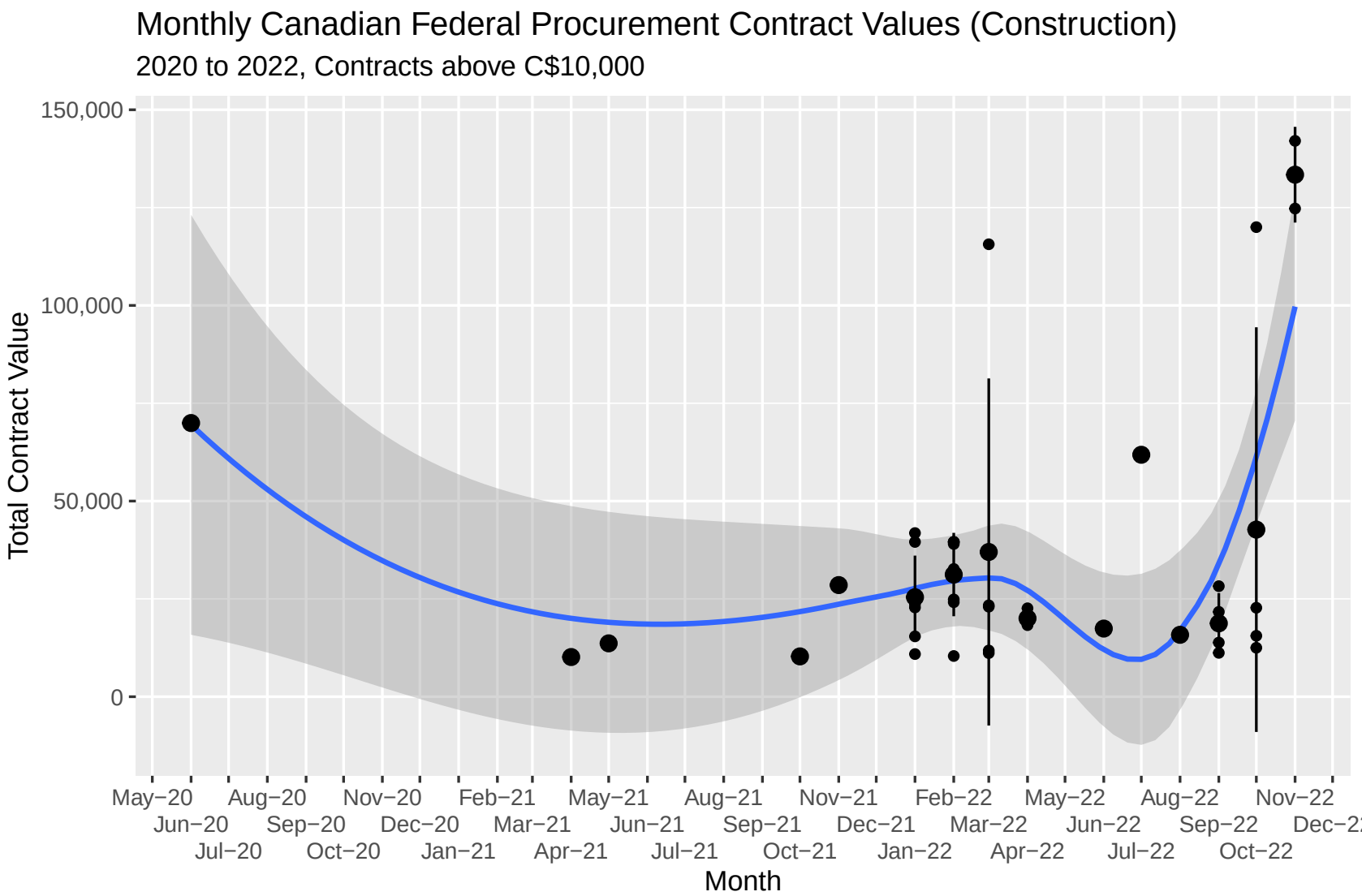
Smoothing (with Ranges) – 2 Variables



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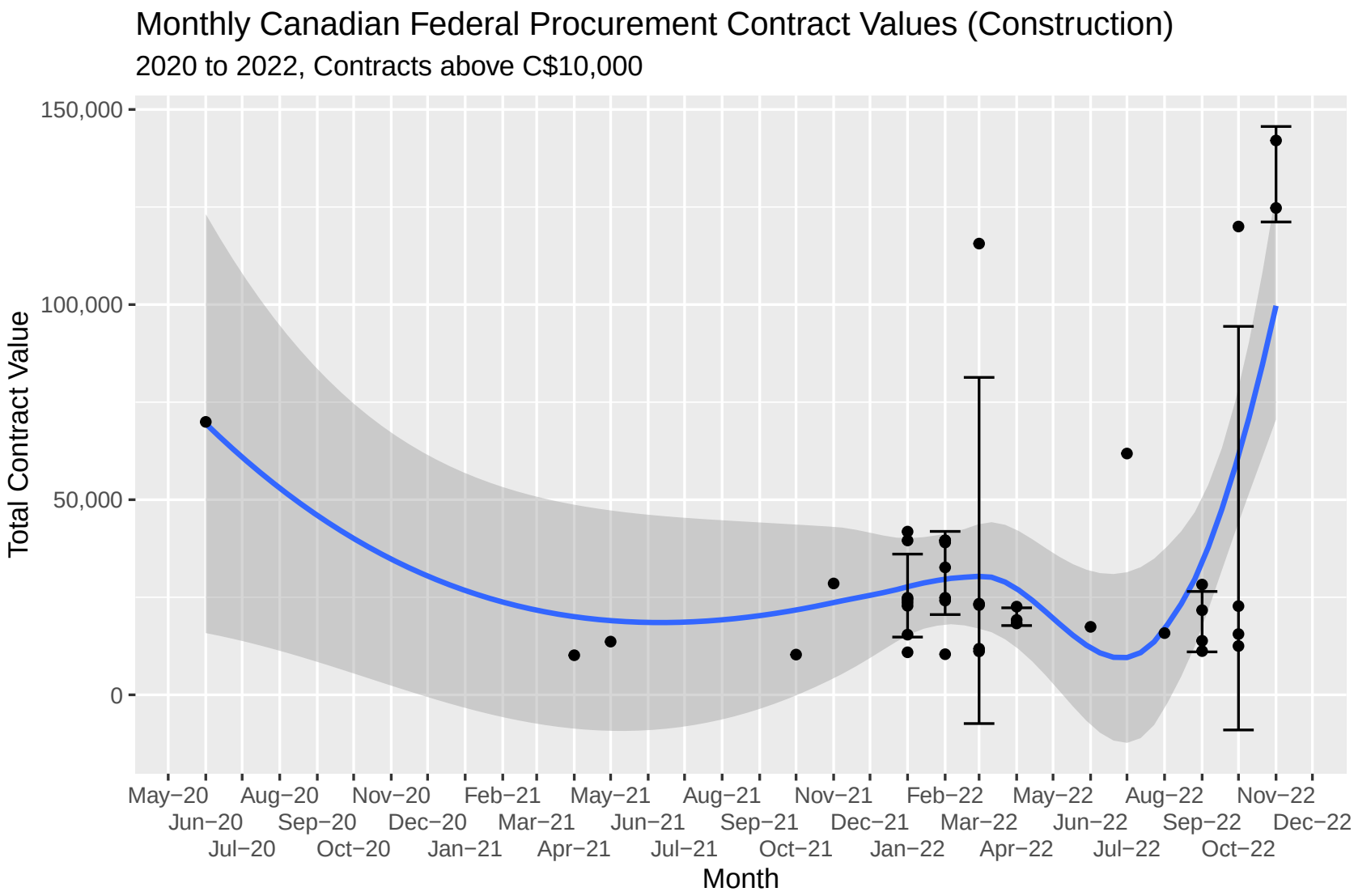
Smoothing (with Ranges) – 2 Variables

```
...

ggplot(aes(contract_week, contract_value)) +
  geom_smooth() +
  geom_point() +
  stat_summary(fun.data=mean_sdl,
               fun.args=list(mult=1),
               geom="pointrange") +

...
```

Smoothing (with Error Bars) – 2 Variables



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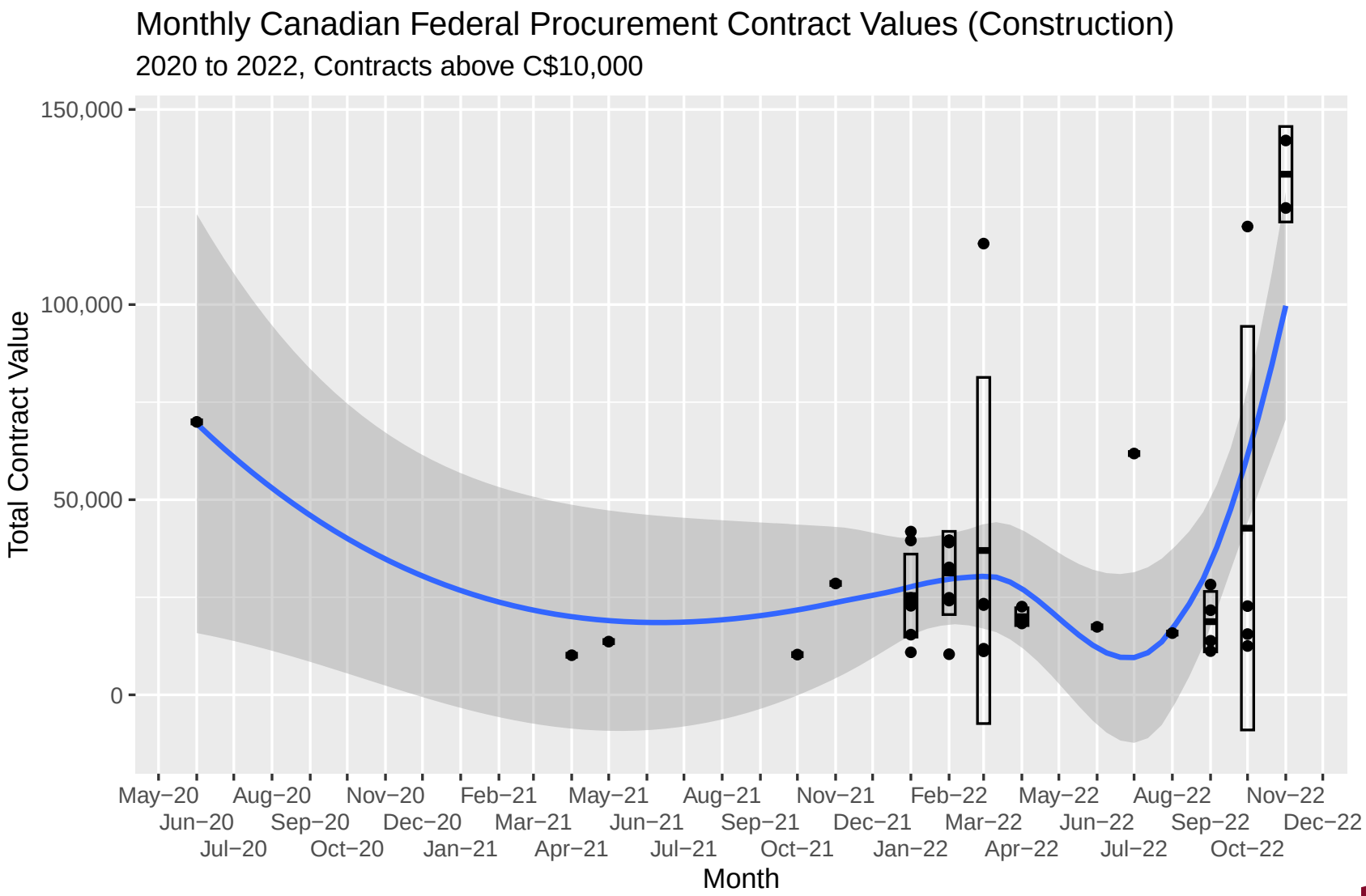
Smoothing (with Error Bars) – 2 Variables

```
...

ggplot(aes(contract_week, contract_value)) +
  geom_smooth() +
  geom_point() +
  stat_summary(fun.data=mean_sdl,
               fun.args=list(mult=1),
               geom="errorbar") +

...
```

Smoothing (with Cross Bars) – 2 Variables



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Smoothing (with Cross Bars) – 2 Variables

```
...

ggplot(aes(contract_week, contract_value)) +
  geom_smooth() +
  geom_point() +
  stat_summary(fun.data=mean_sdl,
               fun.args=list(mult=1),
               geom="crossbar",
               width=10) +

...
```

Example Dataset 2 (”Fuel”)

- Government of Canada, Open Government Portal
- Fuel Consumption Ratings – Battery-electric vehicles – 2012–2023
- Last updated Oct 10, 2023
- https://open.canada.ca/data/en/dataset/98f1a129-f628-4ce4-b24d-6f16bf24dd64

Column	Data Type
Make	Discrete
Model	Discrete
Year	Numeric
Category	Discrete[2]
City	Numeric[3]
Hwy	Numeric
Comb	Numeric
Range	Numeric[4]

[2] Small, Midsize, Large, Pickup, SUV, Station Wagon, etc.
[3] Fuel consumption in l/100km equivalent
[4] Range in km

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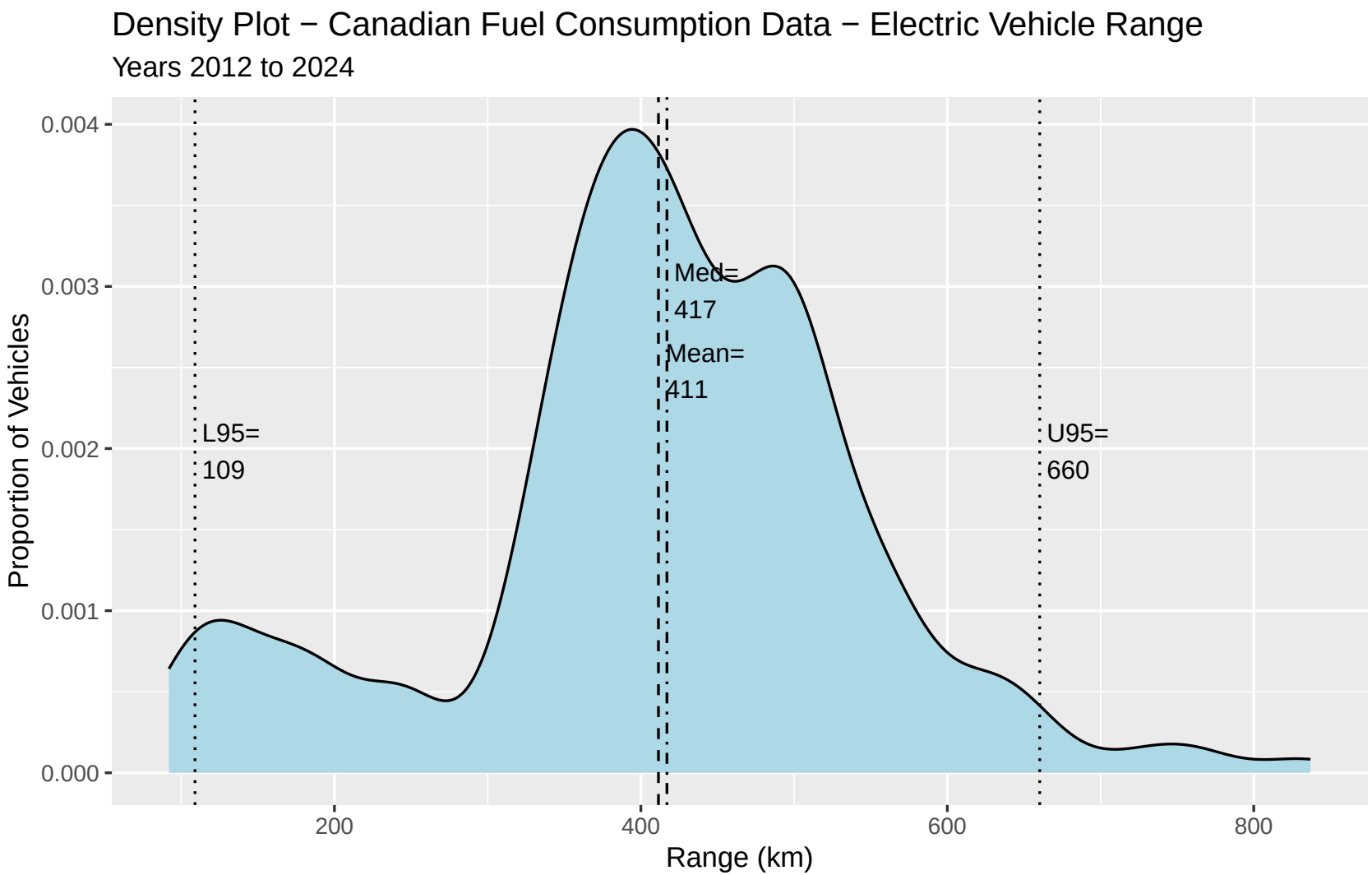
Density Plot



Lower and Upper 95 percentile, median and mean

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Density Plot

```
mean_v <- e.clean %>%
   summarize(mean_v = mean(Range), median_v = median(Range),
             lower95=quantile(Range, .025), upper95=quantile(Range, .9
             maxdensity = max(density(Range)$y))

e.clean %>%
   ggplot(aes(Range)) +
     geom_density(kernel='gaussian', fill='lightblue') +
     scale_x_continuous(labels=scales::comma) +
     scale_y_continuous(labels=scales::comma) +
     labs(x = 'Range (km)', y = 'Proportion of Vehicles',
          title='Density Plot - Canadian Fuel Consumption Data - Elect
          subtitle='Years 2012 to 2024',
          caption='Lower and Upper 95 percentile, median and mean') +
     geom_vline(data=mean_v,
                aes(xintercept=mean_v),
                linetype='dashed') +
     ...
     annotate('text', label = paste(' L95=\n ', round(mean_v$lower95),
              x = mean_v$lower95,
              y = mean_v$maxdensity/2,
              size=3.5, hjust=0) +
     ...
```

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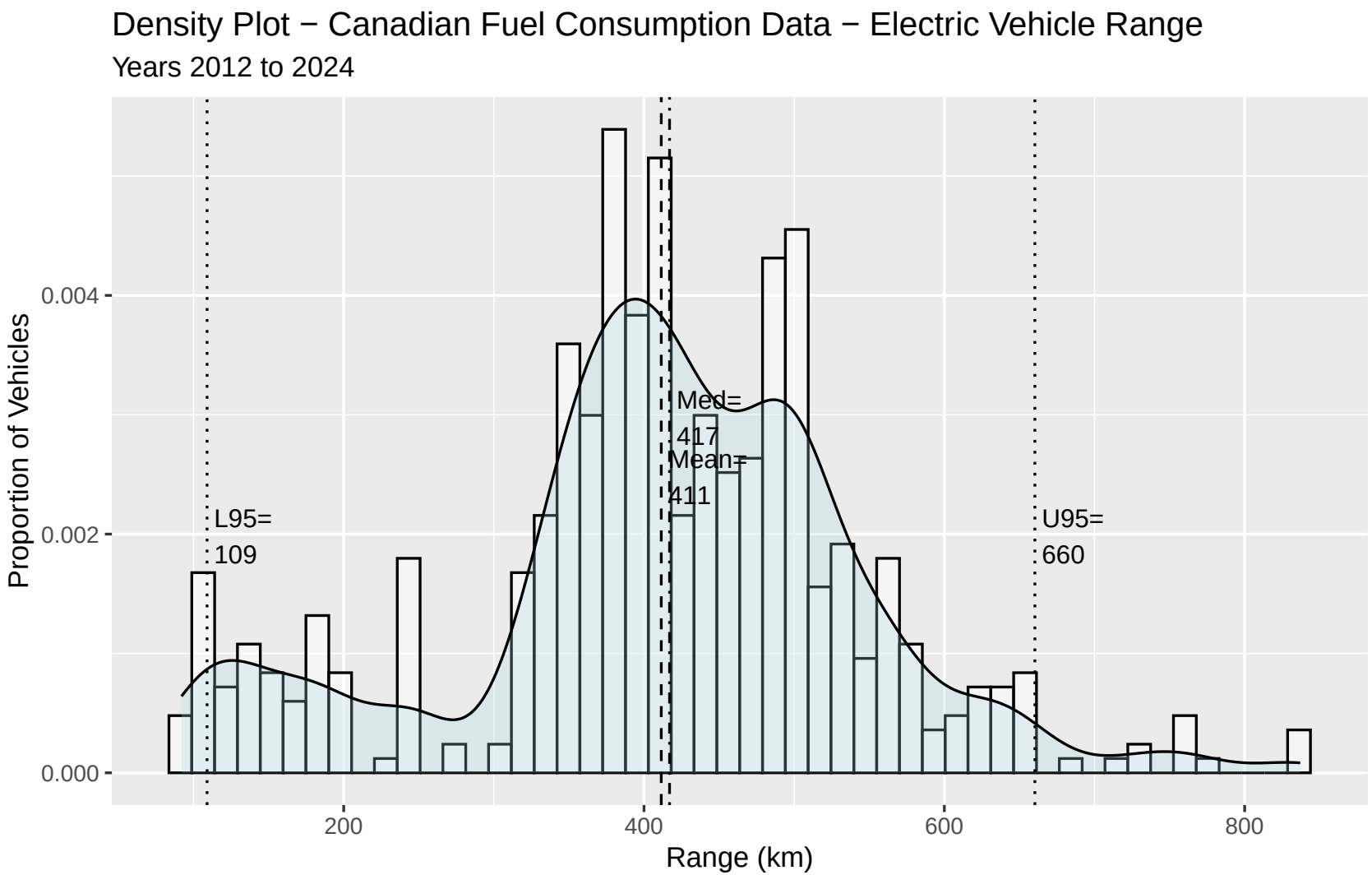
Histogram



Lower and Upper 95 percentile, median and mean

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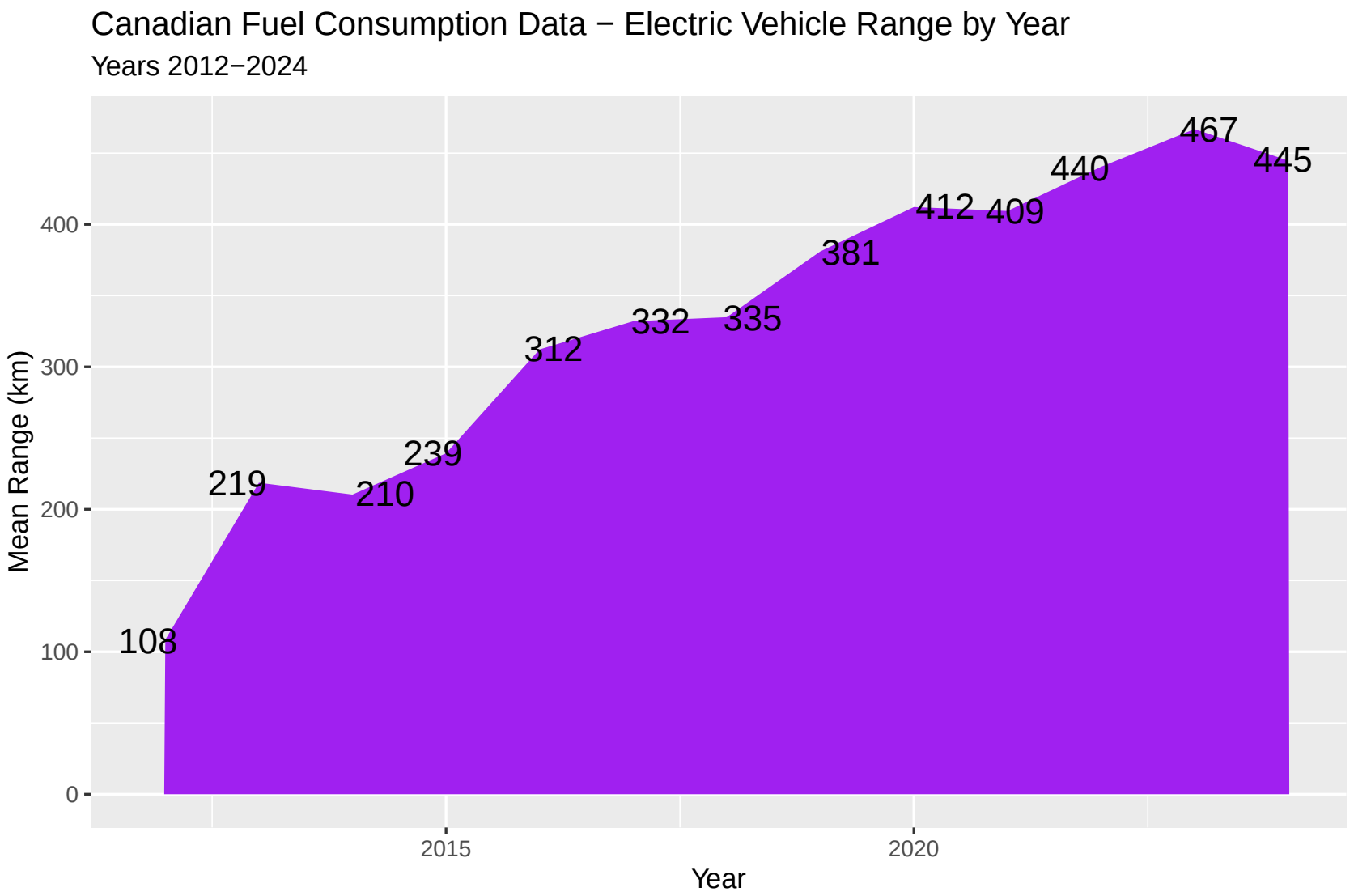
Histogram

```
...

ggplot(aes(Range)) +
  geom_histogram(aes(y=..density..),
                 bins=50,
                 fill='white',
                 color='black',
                 alpha=0.5) +
  geom_density(kernel='gaussian', alpha=0.25, fill='lightblue') +
  scale_x_continuous(labels=scales::comma) +
  scale_y_continuous(labels=scales::comma) +

...
```

Area Plot



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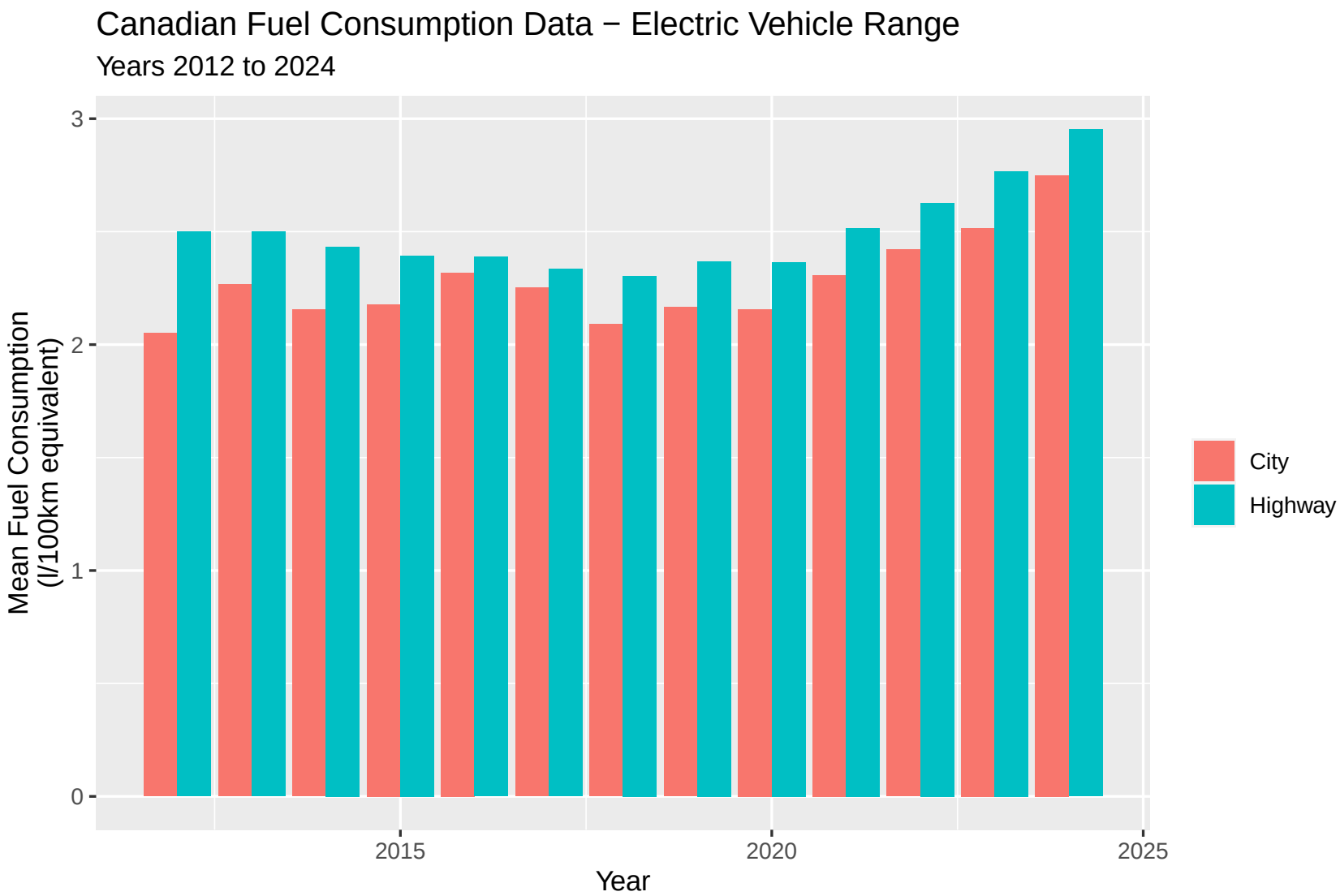
Area Plot

```
e.clean %>%
   group_by(Year) %>%
   summarize(meanRange = mean(Range)) %>%
   ungroup() %>%
   ggplot(aes(Year, meanRange)) +
     geom_area(fill='purple') +
     geom_text(aes(label=round(meanRange)),
               size=5, position='jitter') +
     scale_y_continuous(labels=scales::comma) +
     labs(x = 'Year', y = 'Mean Range (km)',
          title='Canadian Fuel Consumption Data - Electric Vehicle Ran
          subtitle='Years 2012-2024')
```

Column Chart



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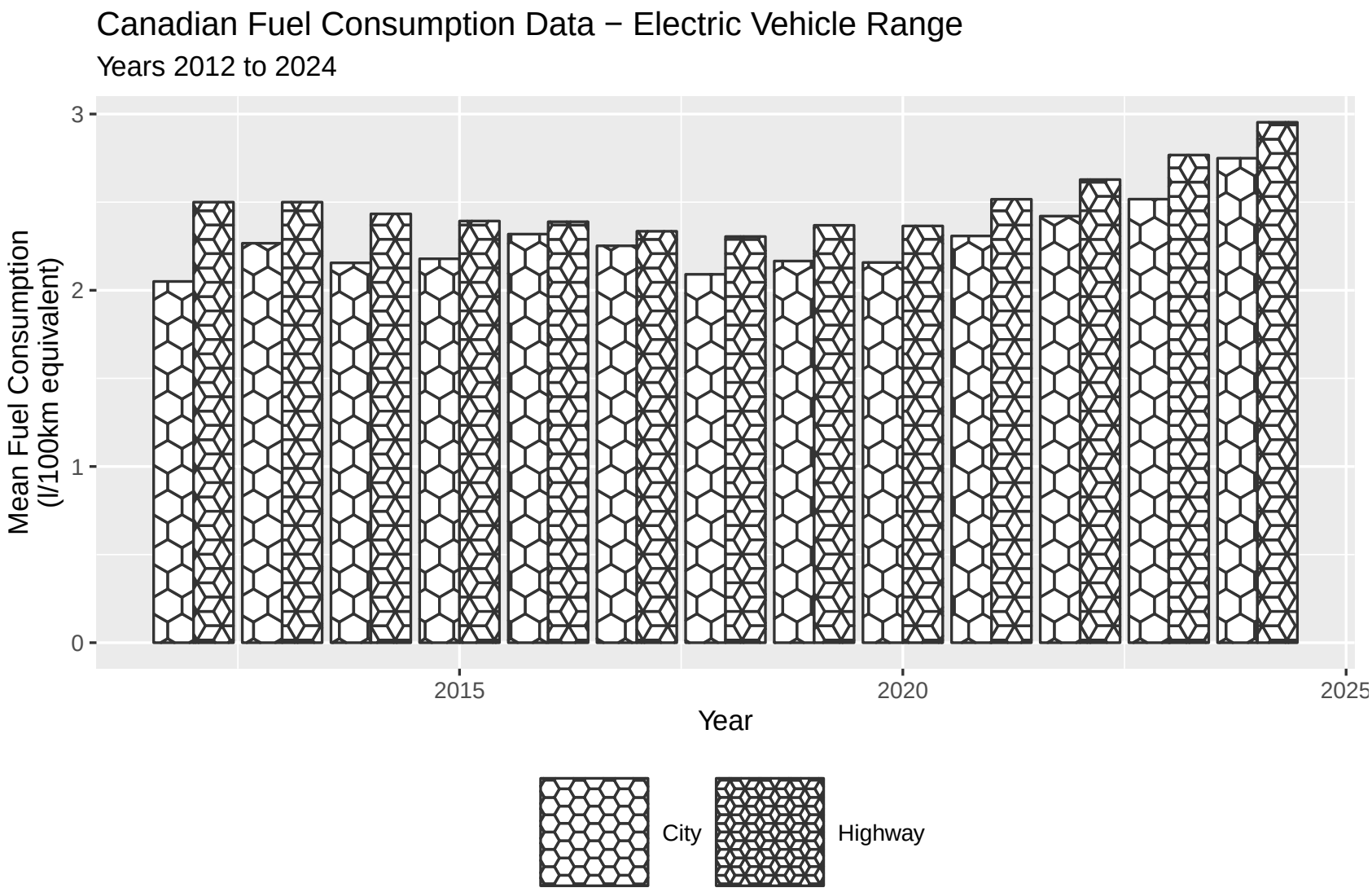
Column Chart

```
e.clean %>%
   group_by(Year) %>%
   summarize(meanCity = mean(City), meanHwy = mean(Hwy)) %>%
   ungroup() %>%
   pivot_longer(cols=c('meanCity', 'meanHwy'),
                names_to='metric',
                values_to='consumption') |>
   ggplot(aes(Year, consumption, fill=metric)) +
      geom_col(position='dodge') +
      scale_fill_brewer(palette="Paired") +
      scale_fill_discrete(labels=c("City", "Highway")) +
      scale_y_continuous(labels=scales::comma) +
      labs(x = 'Year',
           y='Mean Fuel Consumption\n(l/100km equivalent)',
           fill='',
           title='Canadian Fuel Consumption Data - Electric Vehicle Ra
           subtitle='Years 2012 to 2024', )
```

MEMORIAL UNIVERSITY

Column Chart (with Patterns)

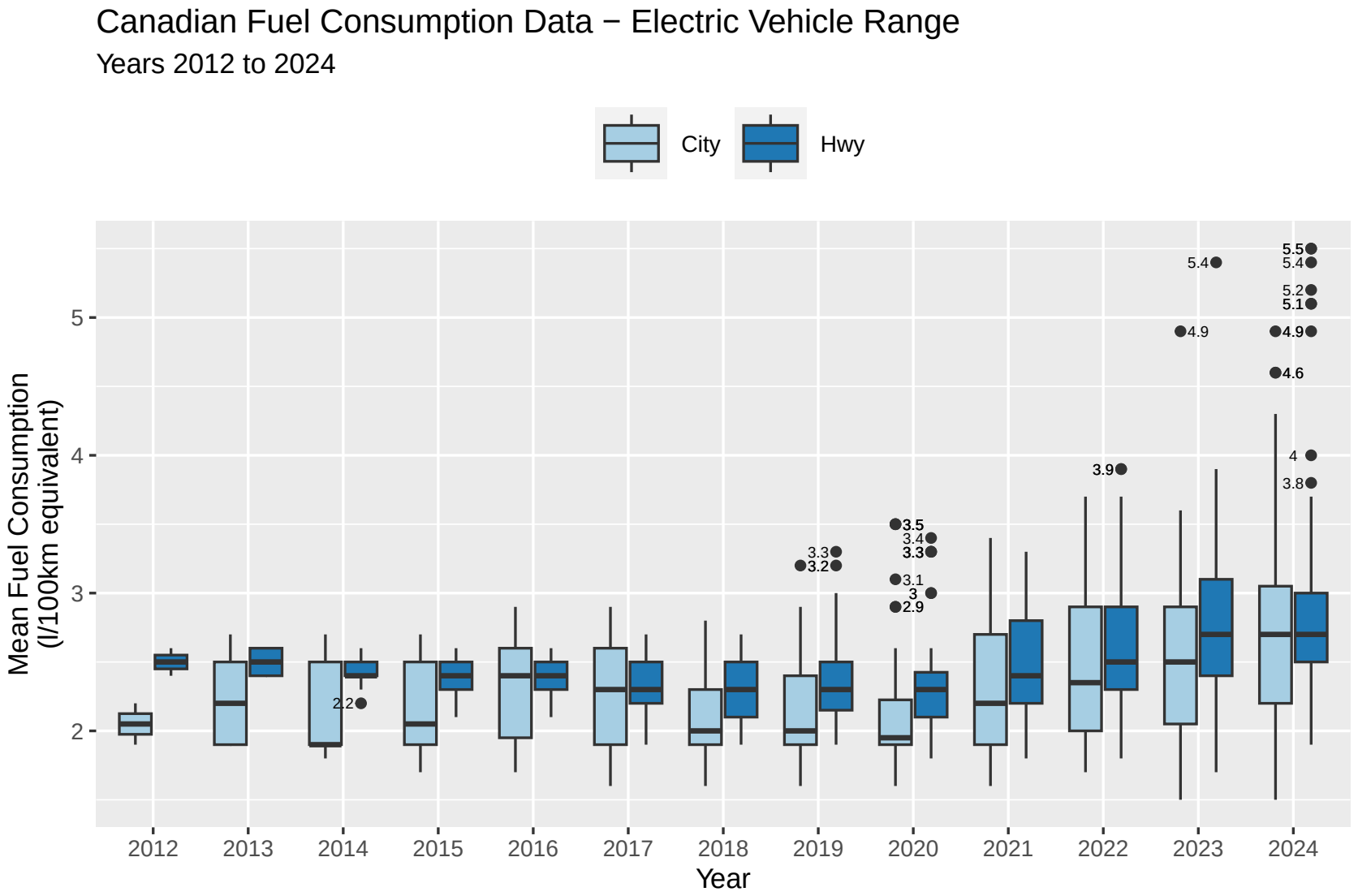


MEMORIAL UNIVERSITY

Column Chart (with Patterns)

```
e.clean %>%
   group_by(Year) %>%
   summarize(meanCity = mean(City), meanHwy = mean(Hwy)) %>%
   ungroup() %>%
   pivot_longer(cols=c('meanCity', 'meanHwy'), names_to='metric', valu
   ggplot(aes(Year, consumption)) +
      geom_col_pattern( aes(pattern_type=metric, pattern_angle=metric)
         position='dodge',
         pattern_fill='white',
         pattern='polygon_tiling',
         pattern_scale=0.5,
         pattern_key_scale_factor=0.4) +
      scale_pattern_type_manual(
         values = c('hexagonal', 'rhombille', 'pythagorean',
                    'truncated_square', 'rhombitrihexagonal',
                    'truncated_trihexagonal'),
         labels=c("City", "Highway")) +
      scale_y_continuous(labels=scales::comma) +
      labs(x = 'Year', y='Mean Fuel Consumption\n(l/100km equivalent)'
           pattern_type='',
           title='Canadian Fuel Consumption Data - Electric Vehicle Ra
           subtitle='Years 2012 to 2024', ) +
      guides(pattern_angle=FALSE, pattern_type=guide_legend(nrow=1)) +
      theme(legend.key.size=unit(1.5, 'cm'),
            legend.position='bottom')
```

Box Plot



MEMORIAL UNIVERSITY

Box Plot

```
e.clean %>%
   pivot_longer(cols=c('City', 'Hwy'),
                names_to='metric',
                values_to='consumption') %>%
   ggplot(aes(x=as.factor(Year), y=consumption, fill=metric)) +
      geom_boxplot() +
          stat_summary(
                aes(label = round(stat(y), 1)),
                geom = "text",
                size=2,
                fun.y =
function(y) {o<-boxplot.stats(y)$out; if(length(o)==0) NA else o}) +
     scale_fill_brewer(palette="Paired") +
     labs(x = 'Year',
          y='Mean Fuel Consumption\n(l/100km equivalent)',
          fill='',
          title='Canadian Fuel Consumption Data - Electric Vehicle Ran
          subtitle='Years 2012 to 2024', ) +
     scale_y_continuous(labels=scales::comma) +
     theme(legend.key.size=unit(1, 'cm'),
           legend.position='top')
```

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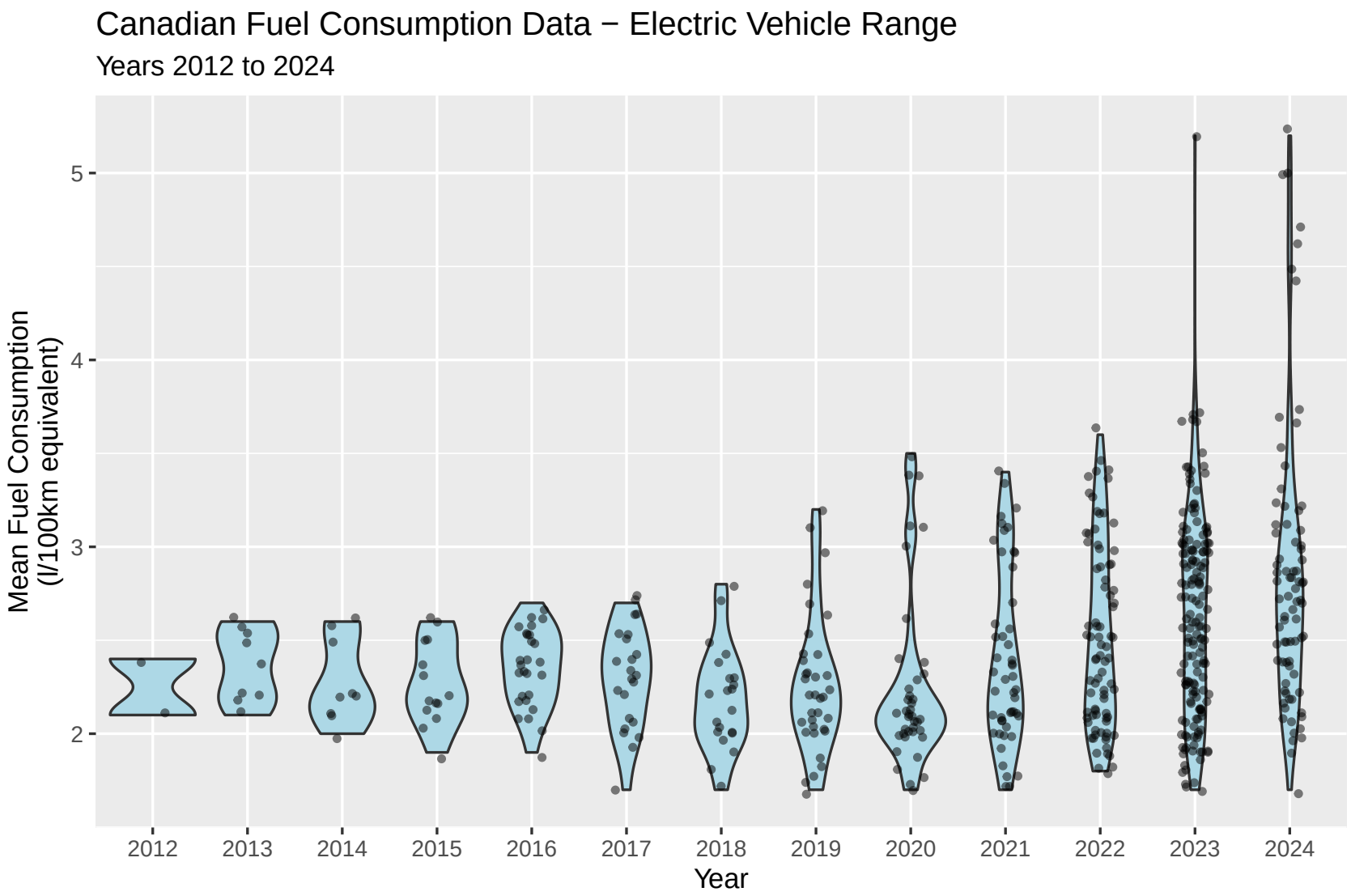
Violin Plot



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Violin Plot

```
e.clean %>%
   ggplot(aes(x=as.factor(Year), y=Comb)) +
     geom_violin(fill='lightblue') +
     geom_jitter(width=0.15, color='black',
                 size=1, fill=NA, alpha=0.5) +
     scale_fill_brewer(palette="Paired") +
     labs(x = 'Year',
          y='Mean Fuel Consumption\n(l/100km equivalent)',
          fill='',
          title='Canadian Fuel Consumption Data - Electric Vehicle Ran
          subtitle='Years 2012 to 2024', ) +
     scale_y_continuous(labels=scales::comma) +
     theme(legend.position='top',
           legend.background=element_blank(),
           legend.box.background=element_rect(color='black',
                                              fill='lightgrey'),
           legend.key.size=unit(1, 'cm'))
```

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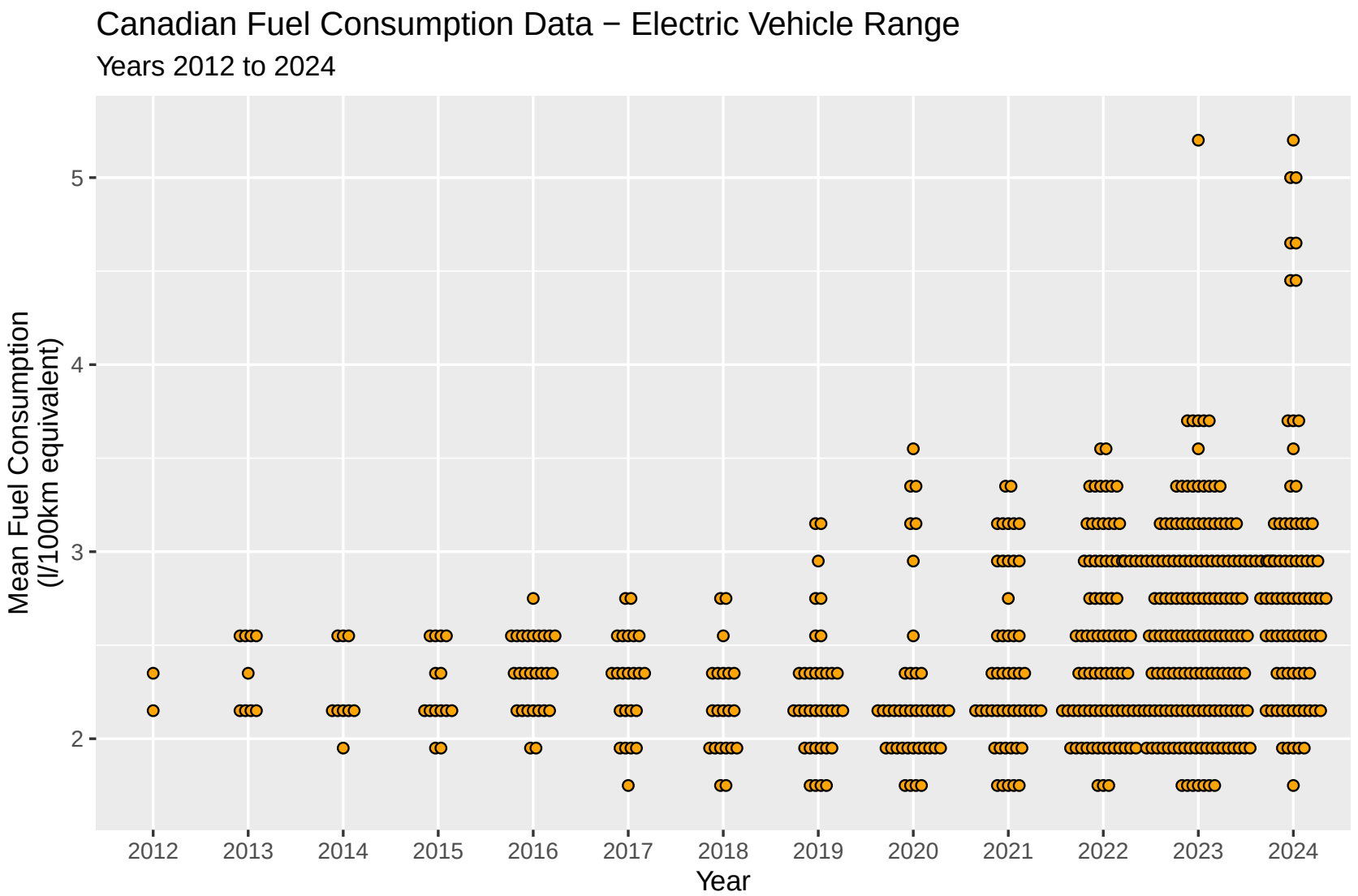
Dot Plot



MEMORIAL UNIVERSITY

Dot Plot

```
e.clean %>%
   ggplot(aes(x=as.factor(Year), y=Comb)) +
     geom_dotplot(binaxis='y',
                  stackdir='center',
                  stackratio=0.5,
                  binpositions='all',
                  dotsize=0.5, color='black', fill='orange') +
     scale_fill_brewer(palette="Paired") +
     labs(x = 'Year',
          y='Mean Fuel Consumption\n(l/100km equivalent)',
          fill='',
          title='Canadian Fuel Consumption Data - Electric Vehicle Ran
          subtitle='Years 2012 to 2024') +
     scale_y_continuous(labels=scales::comma) +
```

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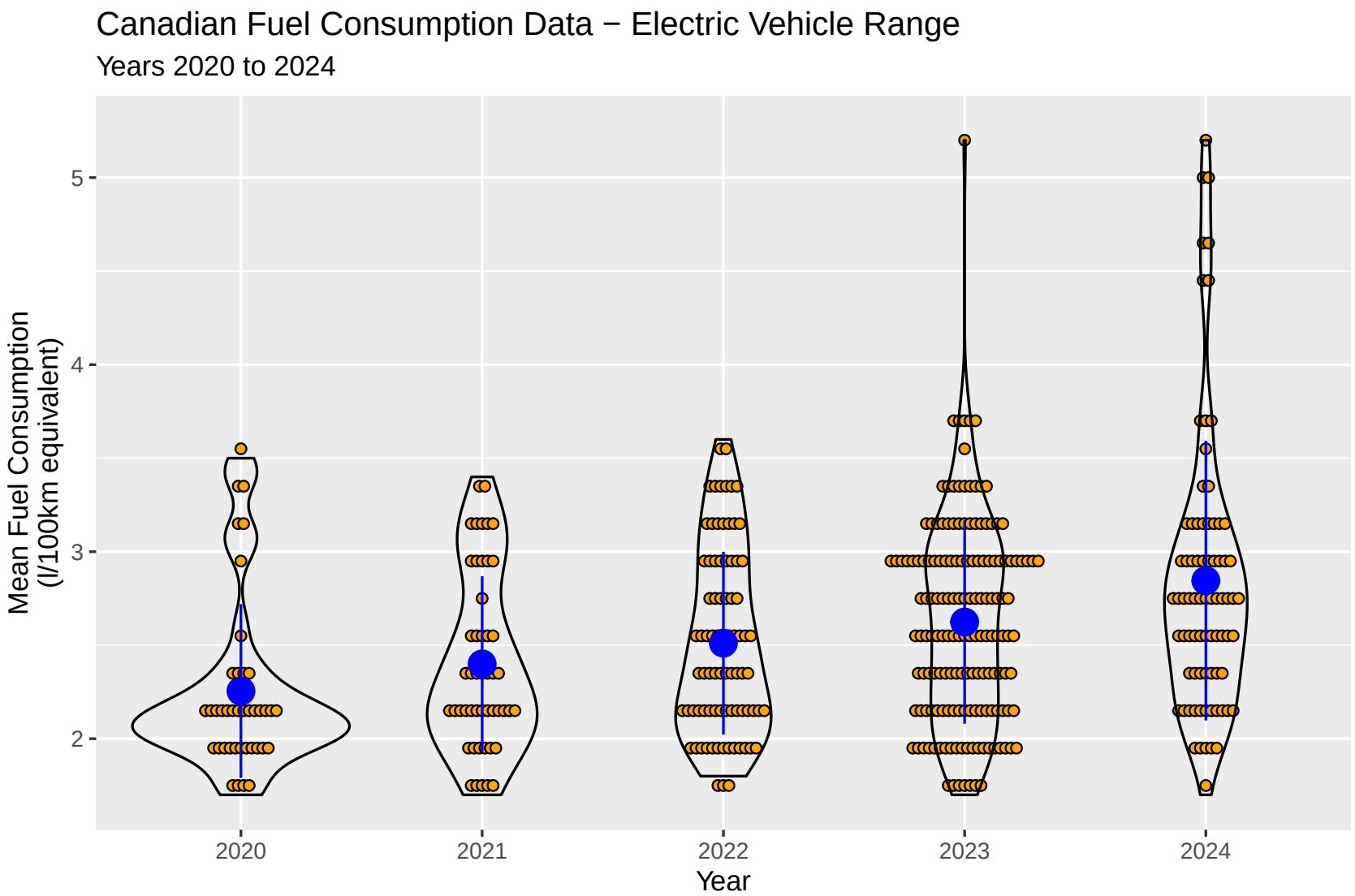
Dot Plot (with Violin and Range Summary)



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Dot Plot (with Violin and Range Summary)

```
e.clean %>%
   filter(Year > 2019) %>%
   ggplot(aes(x=as.factor(Year), y=Comb)) +
     geom_dotplot(binaxis='y',
                  stackdir='center',
                  stackratio=0.5,
                  binpositions='all',
                  dotsize=0.5, color='black', fill='orange') +
     geom_violin(color='black', fill=NA) +
     stat_summary(fun.data=mean_sdl,
                  fun.args=list(mult=1),
                  size=1, color='blue',
                  geom="pointrange") +
     scale_fill_brewer(palette="Paired") +
     labs(x = 'Year',
          y='Mean Fuel Consumption\n(l/100km equivalent)',
          fill='',
          title='Canadian Fuel Consumption Data - Electric Vehicle Ran
          subtitle='Years 2020 to 2024') +
     scale_y_continuous(labels=scales::comma) +
     theme(legend.position='none')
```

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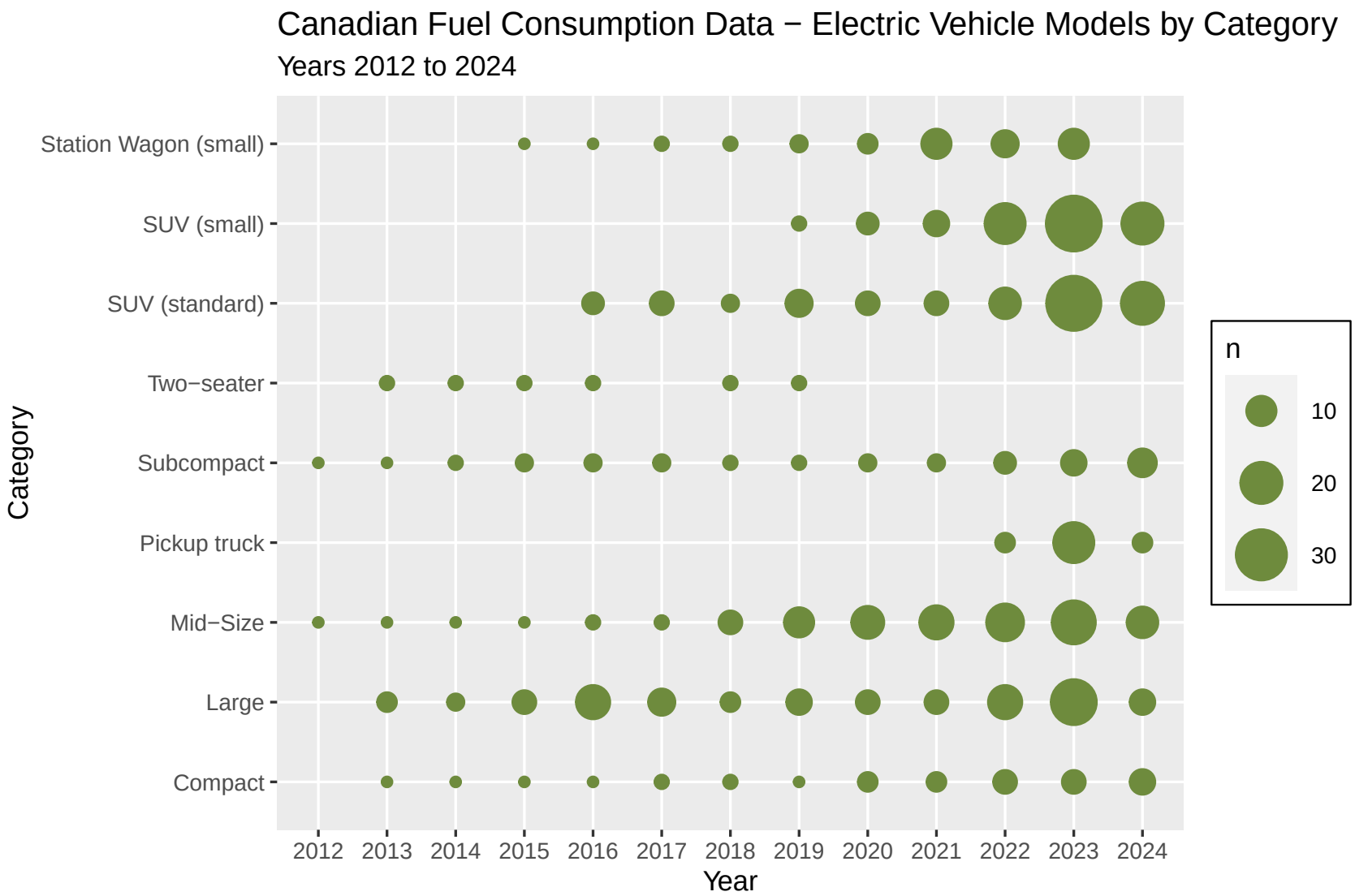
Count Plot



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Count Plot

```
e.clean %>%
   ggplot(aes(as.factor(Year), as.factor(Category))) +
      geom_count(color='darkolivegreen4')+
      scale_size_area(max_size=10, n.breaks=6) +
      scale_color_brewer(palette="Paired") +
          scale_y_discrete(
             labels=c('Compact', 'Large', 'Mid-Size', 'Pickup truck',
                      'Subcompact', 'Two-seater', 'SUV (standard)',
                      'SUV (small)', 'Station Wagon (small)')) +
          guides(color=FALSE) +
      labs(x = 'Year',
           y='Category',
           fill='',
           title='Canadian Fuel Consumption Data - Electric Vehicle Mo
           subtitle='Years 2012 to 2024') +
      theme(legend.background=element_blank(),
            legend.box.background=element_rect(color='black',
                                               fill=NA),
            legend.key.size=unit(1, 'cm'))
```

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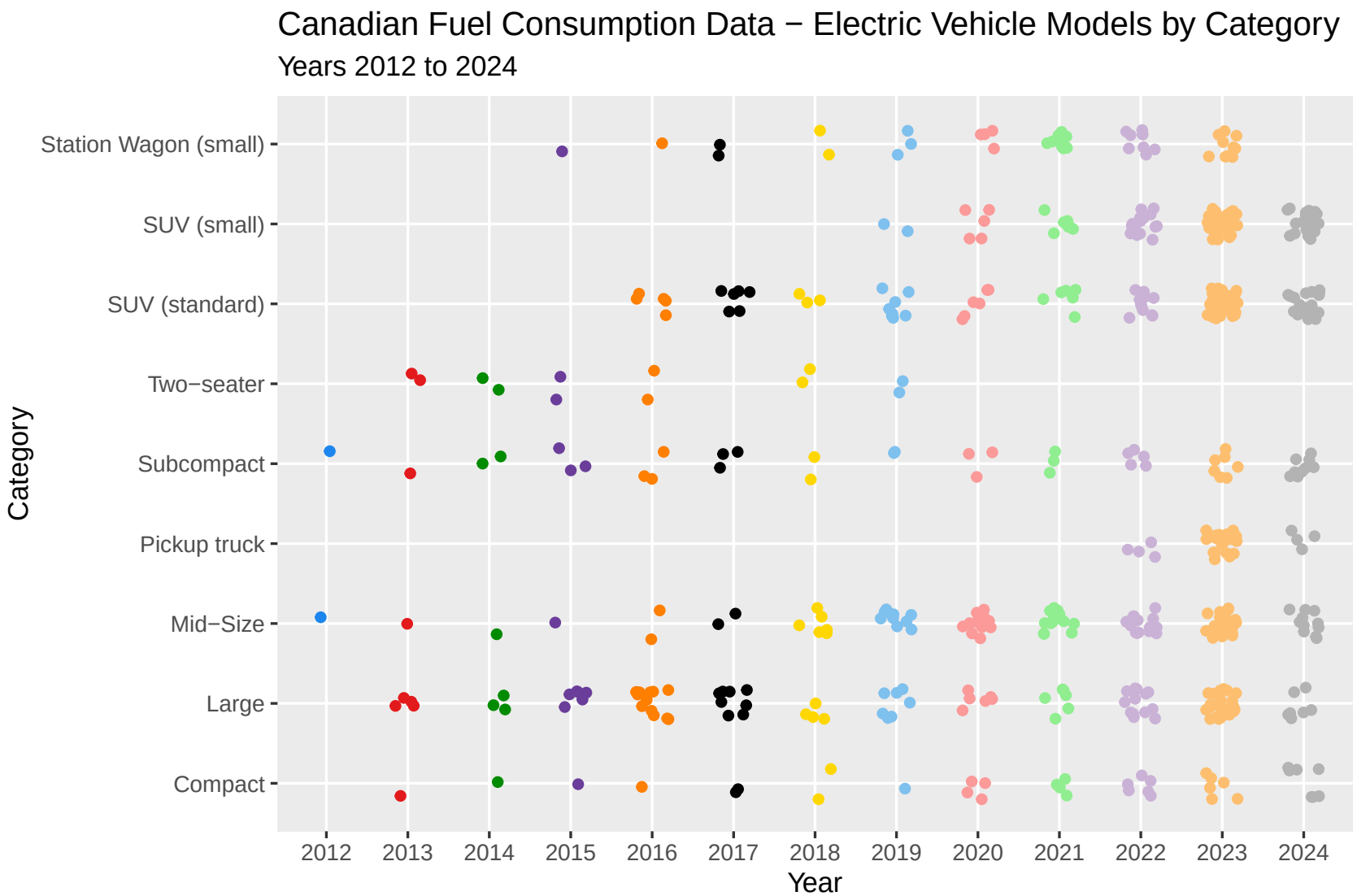
Jitter Plot



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Jitter Plot

```
e.clean %>%
   ggplot(aes(x=as.factor(Year),
              y=as.factor(Category),
              color=as.factor(Year))) +
      geom_jitter(width=0.2, height=0.2) +
      scale_color_manual(values=c25) +
          scale_y_discrete(
              labels=c('Compact', 'Large', 'Mid-Size', 'Pickup truck',
                       'Subcompact', 'Two-seater', 'SUV (standard)',
                       'SUV (small)', 'Station Wagon (small)')) +
          guides(color=FALSE) +
      labs(x = 'Year',
           y='Category',
           fill='Make',
           title='Canadian Fuel Consumption Data - Electric Vehicle Mo
           subtitle='Years 2012 to 2024')
```

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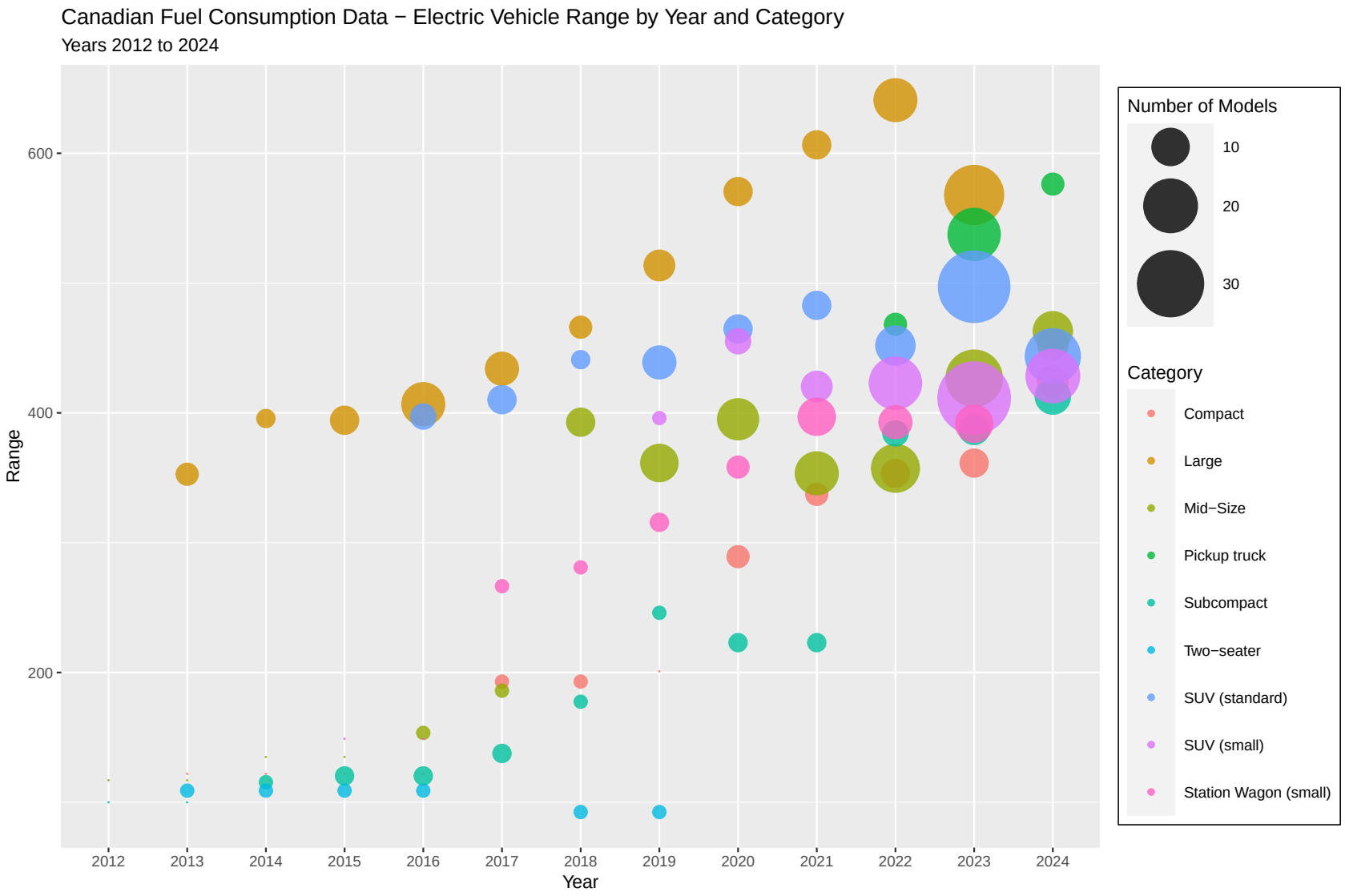
Points Plot



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Points Plot

```
e.clean %>%
   group_by(Year, Category) %>%
   summarize(totalcount=n(), meanRange=mean(Range)) %>%
   ungroup () %>%
   ggplot(aes(x=as.factor(Year), y=meanRange,
              size=totalcount, color=Category)) +
      geom_point(alpha=0.8) +
      scale_size_continuous(range=c(0, 20)) +
      scale_color_tron() +
      scale_y_continuous(labels=scales::comma) +
          scale_color_discrete(
              labels=c('Compact', 'Large', 'Mid-Size', 'Pickup truck',
                       'Subcompact', 'Two-seater', 'SUV (standard)',
                       'SUV (small)', 'Station Wagon (small)')) +
    labs(x = 'Year', y='Range',
    fill='Make', size='Number of Models',
          title='Canadian Fuel Consumption Data - Electric Vehicle Ran
          subtitle='Years 2012 to 2024', ) +
          guides(color=guide_legend(position='bottom'),
                 size=guide_legend(position='right')) +
     theme(legend.background=element_blank(),
           legend.box.background=element_rect(color='black',
                                              fill=NA),
           legend.key.size=unit(1, 'cm'))
```

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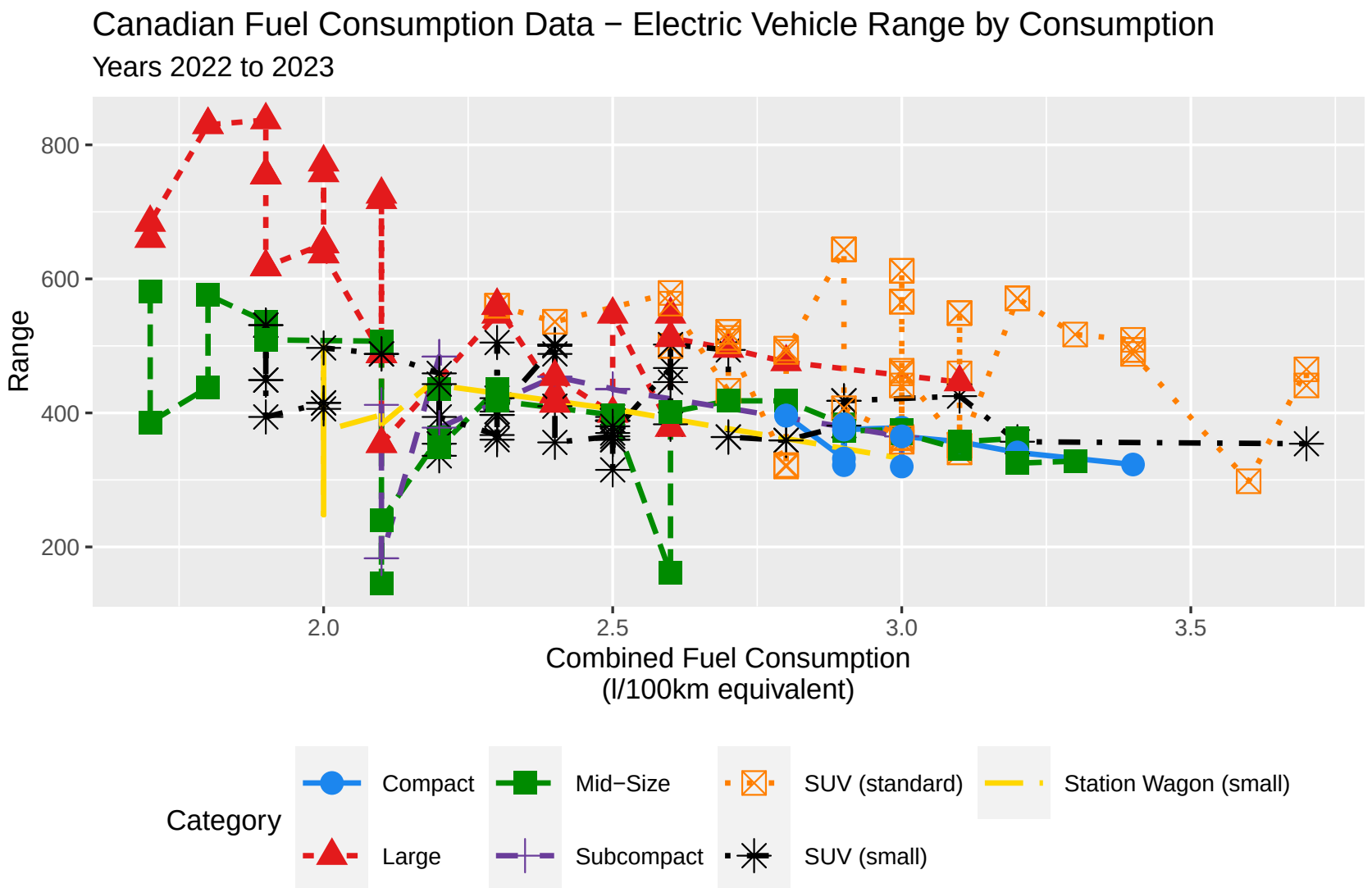
Lines and Points Plot



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Lines and Points Plot

```
e.clean %>%
   filter(Year >= 2022 & Year <= 2023) %>%
   filter(Comb <= 4) %>%
   filter(Category != 'PL') %>%
   filter(Category != 'T') %>%
   ggplot(aes(Comb, Range,
              color=Category,
              shape=Category,
              linetype=Category)) +
      geom_line(size=1) +
      geom_point(size=4) +
      scale_color_manual(values=c25,
        labels=c('Compact', 'Large', 'Mid-Size', 'Subcompact',
                 'SUV (standard)', 'SUV (small)',
                 'Station Wagon (small)')) +
      scale_linetype(
         labels=c('Compact', 'Large', 'Mid-Size', 'Subcompact',
                  'SUV (standard)', 'SUV (small)',
                  'Station Wagon (small)')) +
      scale_shape(
         labels=c('Compact', 'Large', 'Mid-Size', 'Subcompact',
                  'SUV (standard)', 'SUV (small)',
                  'Station Wagon (small)')) +
...
```

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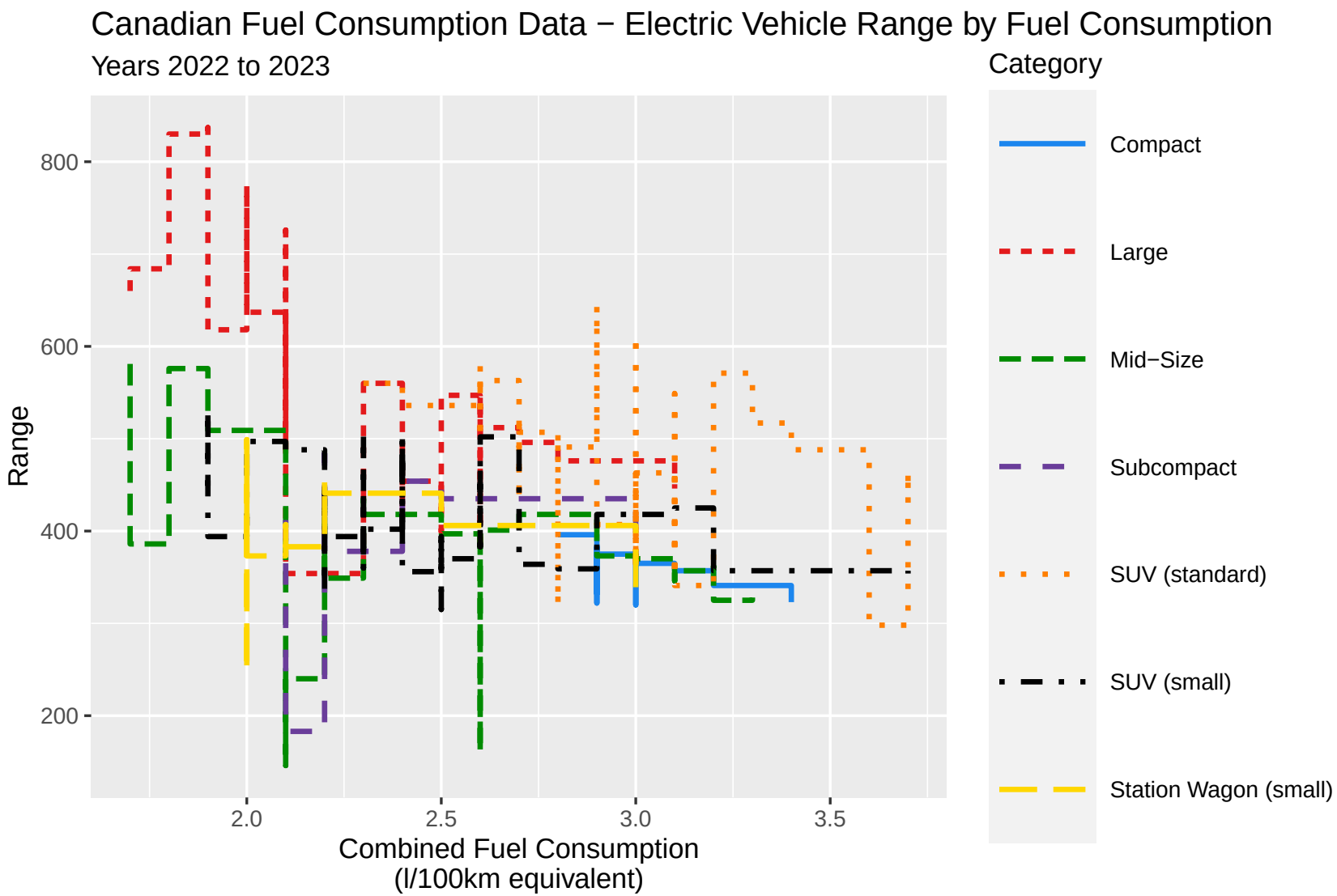
Stepped Lines Plot



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Stepped Lines Plot

```
e.clean %>%
   filter(Year >= 2022 & Year <= 2023) %>%
   filter(Comb <= 4) %>%
   filter(Category != 'PL') %>%
   filter(Category != 'T') %>%
   ggplot(aes(Comb, Range, color=Category, linetype=Category)) +
     geom_step(size=1) +
     scale_color_manual(values=c25,
          labels=c('Compact', 'Large', 'Mid-Size', 'Subcompact',
                   'SUV (standard)', 'SUV (small)',
                   'Station Wagon (small)')) +
     scale_linetype(
          labels=c('Compact', 'Large', 'Mid-Size', 'Subcompact',
                   'SUV (standard)', 'SUV (small)',
                   'Station Wagon (small)')) +
     scale_y_continuous(labels=scales::comma) +
     labs(x = 'Combined Fuel Consumption\n(l/100km equivalent)',
          y='Range',
          title='Canadian Fuel Consumption Data - Electric Vehicle Ran
          subtitle='Years 2022 to 2023', ) +
     theme(legend.key.size=unit(1.5, 'cm'))
```

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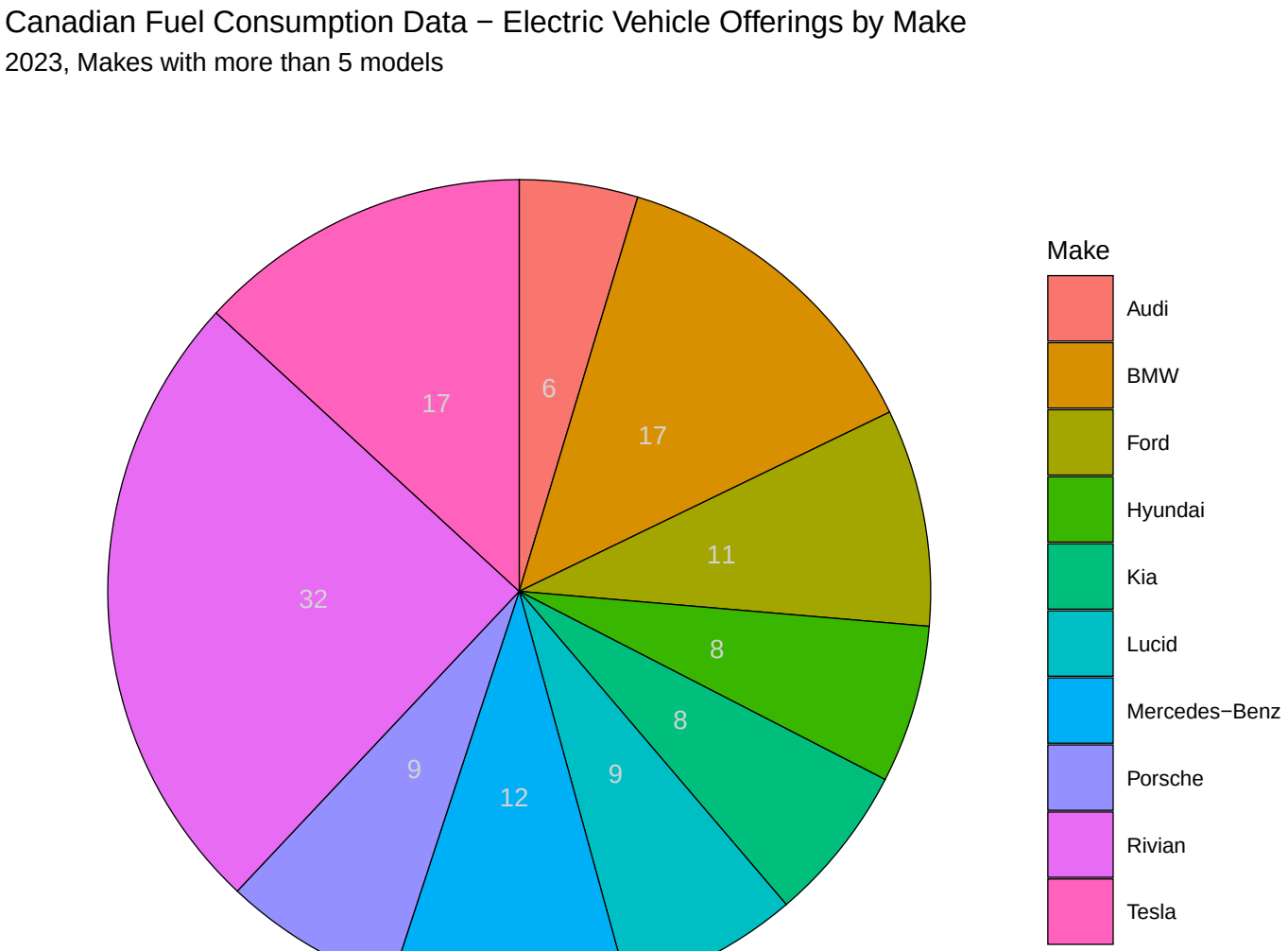
Pie Chart



Pie Chart

```
e.clean %>%
   filter(Year==2023) %>%
   group_by(Make) %>%
   summarize(totalcount = n()) %>%
   filter(totalcount >= 5) %>%
   ungroup() %>%
   ggplot(aes(x='', y=totalcount, fill=Make)) +
     geom_bar(stat='identity', color='black', size=0.25, width=1) +
     coord_polar('y', direction=-1, start=0) +
     geom_text(aes(label=ifelse(totalcount >= 5, totalcount, '')),
                   color='lightgrey',
                   position = position_stack(vjust=0.5)) +
      scale_y_continuous(labels=NULL) +
      scale_color_brewer(palette="Paired") +
      labs(x = '', y = '',  fill='Make',
           title='Canadian Fuel Consumption Data - Electric Vehicle Of
           subtitle='2023, Makes with more than 5 models') +
      theme_void() +
      theme(legend.key.size=unit(1, 'cm'))
```

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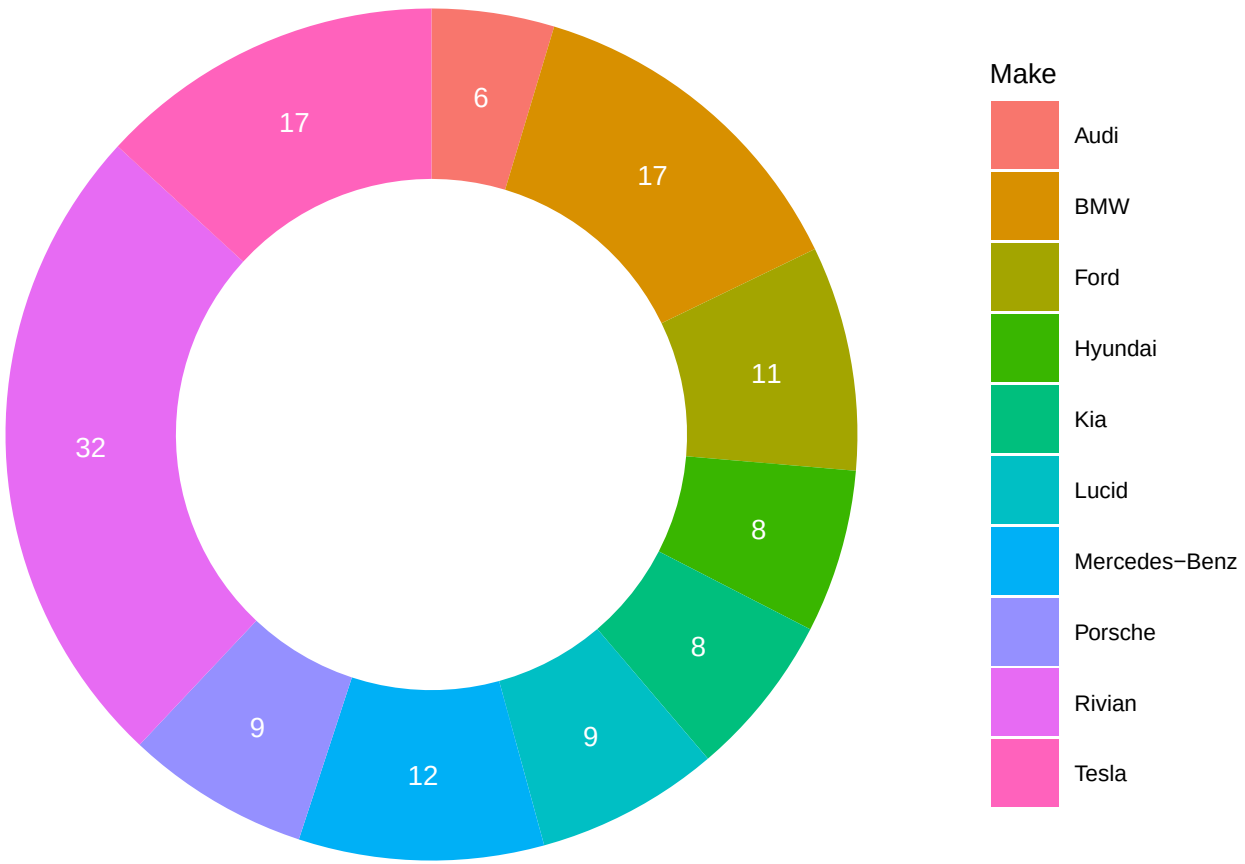
Donut Chart

Canadian Fuel Consumption Data − Electric Vehicle Offerings by Make

2023, Makes with more than 5 models



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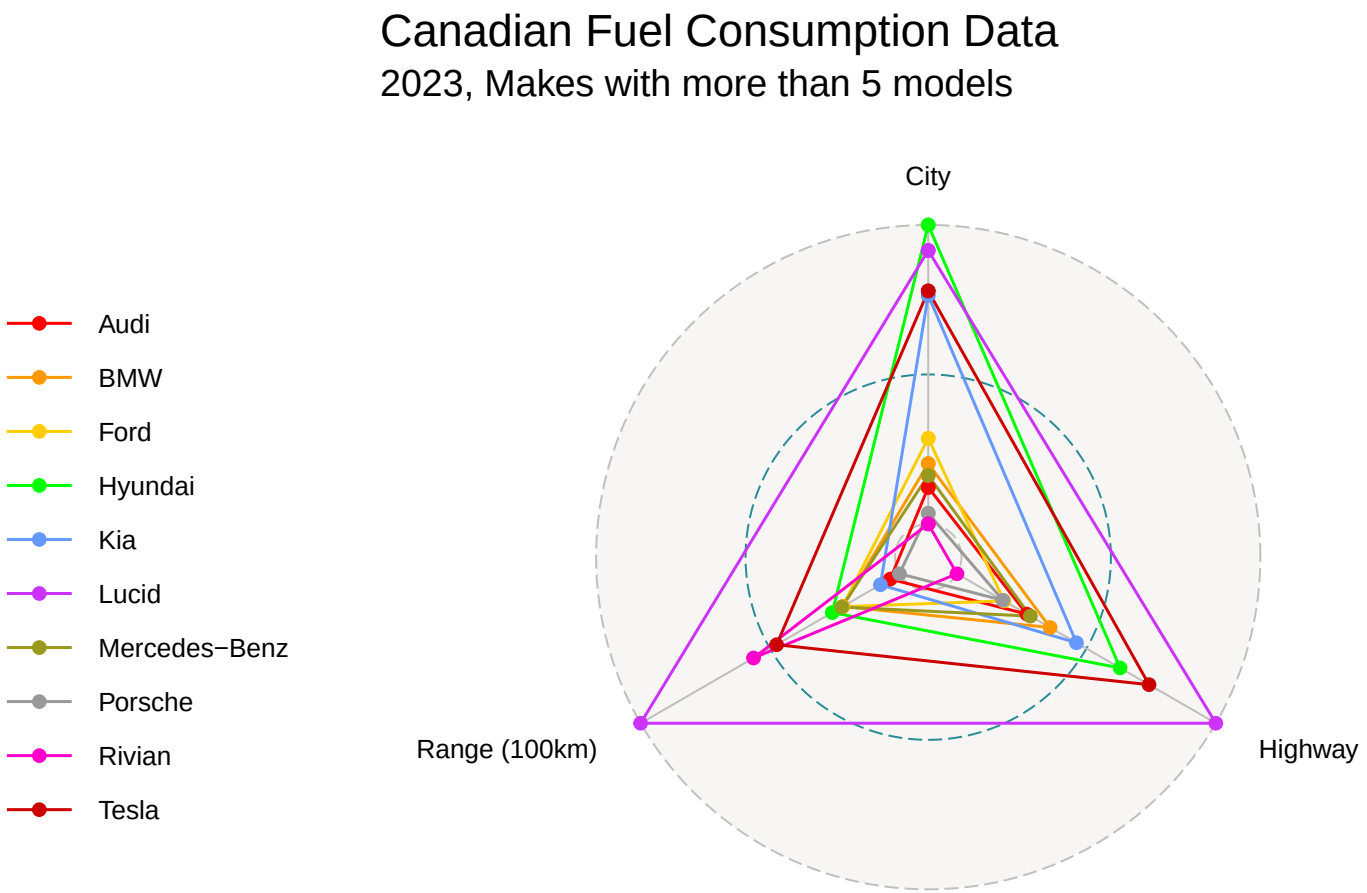
Donut Chart

```
holesize <- 2

....

   ggplot(aes(x=holesize, y=totalcount, fill=Make)) +
     geom_col() +
     coord_polar('y', direction=-1, start=0) +
     xlim(c(0.2, holesize+0.5)) +
     geom_text(aes(label=ifelse(totalcount > 5, totalcount, '')),
               color='white',
               position = position_stack(vjust=0.5)) +
...
```

Radar Plot



Radar Plot

```
e.clean %>%
   filter(Year == 2023) %>%
   group_by(Make) %>%
   summarize(meanCity = 1/mean(City),
             meanHwy = 1/mean(Hwy),
             meanRange = mean(Range)/100,
             nModels = n()) %>%
   filter(nModels >= 5) %>%
   ungroup() %>%
   select(-nModels) %>%
   mutate_at(vars(-Make), rescale) %>%
   ggradar(axis.labels=c('City', 'Highway', 'Range (100km)'),
           values.radar='',
           group.line.width=0.75,
           group.point.size=3) +
      scale_color_ucscgb() +
      labs(x = '', y = '',  fill='Make',
           title='Canadian Fuel Consumption Data',
           subtitle='2023, Makes with more than 5 models')
```

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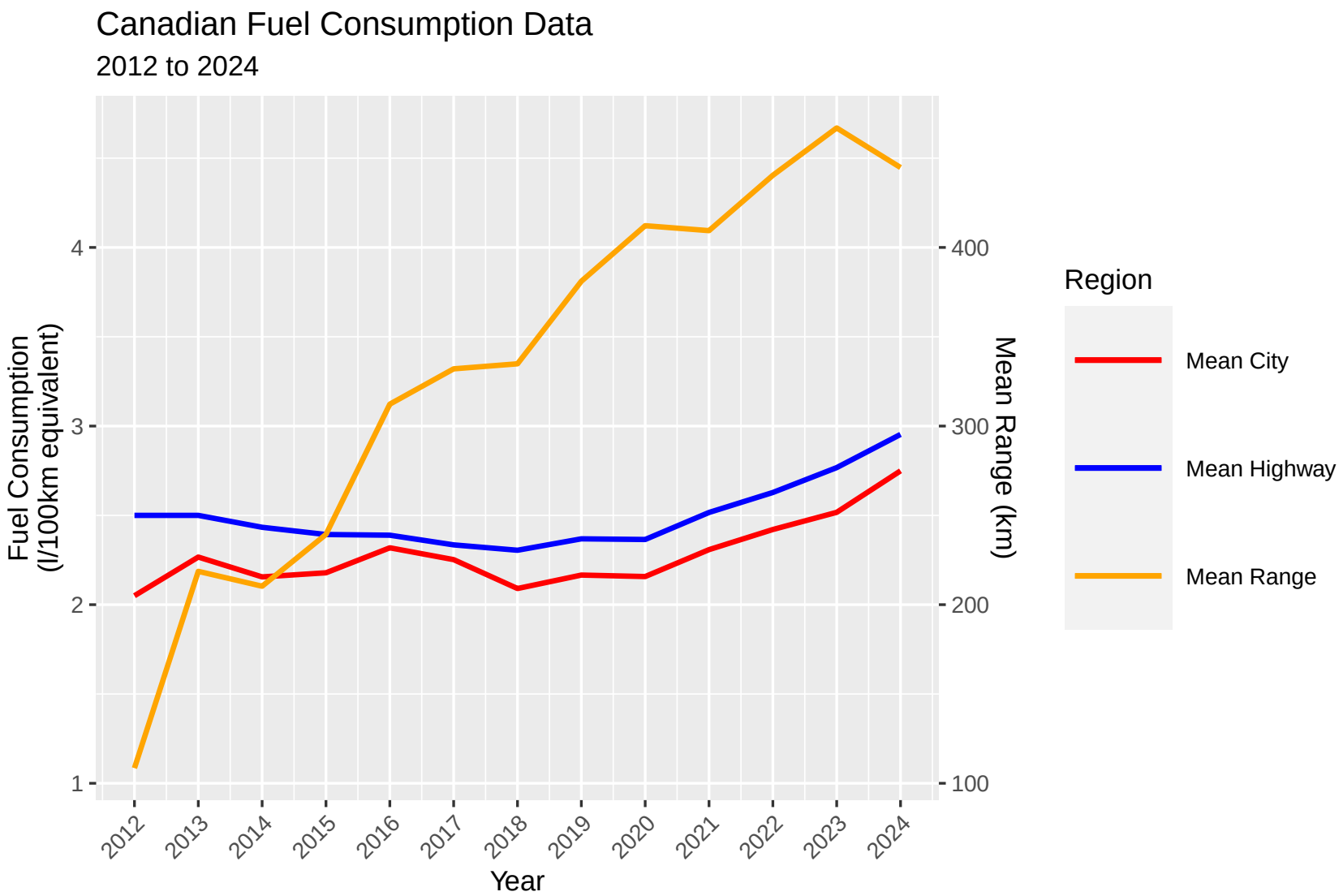
Lines with Multiple Axes



MEMORIAL UNIVERSITY

Lines with Multiple Axes

```
e.clean %>%
   group_by(Year) %>%
   summarize(meanCity = mean(City),
             meanHwy = mean(Hwy),
             meanRange = mean(Range)) %>%
   ungroup() %>%
   mutate(meanRange2 = meanRange/100) %>%
   ggplot(aes(x=Year)) +
      scale_color_manual(name='Region',
          values=c('Mean City' = 'red',
                   'Mean Highway' = 'blue',
                   'Mean Range' = 'orange')) +
      geom_line(aes(y=meanCity, color='Mean City'), size=1) +
      geom_line(aes(y=meanHwy, color='Mean Highway'), size=1) +
      geom_line(aes(y=meanRange2, color='Mean Range'), size=1) +
      scale_y_continuous(labels=scales::comma,
          name="Fuel Consumption\n(l/100km equivalent)",
          sec.axis=sec_axis(~ .*100, labels=scales::comma,
                            name="Mean Range (km)")) +
          scale_x_continuous(breaks=seq(from=2012, to=2024, by=1)) +
      labs(x = 'Year', color='', y = 'Mean Fuel Consumption\n(l/100km
           title='Canadian Fuel Consumption Data',
           subtitle='2012 to 2024') +
      theme(legend.key.size=unit(1.5, 'cm'),
            axis.text.x = element_text(angle=45, hjust=1))
```

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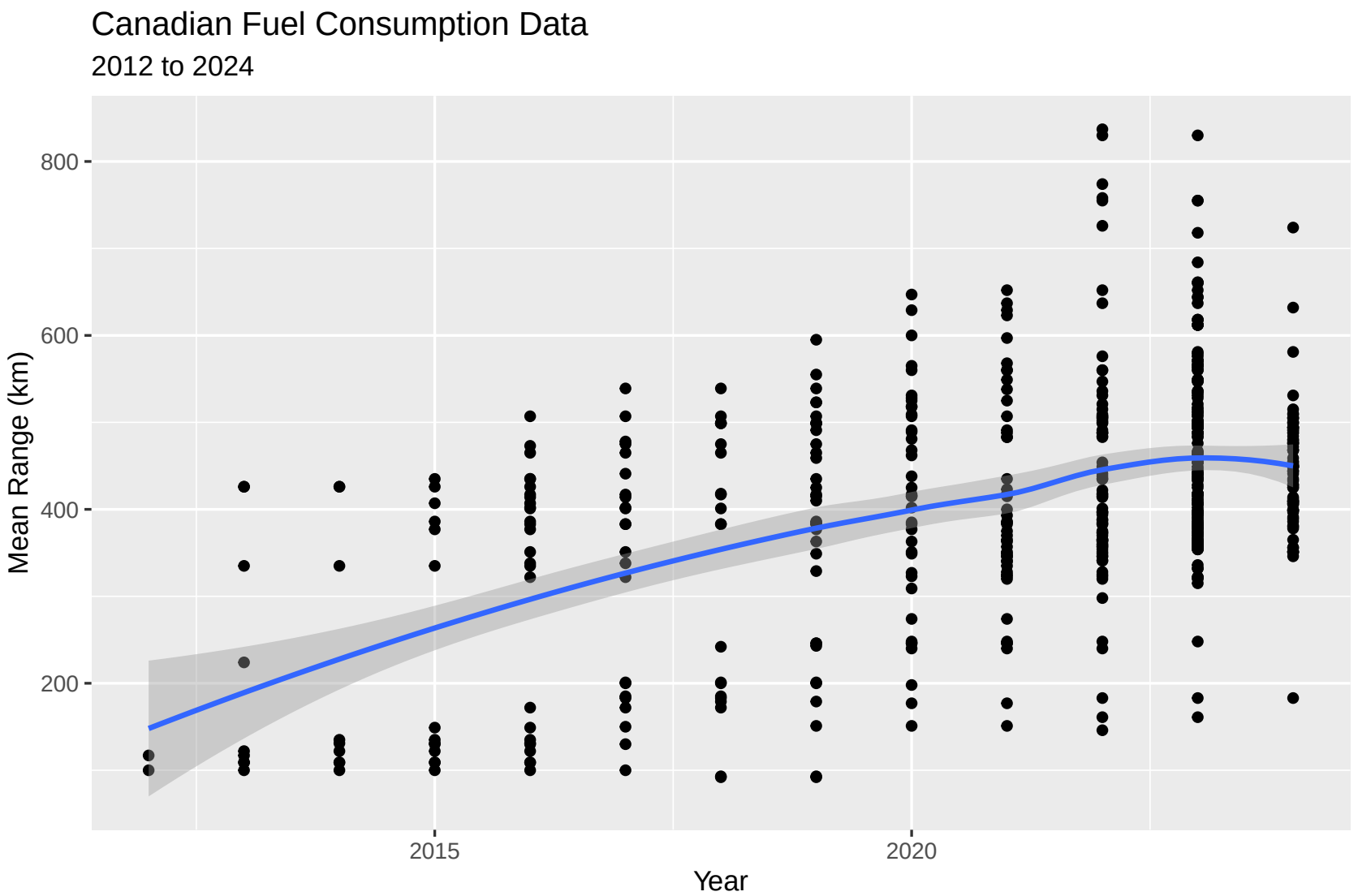
Local Regression Smoothing Plot



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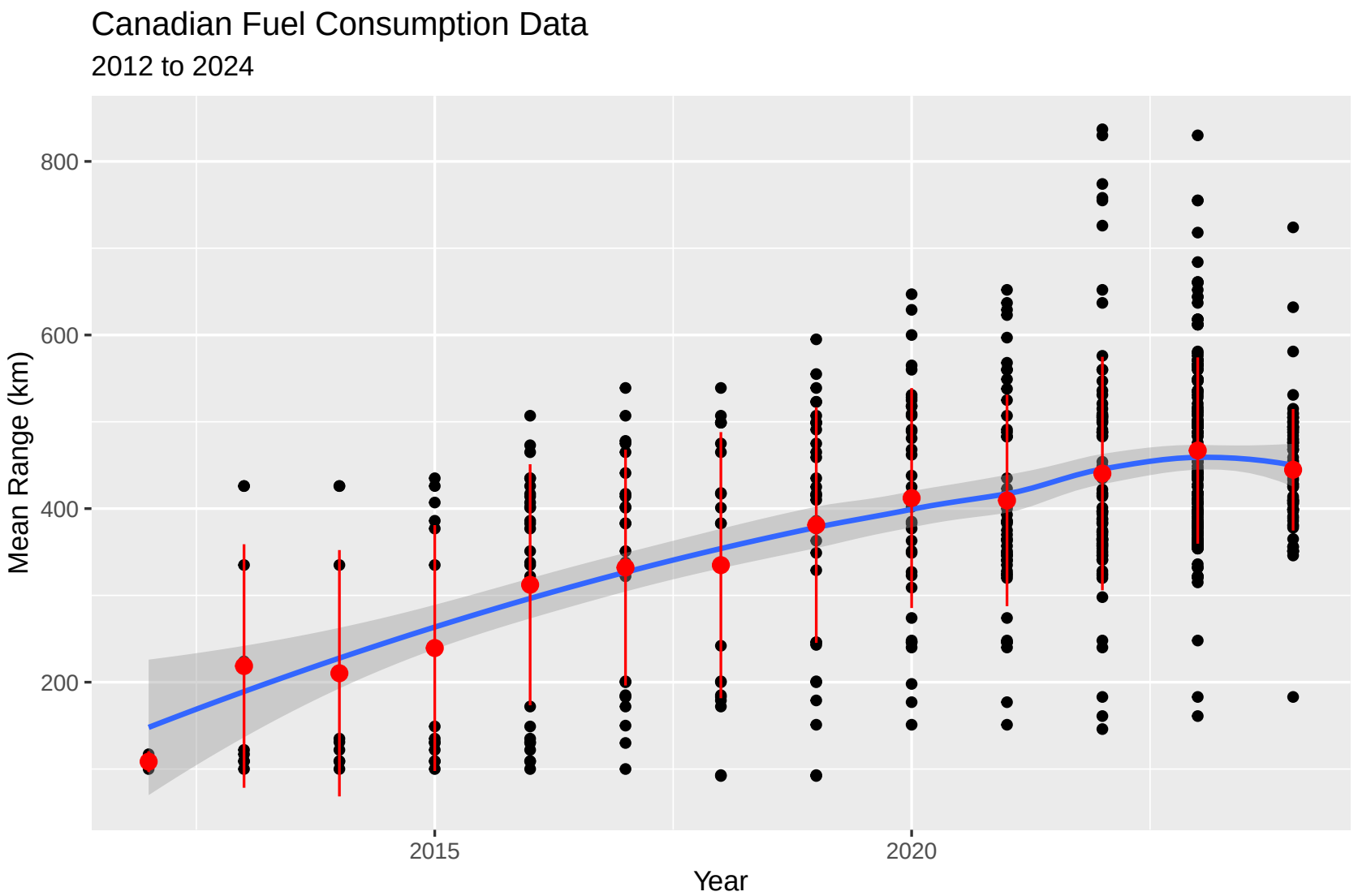
Local Regression Smoothing Plot

```
e.clean %>%
   ggplot(aes(Year, Range)) +
      geom_point() +
      geom_smooth() +
      scale_y_continuous(labels=scales::comma) +
      labs(x = 'Year', color='', y = 'Mean Range (km)',
           title='Canadian Fuel Consumption Data',
           subtitle='2012 to 2024')
```

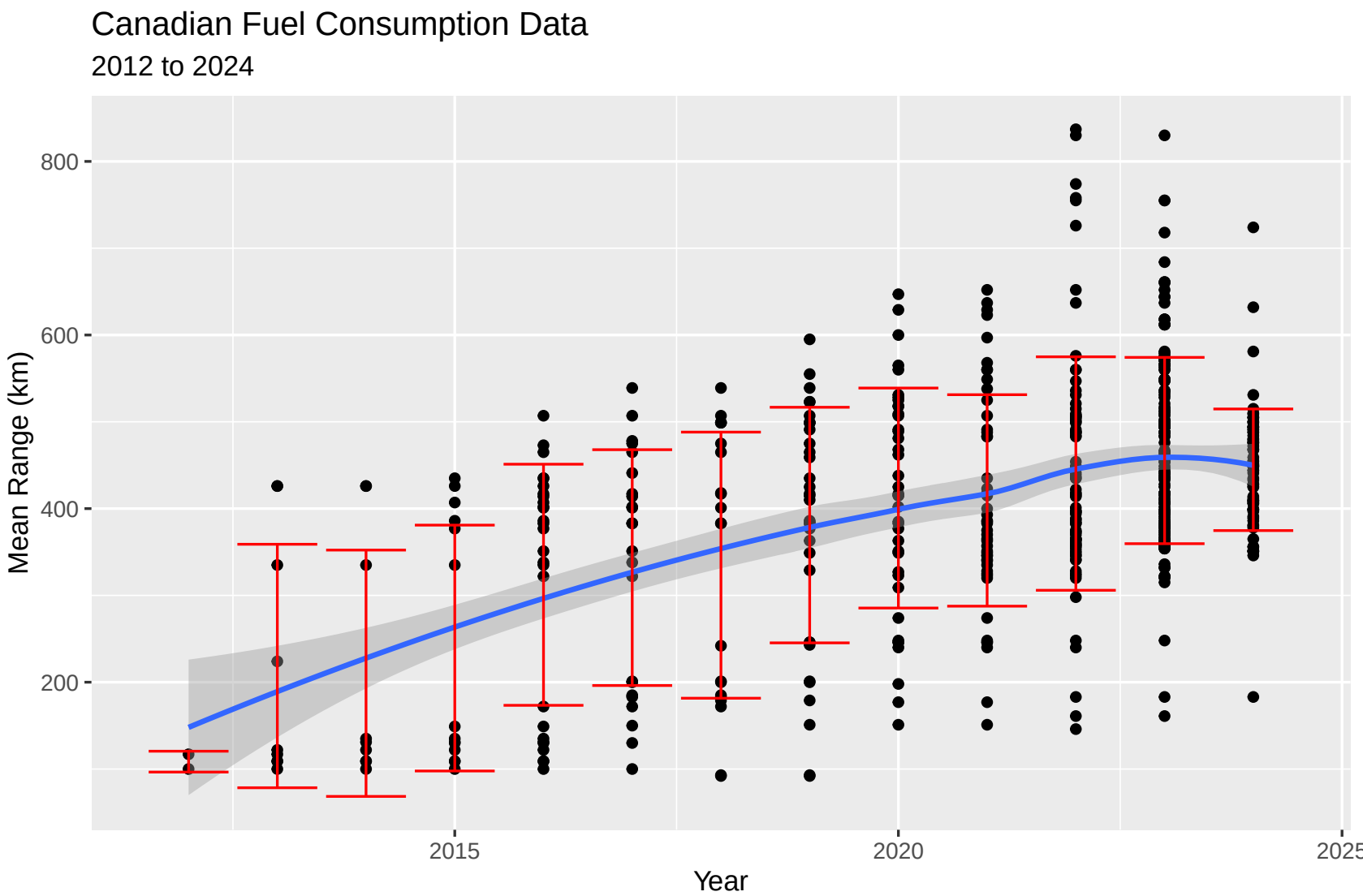
Local Regression Smoothing Plot (with range bar)



Local Regression Smoothing Plot (with range bar)

```
e.clean %>%
   ggplot(aes(Year, Range)) +
      geom_point() +
      geom_smooth() +
      stat_summary(
          fun.data=mean_sdl,
          fun.args=list(mult=1),
          color='red',
          geom="pointrange") +
      scale_y_continuous(labels=scales::comma) +
      labs(x = 'Year', color='', y = 'Mean Range (km)',
      title='Canadian Fuel Consumption Data',
      subtitle='2012 to 2024')
```

Local Regression Smoothing Plot (with error bars)



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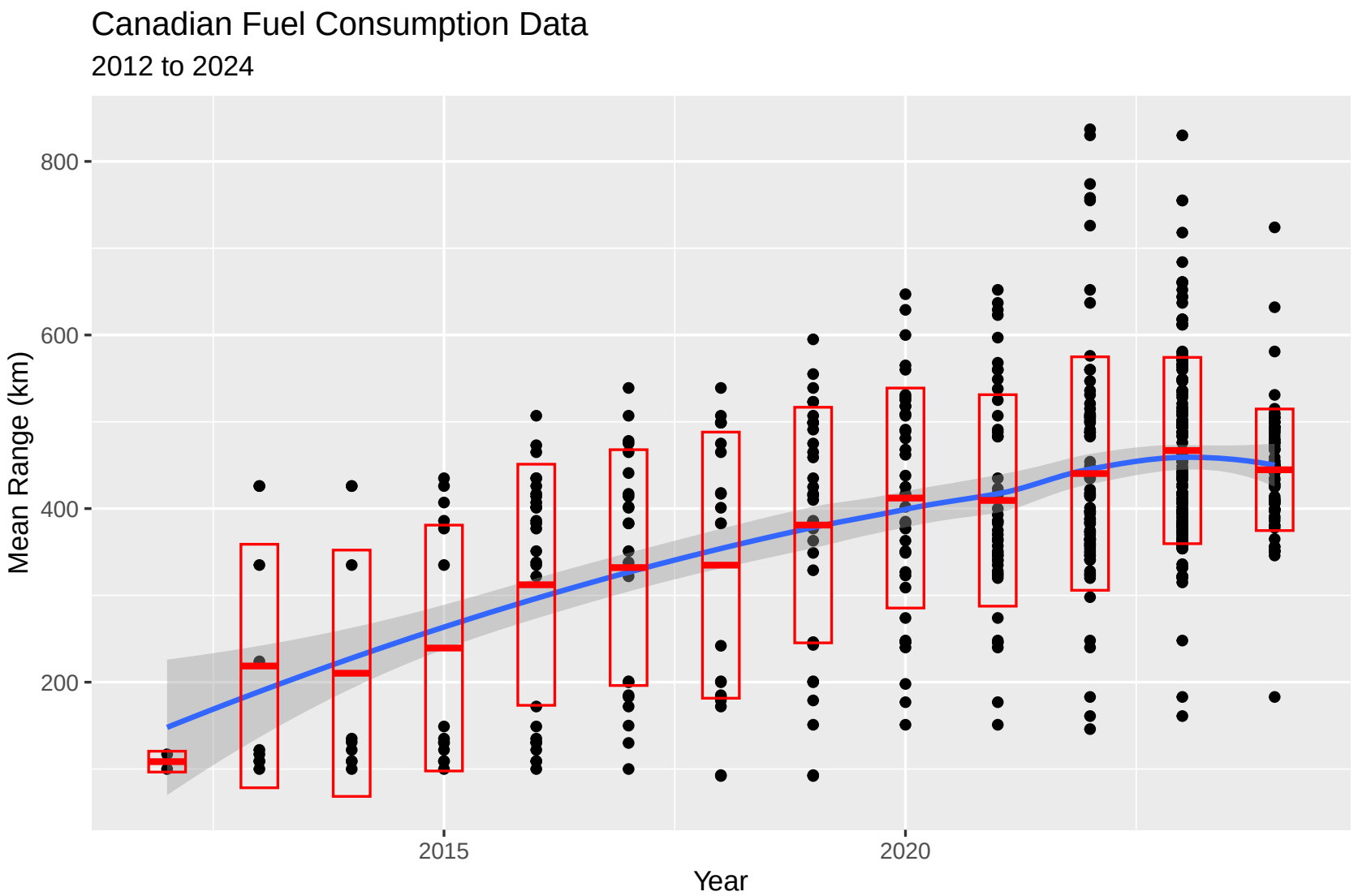
Local Regression Smoothing Plot (with error bars)

```
e.clean %>%
    ggplot(aes(Year, Range)) +
        geom_point() +
        geom_smooth() +
        stat_summary(
            fun.data=mean_sdl,
            fun.args=list(mult=1),
            color='red',
            geom="errorbar") +
        scale_y_continuous(labels=scales::comma) +
        labs(x = 'Year', color='', y = 'Mean Range (km)',
        title='Canadian Fuel Consumption Data',
        subtitle='2012 to 2024')
```

Local Regression Smoothing Plot (with cross bars)



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Local Regression Smoothing Plot (with cross bars)

```
e.clean %>%
   ggplot(aes(Year, Range)) +
      geom_point() +
      geom_smooth() +
      stat_summary(
          fun.data=mean_sdl,
          fun.args=list(mult=1),
          color='red',
          geom="crossbar",
          width=0.4) +
      scale_y_continuous(labels=scales::comma) +
      labs(x = 'Year', color='', y = 'Mean Range (km)',
      title='Canadian Fuel Consumption Data',
      subtitle='2012 to 2024')
```

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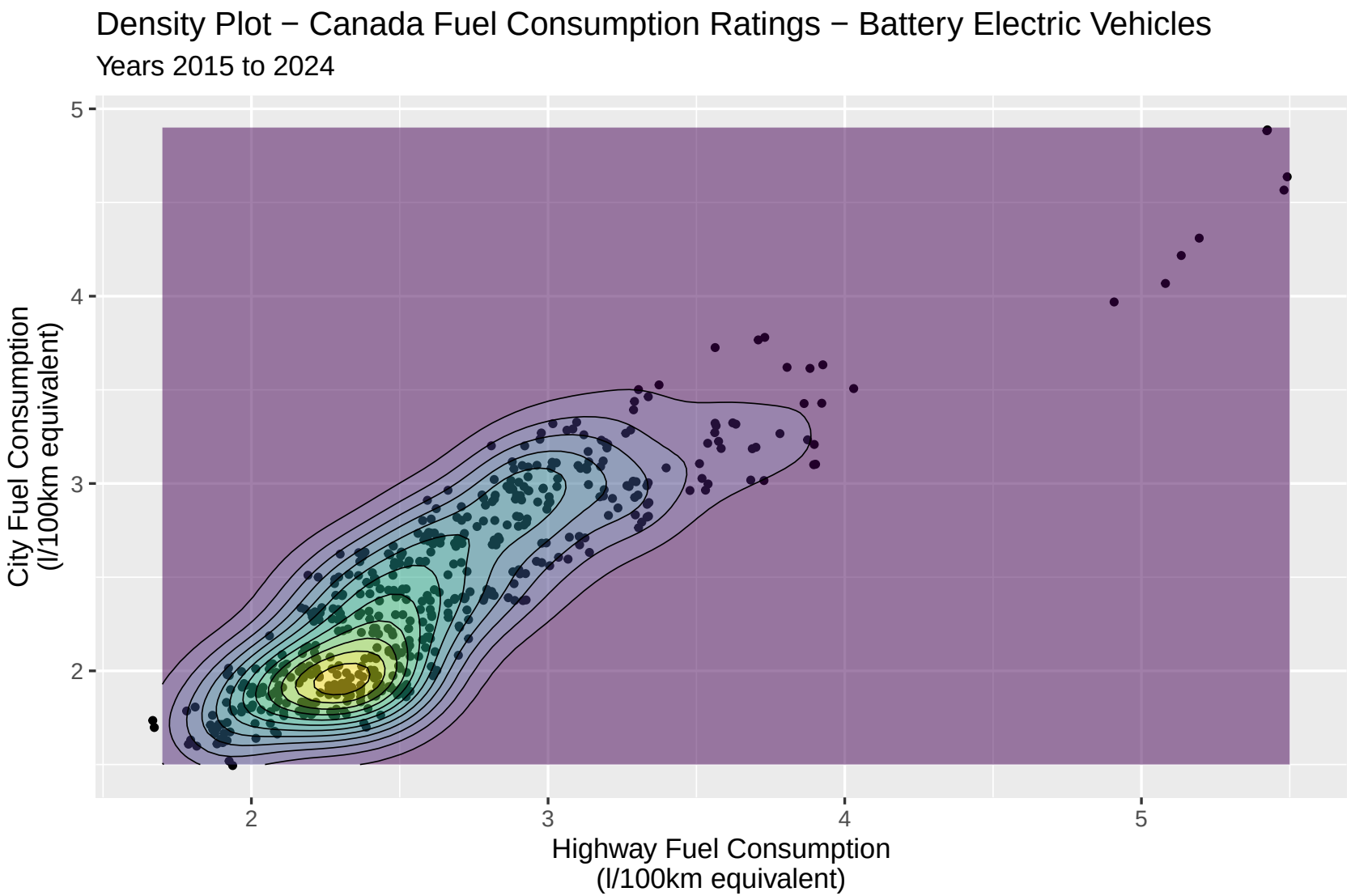
2D Density Plot



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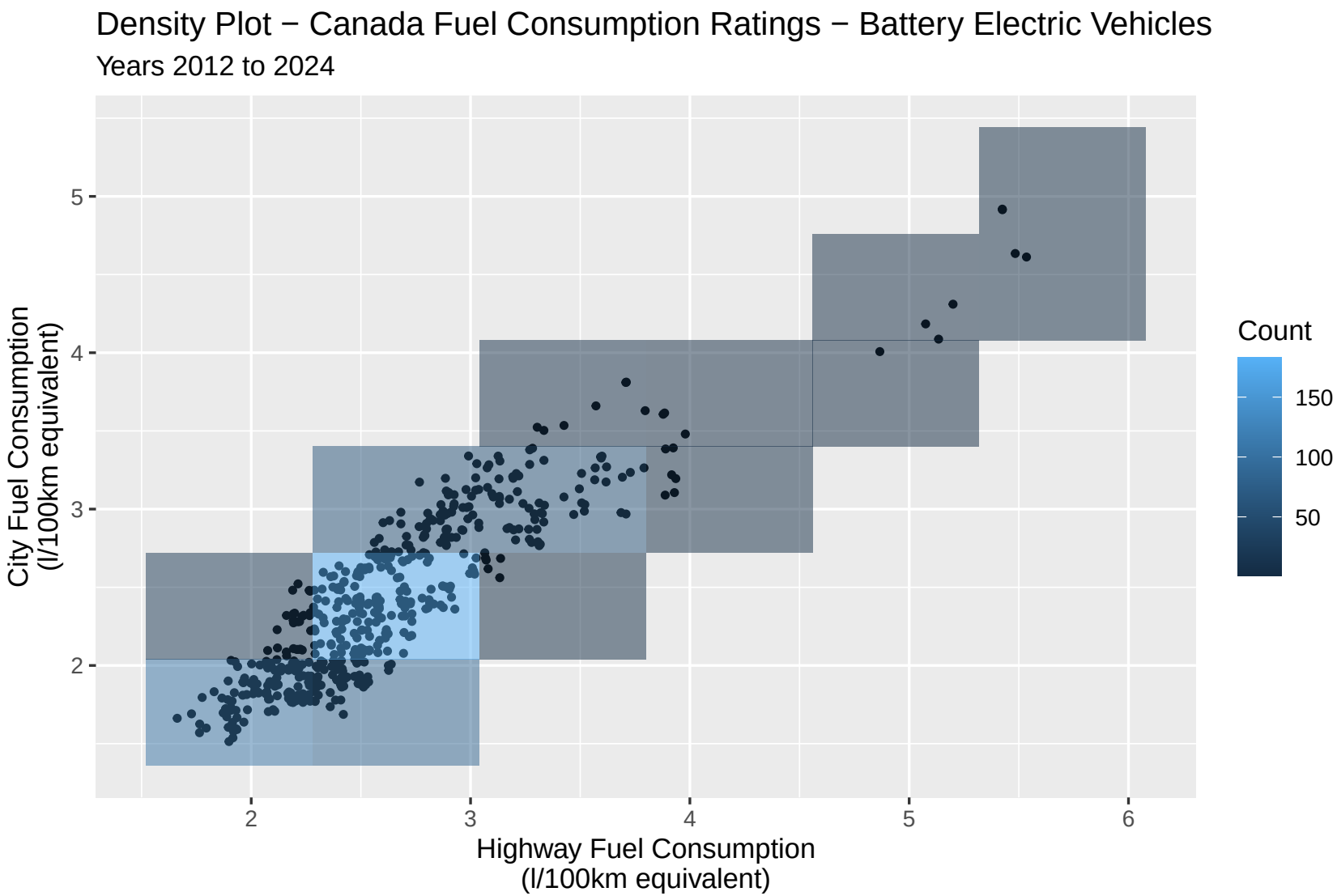
2D Density Plot

```
e.clean %>%
   ggplot(aes(x=Hwy, y=City)) +
     geom_point(color="black", size=1, position='jitter') +
     geom_density_2d_filled(alpha=0.5) +
     geom_density_2d(linewidth=0.25, colour='black') +
     scale_x_continuous(labels=scales::comma) +
     labs(x = 'Highway Fuel Consumption\n(l/100km equivalent)',
          y = 'City Fuel Consumption\n(l/100km equivalent)',
          title='Density Plot - Canada Fuel Consumption Ratings - Batt
          subtitle='Years 2015 to 2024') +
     theme(legend.position='none')
```

2D Bin Plot



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2D Bin Plot

```
e.clean %>%
   ggplot(aes(x=Hwy, y=City)) +
     geom_point(color="black", size=1, position='jitter') +
     geom_bin2d(alpha=0.5, bins=5) +
     scale_x_continuous(labels=scales::comma) +
     labs(x = 'Highway Fuel Consumption\n(l/100km equivalent)',
          y = 'City Fuel Consumption\n(l/100km equivalent)',
          fill='Count',
          title='Density Plot - Canada Fuel Consumption Ratings - Batt
          subtitle='Years 2012 to 2024')
```

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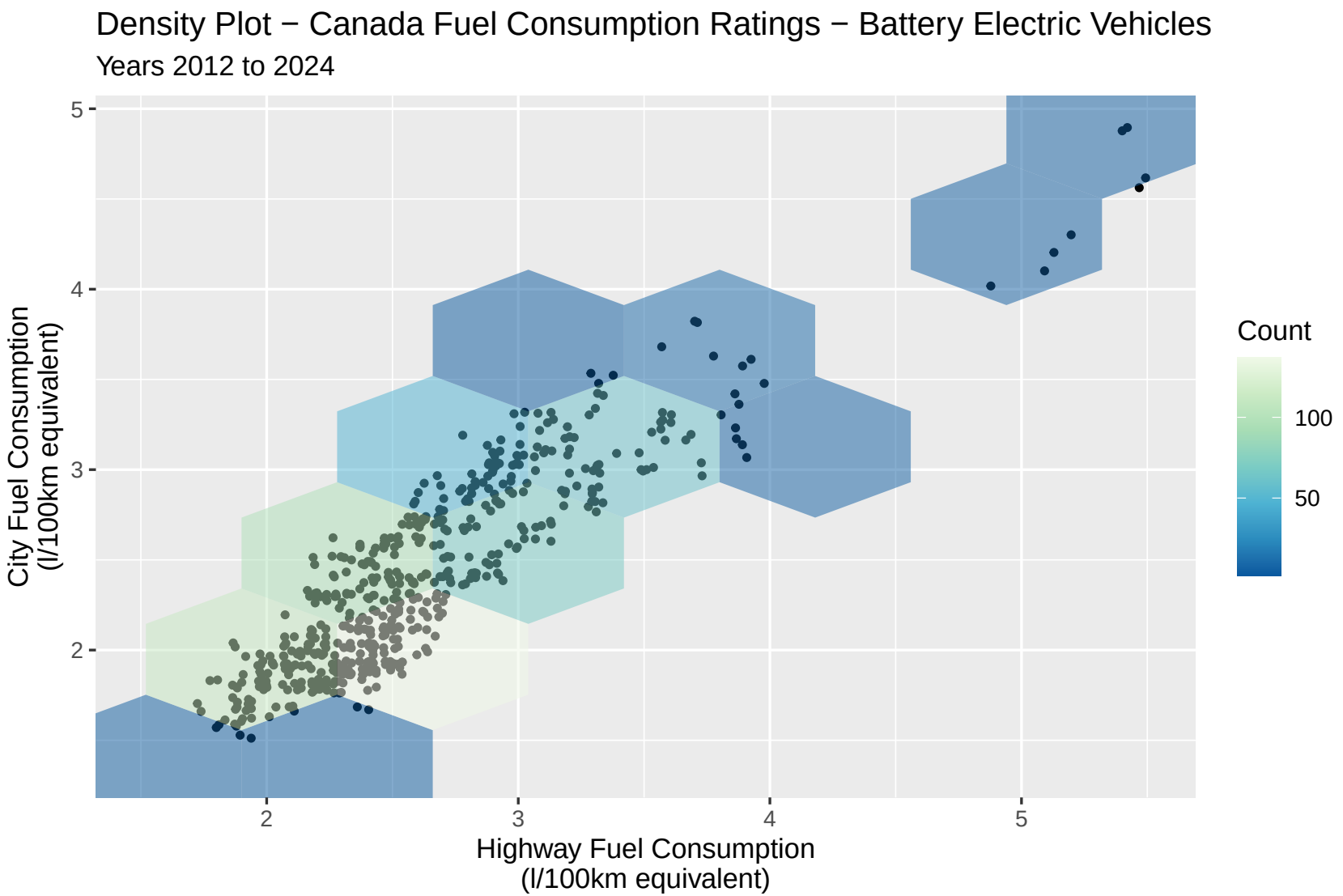
2D Hex Plot



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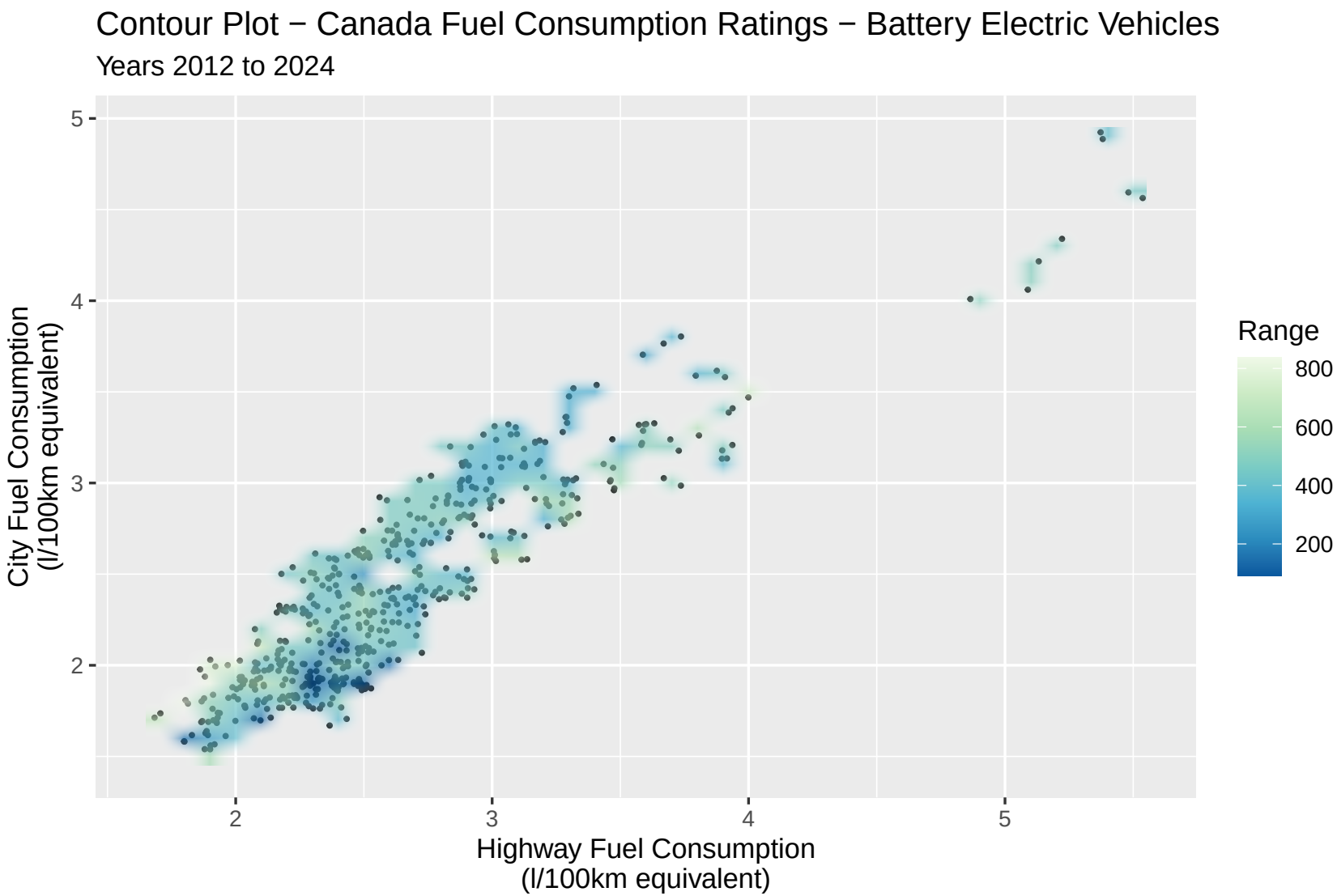
2D Hex Plot

```
e.clean %>%
   ggplot(aes(x=Hwy, y=City)) +
     geom_point(color="black", size=1, position='jitter') +
     geom_hex(alpha=0.5, bins=5) +
     scale_fill_distiller(palette=4, direction=-1) +
     scale_x_continuous(labels=scales::comma) +
     labs(x = 'Highway Fuel Consumption\n(l/100km equivalent)',
          y = 'City Fuel Consumption\n(l/100km equivalent)',
          fill='Count',
          title='Density Plot - Canada Fuel Consumption Ratings - Batt
          subtitle='Years 2012 to 2024')
```

3D Raster Plot



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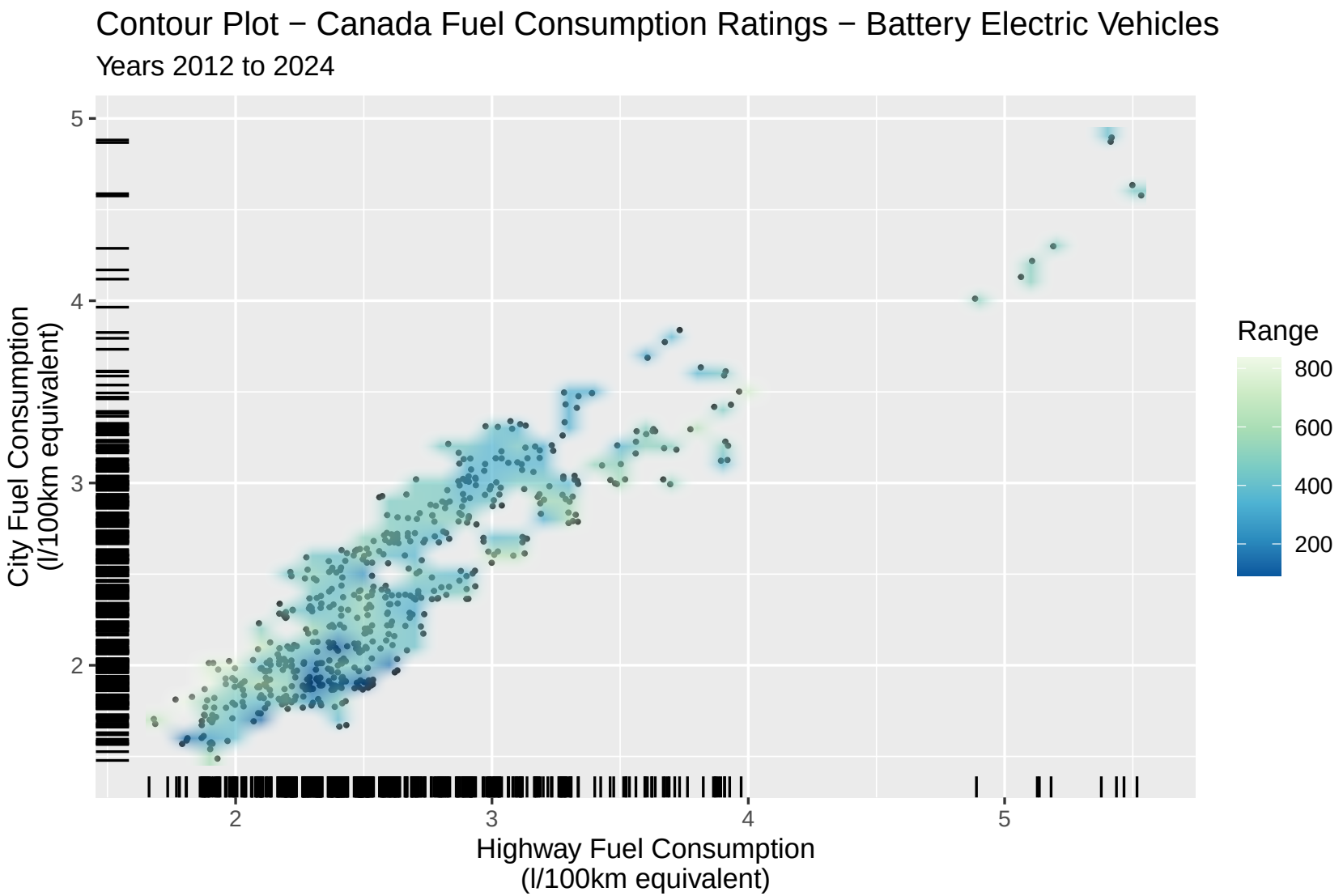
3D Raster Plot

```
e.clean %>%
   ggplot(aes(x=Hwy, y=City)) +
     geom_point(color="black", size=0.5, position='jitter') +
     geom_raster(aes(fill=Range), alpha=0.7, interpolate=TRUE) +
     scale_fill_distiller(palette=4, direction=-1) +
     scale_x_continuous(labels=scales::comma) +
     labs(x = 'Highway Fuel Consumption\n(l/100km equivalent)',
          y = 'City Fuel Consumption\n(l/100km equivalent)',
          fill='Range',
          title='Contour Plot - Canada Fuel Consumption Ratings - Batt
          subtitle='Years 2012 to 2024')
```

3D Raster Plot (with rug)



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3D Raster Plot (with rug)

```
e.clean %>%
   ggplot(aes(x=Hwy, y=City)) +
     geom_point(color="black", size=0.5, position='jitter') +
     geom_rug(position='jitter') +
     geom_raster(aes(fill=Range), alpha=0.7, interpolate=TRUE) +
     scale_fill_distiller(palette=4, direction=-1) +
     scale_x_continuous(labels=scales::comma) +
     labs(x = 'Highway Fuel Consumption\n(l/100km equivalent)',
          y = 'City Fuel Consumption\n(l/100km equivalent)',
          fill='Range',
          title='Contour Plot - Canada Fuel Consumption Ratings - Batt
          subtitle='Years 2012 to 2024')
```

Geographic Data (Maps)

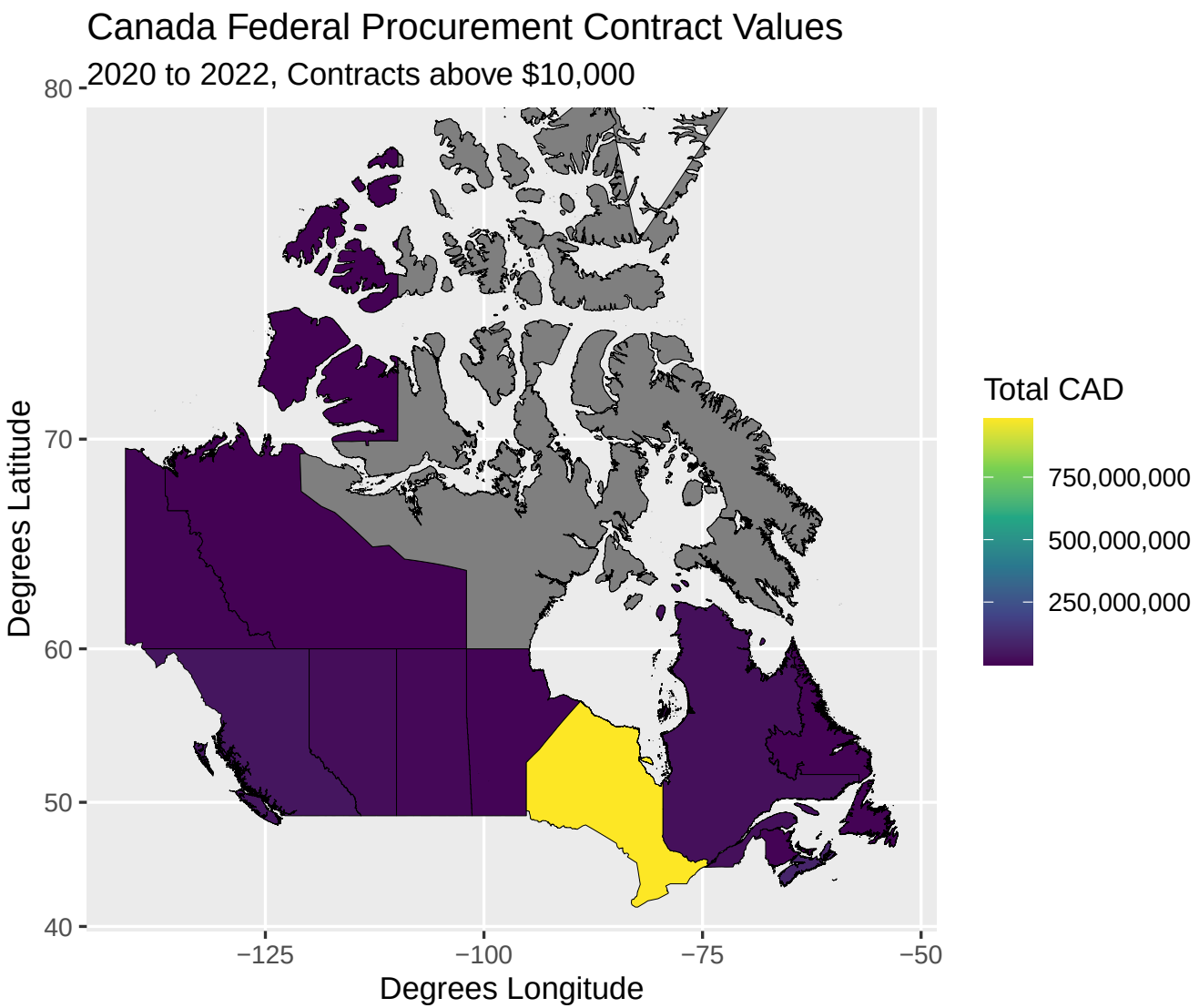
GADM Data

- Database of Global Administrative Areas
- https://gadm.org/
- ArcGIS shape file package for Canada

Statistics Canada Data

- 2016 Census Boundary Files
- https://www12.statcan.gc.ca/census-recensement/2011/geo/bound-limit/bound-limit-2016-eng.cfm
- ArcGIS shape file for provinces/territories

Contracts Data Set (GADM Data)



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Contracts Data Set (GADM Data)

```
canada.gadm <- getData("GADM",country="CAN",level=1)
canada.gadm.tidy <- tidy(canada.gadm)

d.gadm.id <- as.data.frame(
        d.clean %>% mutate(id = case_when(
                vendor_province == 'NL' ~ '9',
                vendor_province == 'PE' ~ '2',
                vendor_province == 'NS' ~ '11',
                vendor_province == 'NB' ~ '8',
                vendor_province == 'QC' ~ '3',
                vendor_province == 'ON' ~ '13',
                vendor_province == 'MB' ~ '7',
                vendor_province == 'SK' ~ '4',
                vendor_province == 'AB' ~ '1',
                vendor_province == 'BC' ~ '6',
                vendor_province == 'NT' ~ '10',
                vendor_province == 'YK' ~ '5',
                vendor_province == 'NU' ~ '12',
                TRUE ~ '-1')) %>%
        filter(vendor_province != 'UNKWN') %>%
        filter(contract_date >= '2020-01-01') %>%
        filter(contract_date <= '2022-12-31') %>%
        group_by(id) %>%
        summarize(totalvalue = sum(contract_value) %>%
        ungroup())
```

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Contracts Data Set (GADM Data)

```
canada.gadm.data <- left_join(canada.gadm.tidy, d.gadm.id, by='id')

ggplot(canada.gadm.data, aes(x=long,y=lat,group=group))+
  geom_polygon(aes(fill=totalvalue), linewidth=0.1, color='black') +
  coord_map() +
  scale_fill_continuous(type='viridis', labels=scales::comma) +
  guides(x='none', y='none') +
  labs(x='Degrees Longitude', y='Degrees Latitude', fill='Total CAD',
       title='Canada Federal Procurement Contract Values',
       subtitle='2020 to 2022, Contracts above $10,000')
```

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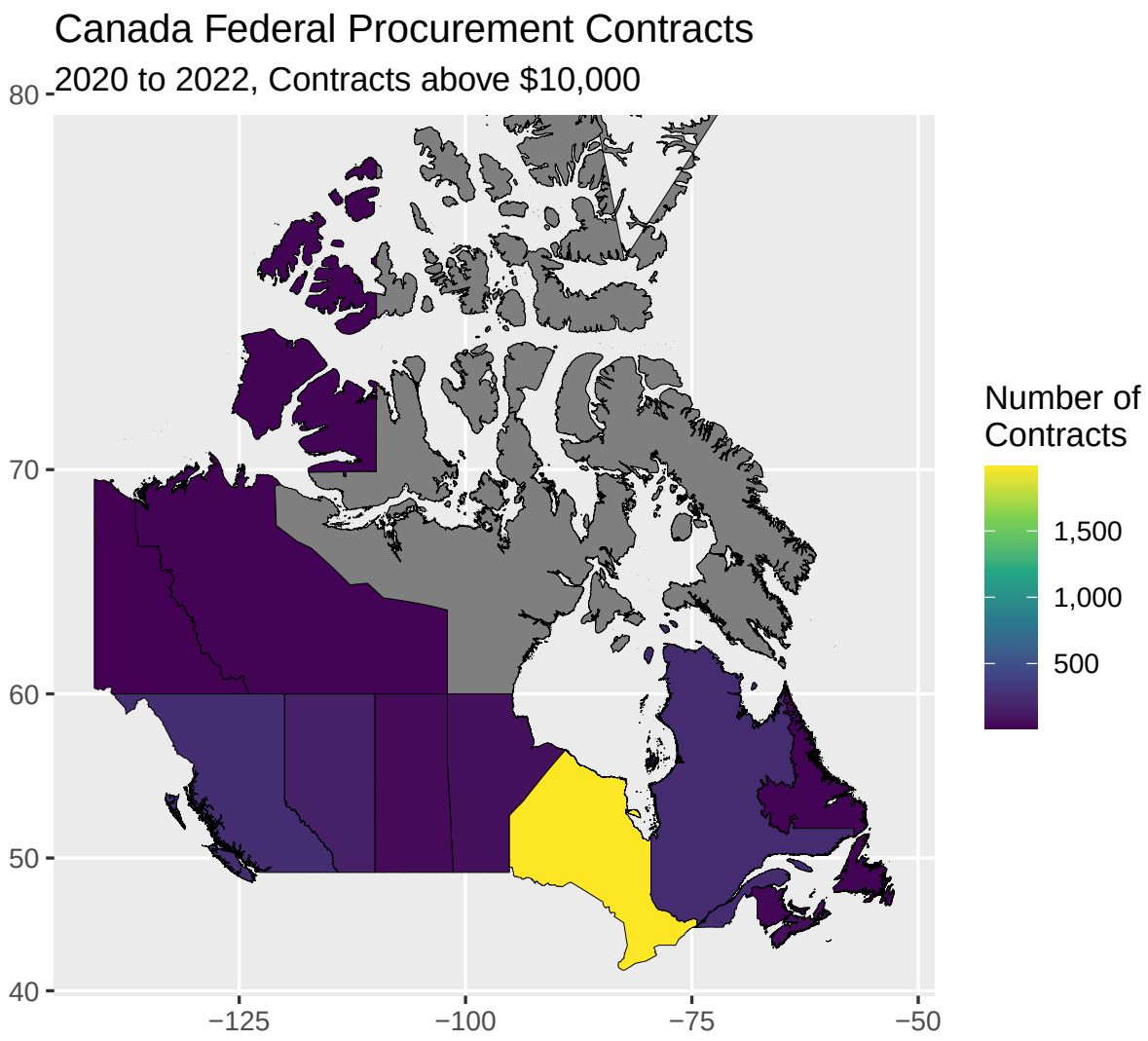
Contracts Data Set (GADM Data)



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Contracts Data Set (GADM Data)

```
canada.gadm <- shapefile('gadm41_CAN_1.shp')
canada.gadm.tidy <- tidy(canada.gadm)

...
```

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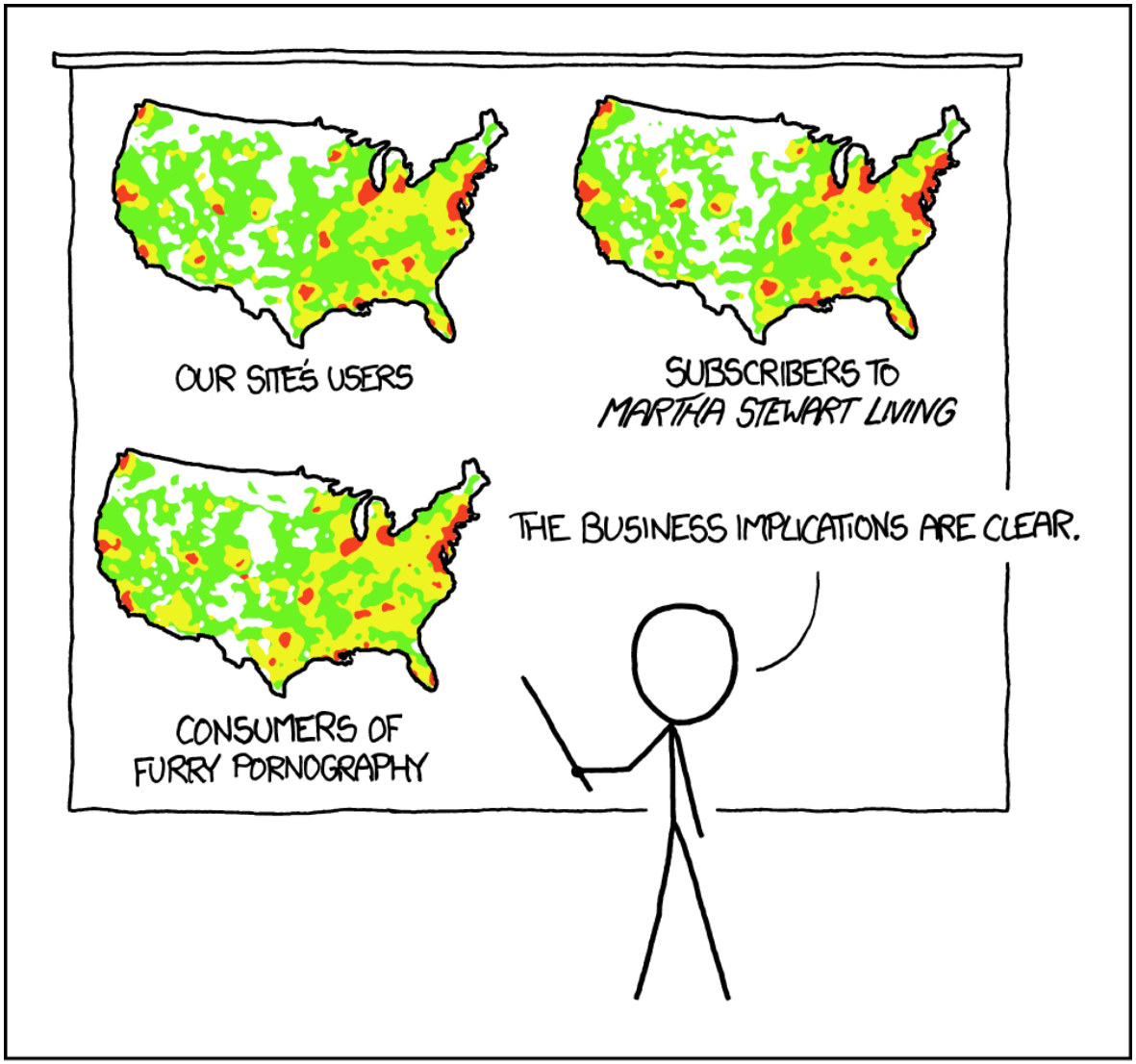
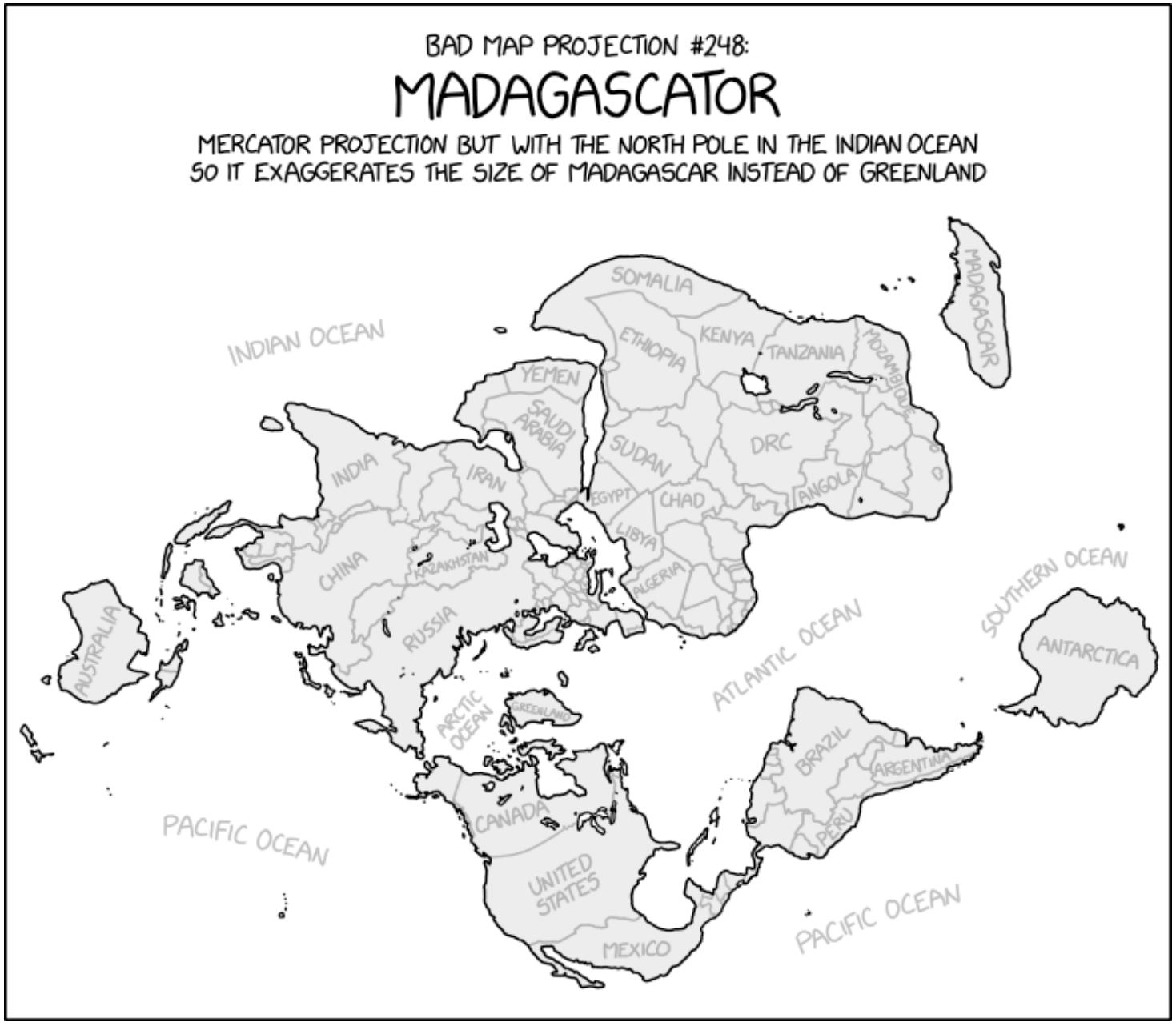
What not do with maps (XKCD)



PET PEEVE #208:

GEOGRAPHIC PROFILE MAPS WHICH ARE BASICALLY JUST POPULATION MAPS

What not do with maps (XKCD)



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What not do with maps (XKCD)

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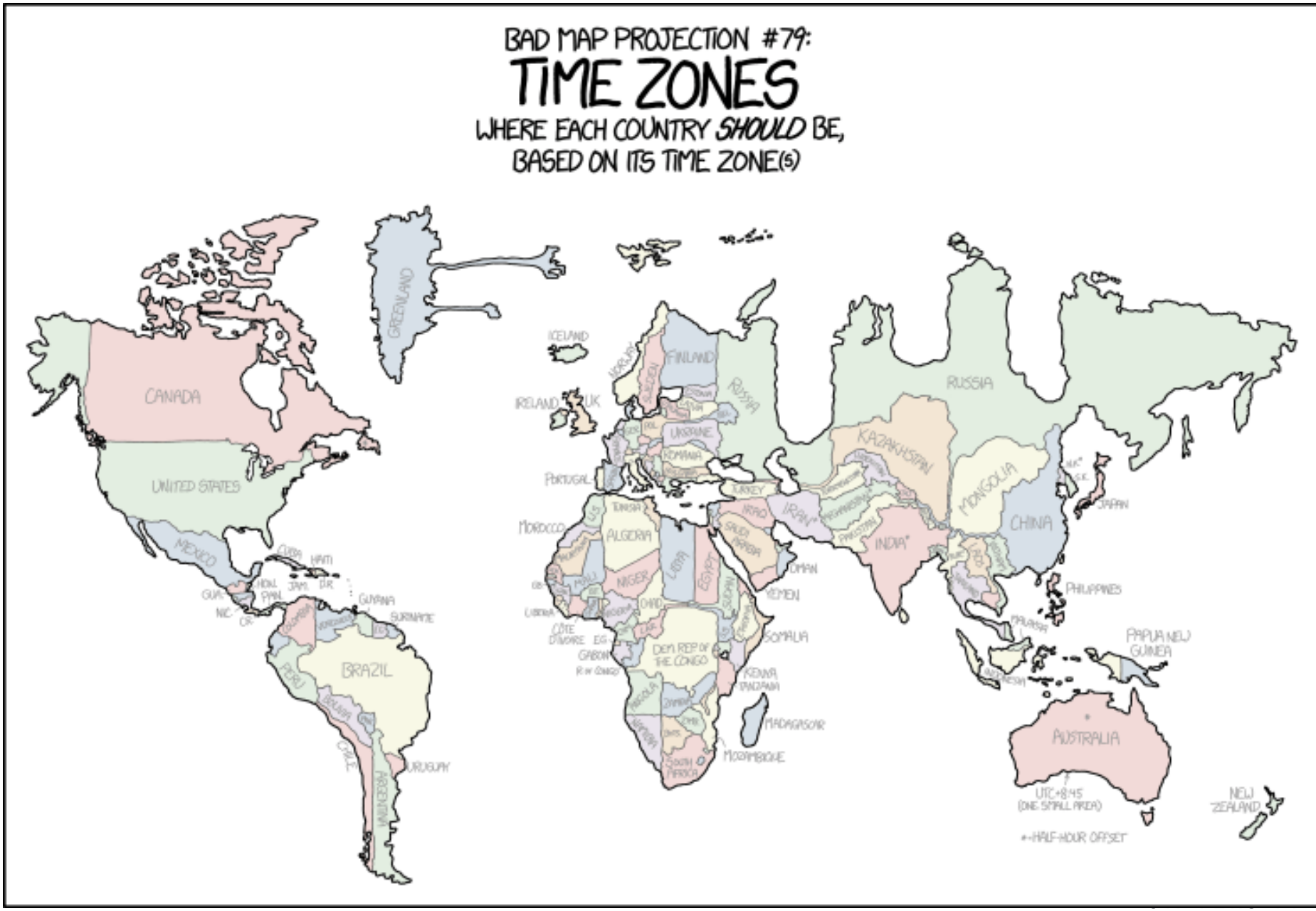
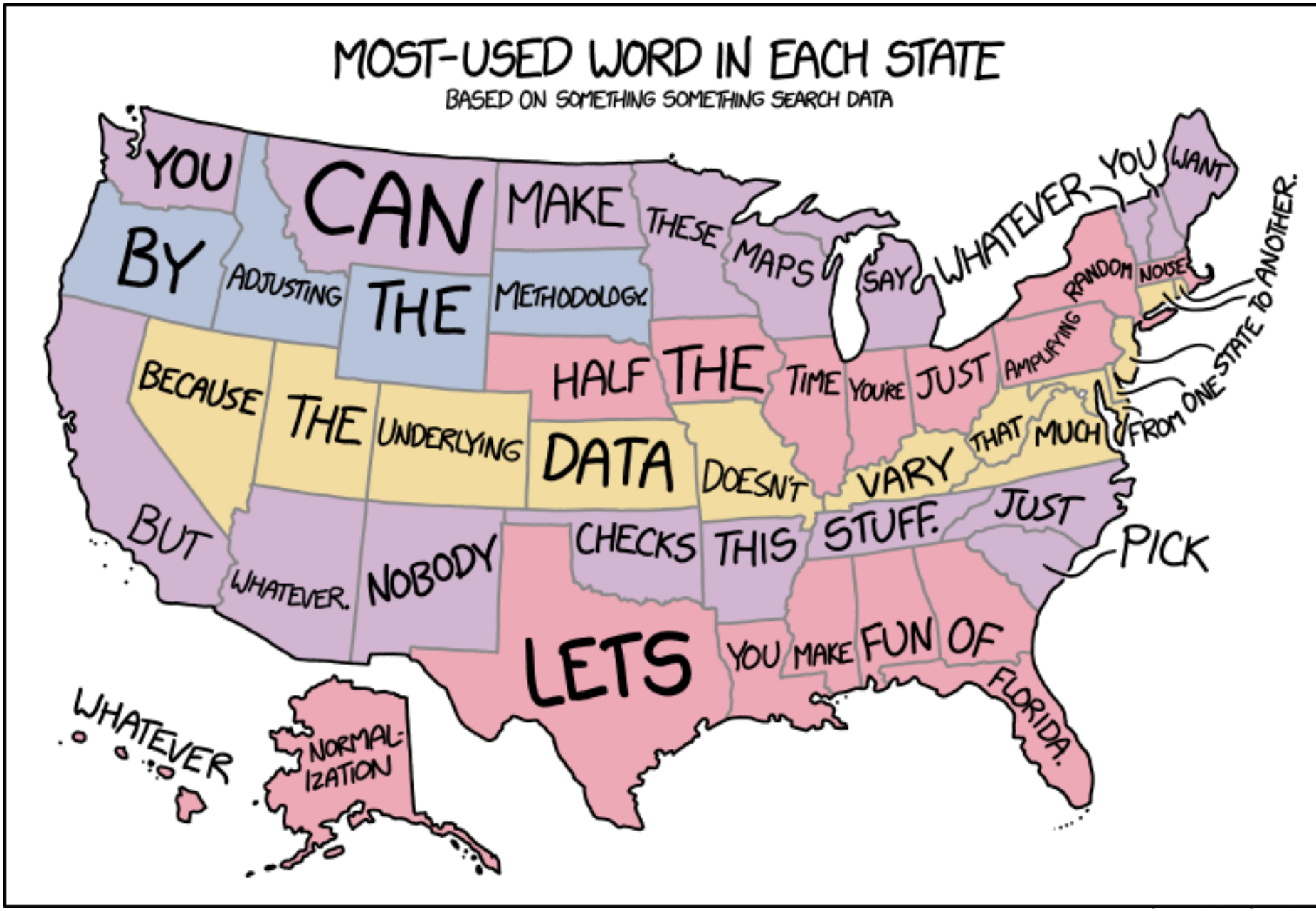
What not do with maps (XKCD)



What not do with maps (XKCD)



Using Plotly Express and Plotly Dash

Pre-Processing

```
contractsData = pd.read_csv('contracts.cleaned.csv', low_memory=False)

contractsData['contract_date'] =
   pd.to_datetime(contractsData['contract_date'])
contractsData['contract_period_start'] =
   pd.to_datetime(contractsData['contract_period_start'])
contractsData['economic_object_code'] =
   contractsData['economic_object_code'].astype('category')
contractsData['commodity_type'] =
   contractsData['commodity_type'].astype('category')
contractsData['country_of_vendor'] =
   contractsData['country_of_vendor'].astype('category')
contractsData['solicitation_procedure'] =
   contractsData['solicitation_procedure'].astype('category')
contractsData['limited_tendering_reason'] =
   contractsData['limited_tendering_reason'].astype('category')
contractsData['trade_agreement_exceptions'] =
   contractsData['trade_agreement_exceptions'].astype('category')
contractsData['award_criteria'] =
   contractsData['award_criteria'].astype('category')
```

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Pre-Processing

```
def prov_from_postal(row):
    if str(row['vendor_postal_code']).startswith('A'): return 'NL'
    if str(row['vendor_postal_code']).startswith('B'): return 'NS'
    if str(row['vendor_postal_code']).startswith('C'): return 'PE'
    if str(row['vendor_postal_code']).startswith('E'): return 'NB'
    if str(row['vendor_postal_code']).startswith('G'): return 'QC'
    if str(row['vendor_postal_code']).startswith('J'): return 'QC'
    if str(row['vendor_postal_code']).startswith('L'): return 'ON'
    if str(row['vendor_postal_code']).startswith('M'): return 'ON'
    if str(row['vendor_postal_code']).startswith('N'): return 'ON'
    if str(row['vendor_postal_code']).startswith('K'): return 'ON'
    if str(row['vendor_postal_code']).startswith('P'): return 'ON'
    if str(row['vendor_postal_code']).startswith('R'): return 'MB'
    if str(row['vendor_postal_code']).startswith('S'): return 'SK'
    if str(row['vendor_postal_code']).startswith('T'): return 'AB'
    if str(row['vendor_postal_code']).startswith('V'): return 'BC'
    if str(row['vendor_postal_code']).startswith('X'): return 'NT'
    if str(row['vendor_postal_code']).startswith('Y'): return 'YK'
    return 'UNKWN'

contractsData['vendor_province'] =
   contractsData.apply(prov_from_postal, axis=1)
contractsData['vendor_province'] =
   contractsData['vendor_province'].astype('category')
```

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Pre-Processing

```
def region_from_prov(row):
    if str(row['vendor_province']) in ['NL', 'NS', 'PE', 'NB']: return
    if str(row['vendor_province']) in ['YK', 'NT']: return 'Northern'
    if str(row['vendor_province']) in ['QC', 'ON']: return 'Central'
    if str(row['vendor_province']) in ['AB', 'SK', 'MB']: return 'Prai
    if str(row['vendor_province']) in ['BC']: return 'Western'
    if str(row['vendor_province']) in ['UNKWN']: return 'Unknown'
    return 'Unknown'

contractsData['vendor_region'] =
   contractsData.apply(region_from_prov, axis=1)
contractsData['vendor_region'] =
   contractsData['vendor_region'].astype('category')

contractsData = contractsData[
   (contractsData['original_value'] <
        contractsData['original_value'].quantile(.90)) &
   (contractsData['contract_value'] <
        contractsData['contract_value'].quantile(.90))]
```

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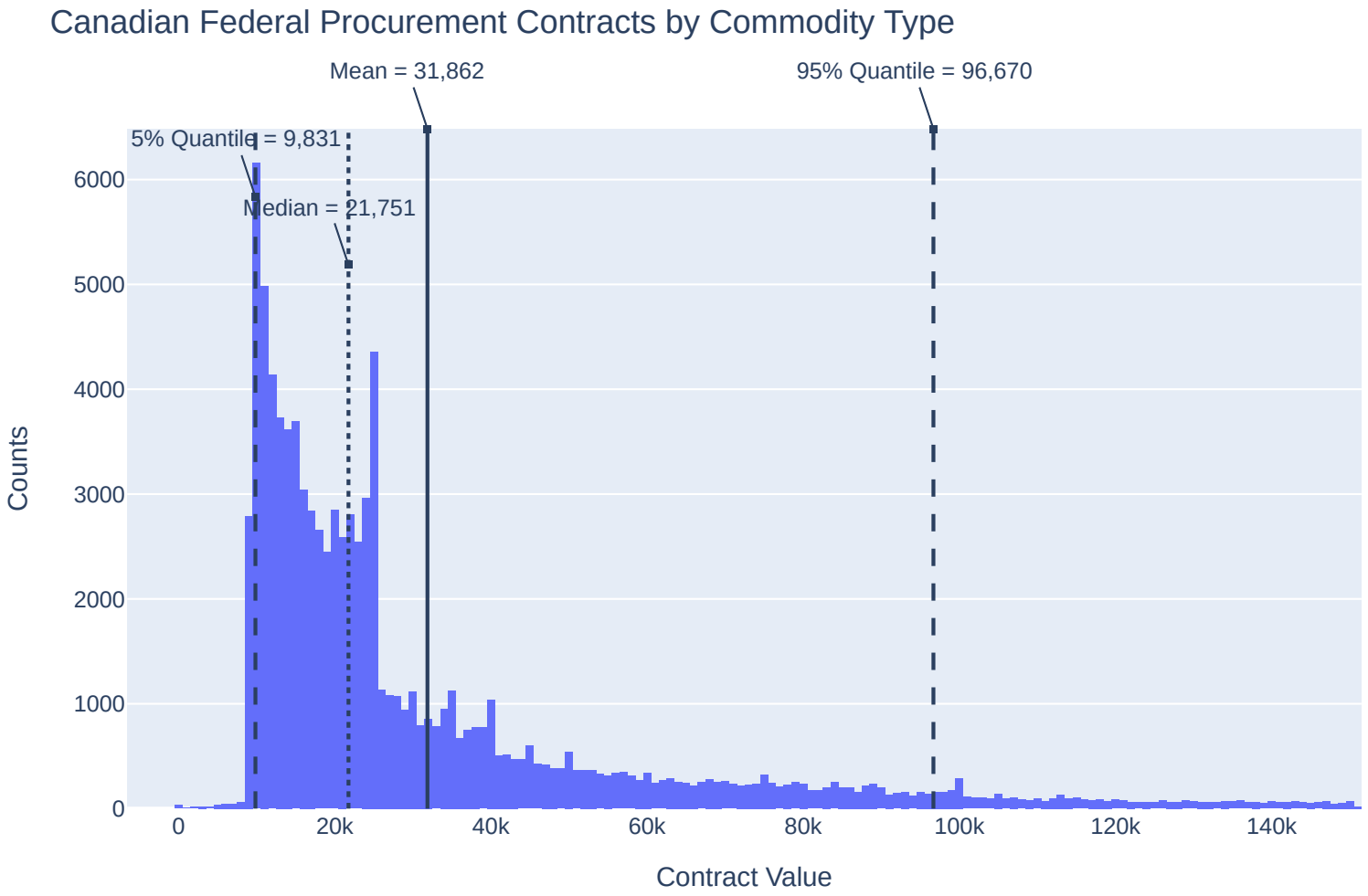
Histogram



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Histogram

```
fig = px.histogram(
          data_frame = df,
          x = 'contract_value',
          histfunc = 'count',
          title = 'Canadian Federal Procurement Contracts by Commodity
          labels = {'contract_value': 'Contract Value', 'y': 'Count'})
fig.add_vline(x = df.contract_value.mean(), line_dash='solid')
fig.add_vline(x = df.contract_value.median(), line_dash='dot')
fig.add_vline(x = df.contract_value.quantile(.05), line_dash='dash')
fig.add_vline(x = df.contract_value.quantile(.95), line_dash='dash')
fig.add_annotation(
             x=df.contract_value.mean(),
             y=1,
             xref='x',
             yref='paper',
             text="Mean = {:,.0f}".format(df.contract_value.mean()),
             showarrow=True,
             arrowhead=7)

...

fig.update_layout(yaxis_title='Counts')
```

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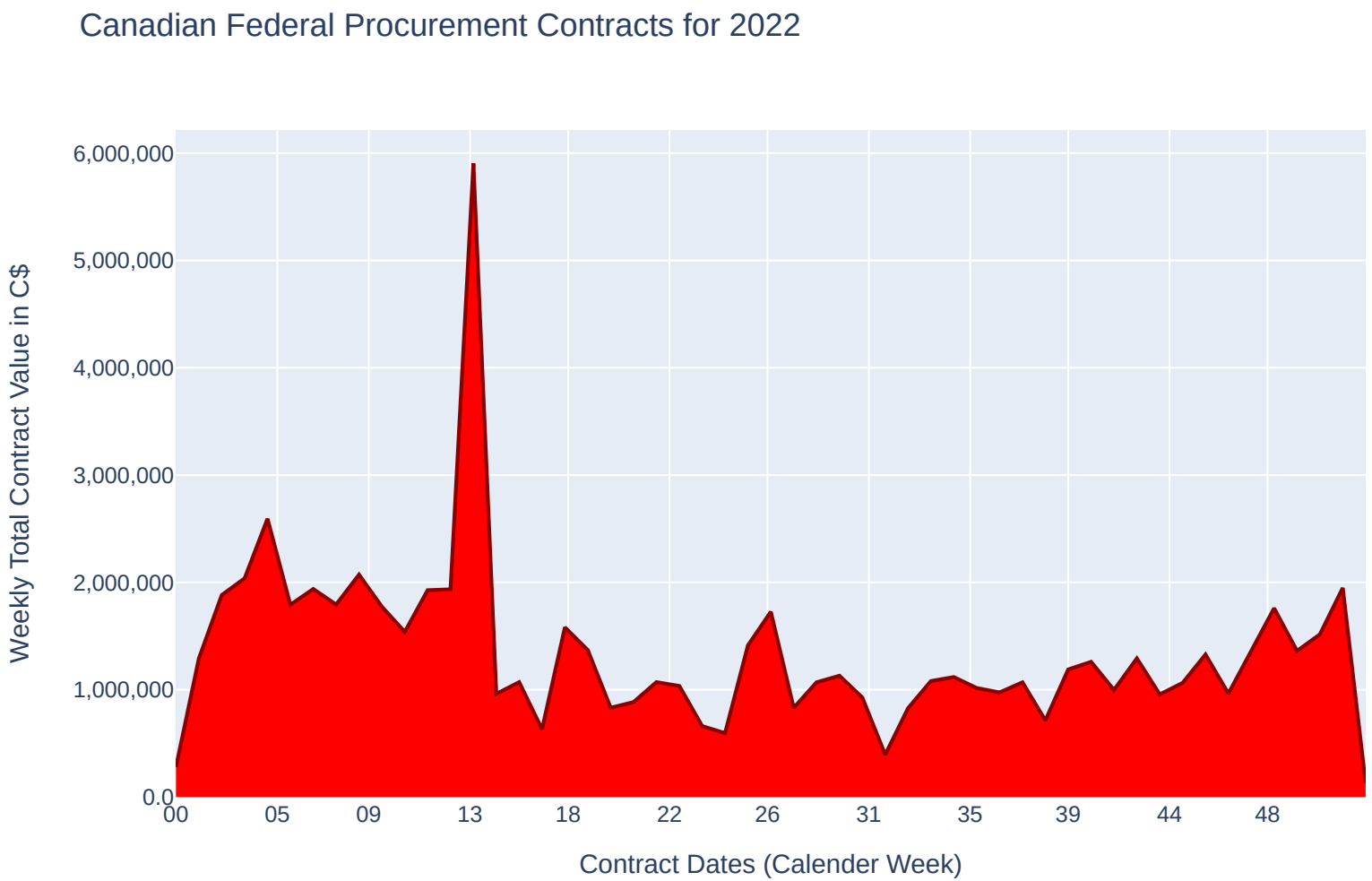
Area – One Series



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Area – One Series

```
df = contractsData[
      (contractsData['contract_date'] >= pd.to_datetime('2022-01-01'))
      (contractsData['contract_date'] <= pd.to_datetime('2022-12-31'))
df = df.groupby(pd.Grouper(key='contract_date', axis=0, freq='W'))
      ['contract_value'].sum().reset_index()

fig = px.area(
          data_frame = df,
          x = 'contract_date',
          y = 'contract_value',
          title = 'Canadian Federal Procurement Contracts for 2022',
          labels = {'contract_value': 'Weekly Total Contract Value in
                    'contract_date': 'Contract Dates (Calender Week)'}
fig.update_xaxes(dtick="M1", tickformat='%W', tick0='2022-01-02')
fig.update_yaxes(tickformat=',.2r')
fig.update_traces(fillcolor='red', line=dict(color='darkred'))
```

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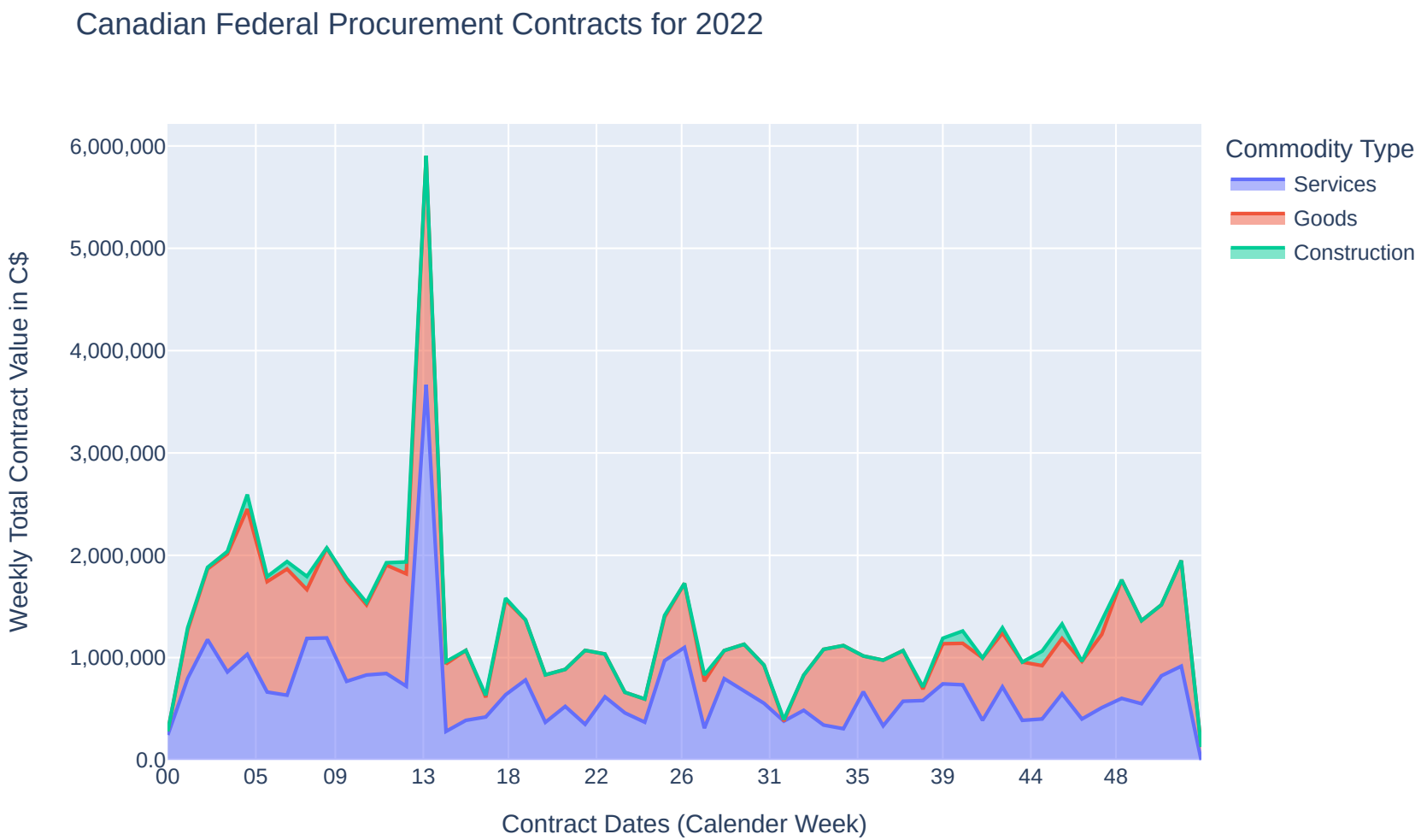
Area – Three Series



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Area – Three Series

```
df = contractsData[
      (contractsData['contract_date'] >= pd.to_datetime('2022-01-01'))
      (contractsData['contract_date'] <= pd.to_datetime('2022-12-31'))
df = df.groupby([
          pd.Grouper(key='contract_date', axis=0, freq='W'),
          pd.Grouper(key='commodity_type', axis=0)])
      ['contract_value'].sum().reset_index()
df['commodity_type'] = df['commodity_type'].astype(str)

fig = px.area(
        data_frame = df,
        x = 'contract_date',
        y = 'contract_value',
        color = 'commodity_type',
        title = 'Canadian Federal Procurement Contracts for 2022',
        labels = {'contract_value': 'Weekly Total Contract Value in C$
                  'contract_date': 'Contract Dates (Calender Week)',
                  'commodity_type': 'Commodity Type'})
fig.update_xaxes(dtick="M1", tickformat='%W', tick0='2022-01-02')
fig.update_yaxes(tickformat=',.2r')
```

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Area – Three Series

```
newnames = {'S':'Services', 'G': 'Goods', 'C': 'Construction'}
fig.for_each_trace(lambda t: t.update(
                name = newnames[t.name],
                legendgroup = newnames[t.name],
                hovertemplate =
                   t.hovertemplate.replace(t.name, newnames[t.name])
                                       ))
```

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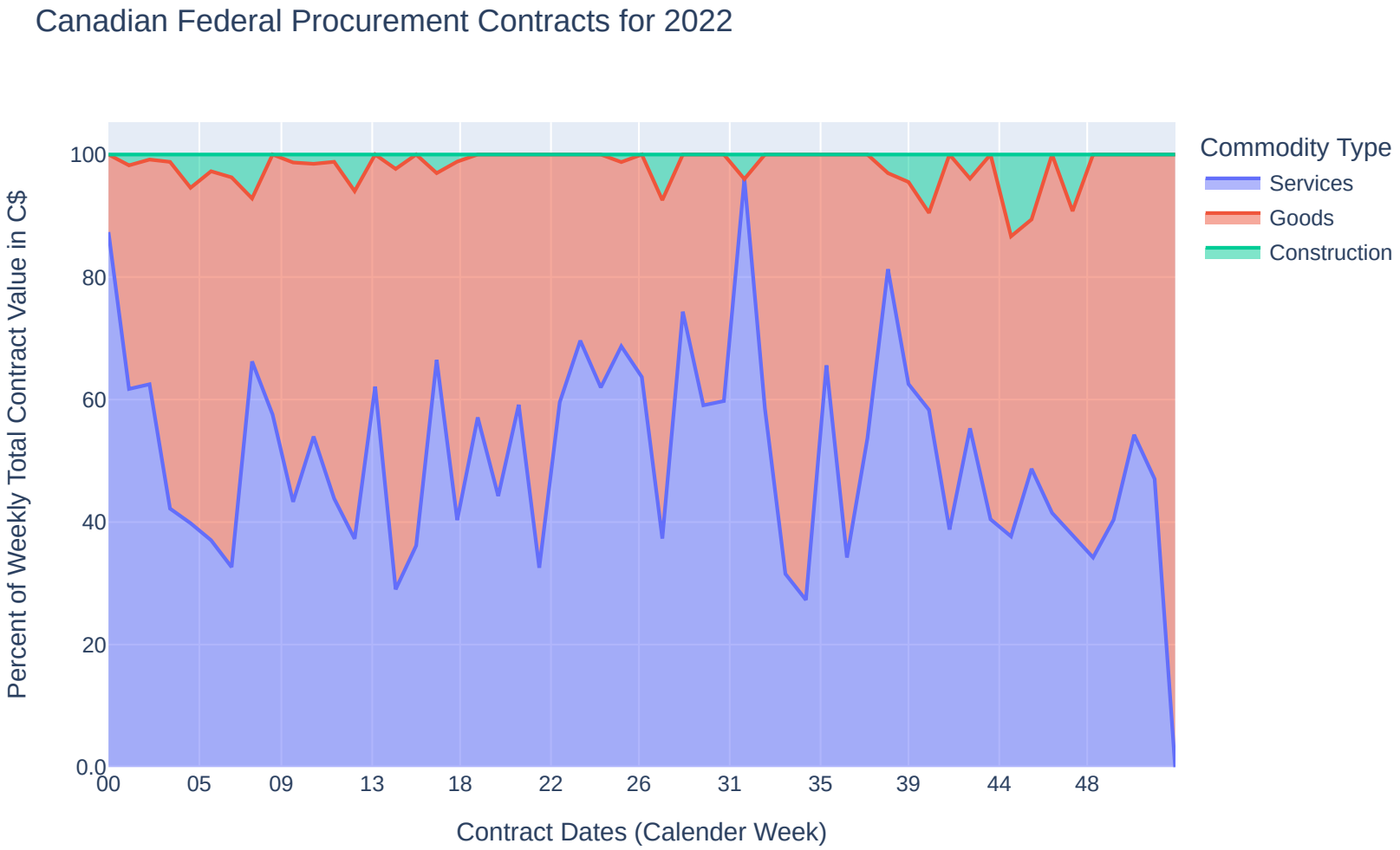
Area – Three Series, Normalized



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Area – Three Series, Normalized

```
...
fig = px.area(data_frame = df,
              x = 'contract_date',
              y = 'contract_value',
              color = 'commodity_type',
              title = 'Canadian Federal Procurement Contracts for 2022',
              groupnorm = 'percent',
              labels = {'contract_value': 'Percent of Weekly Total Contra
                 'contract_date': 'Contract Dates (Calender Week)',
                 'commodity_type': 'Commodity Type'})

...
```

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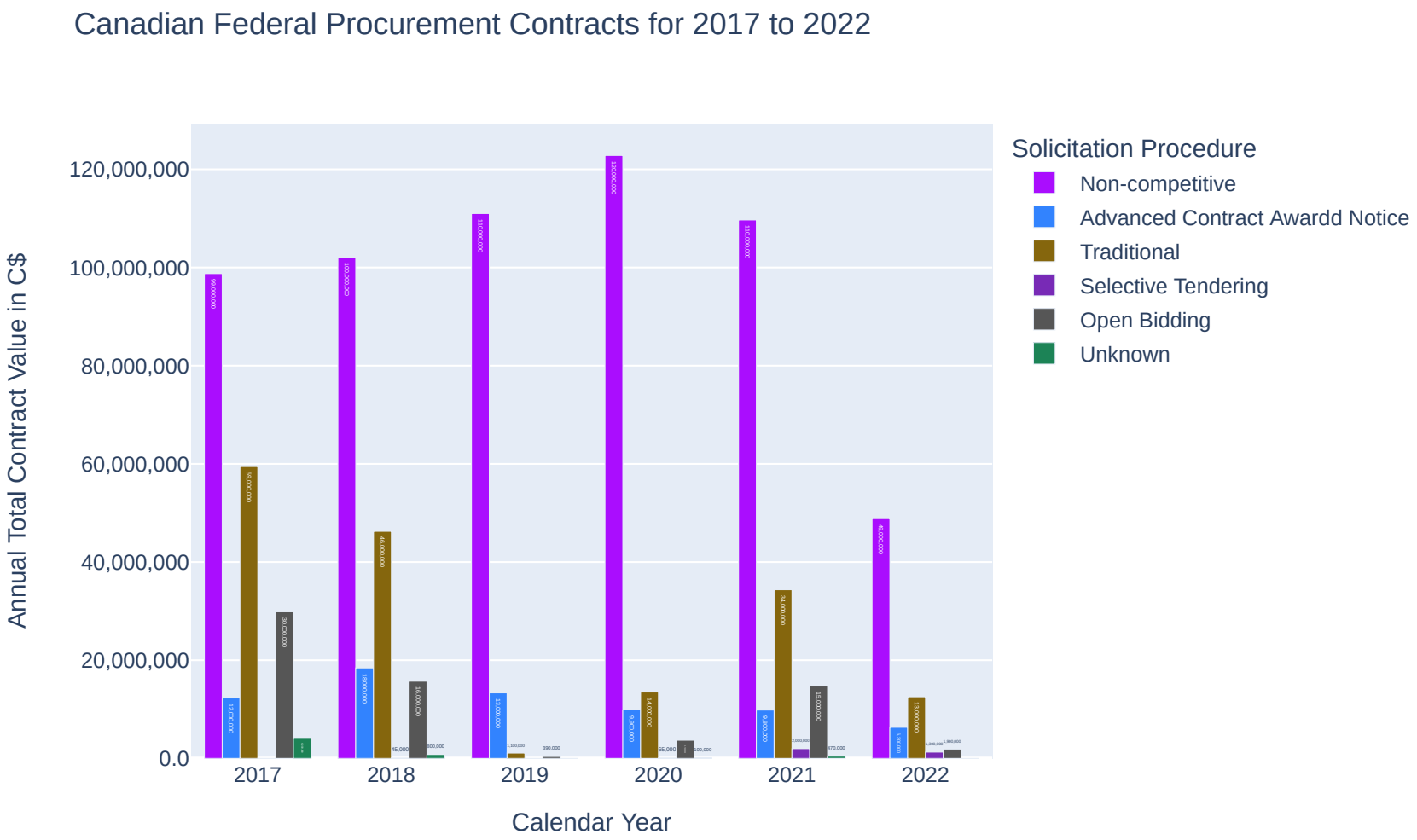
Bar – Three Series, Grouped



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Bar – Three Series, Grouped

```
...

fig = px.bar(
        data_frame = df,
        x = 'commodity_type',
        y = 'contract_value',
        color = 'solicitation_procedure',
        barmode = 'group',
        title = 'Canadian Federal Procurement Contracts for 2017 to 20
        text_auto=True,
        color_discrete_sequence = px.colors.qualitative.Alphabet,
        labels = {'contract_value': 'Annual Total Contract Value in C$
            'year': 'Calendar Year',
            'solicitation_procedure': 'Solicitation Procedure'})

...
```

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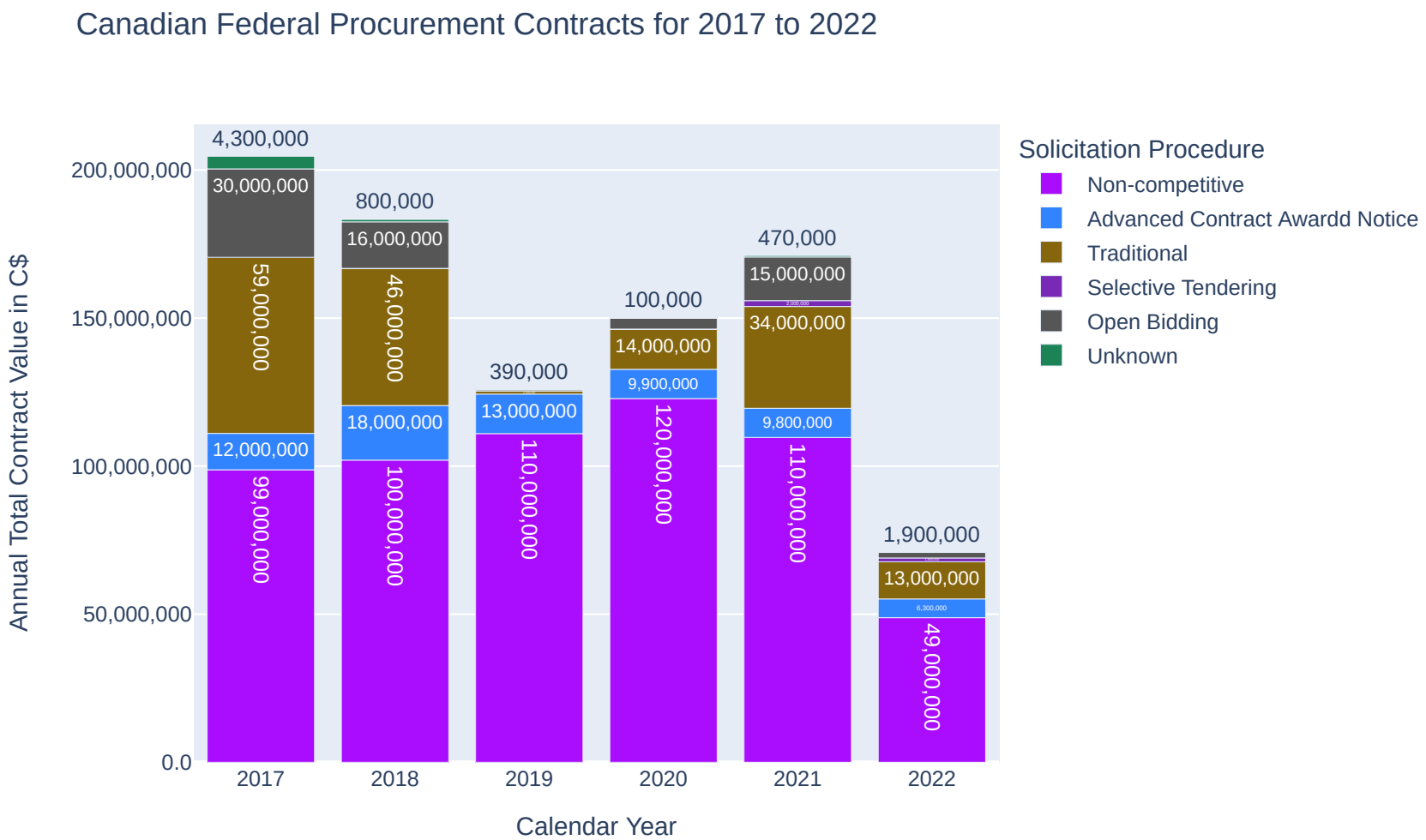
Bar – Three Series, Stacked



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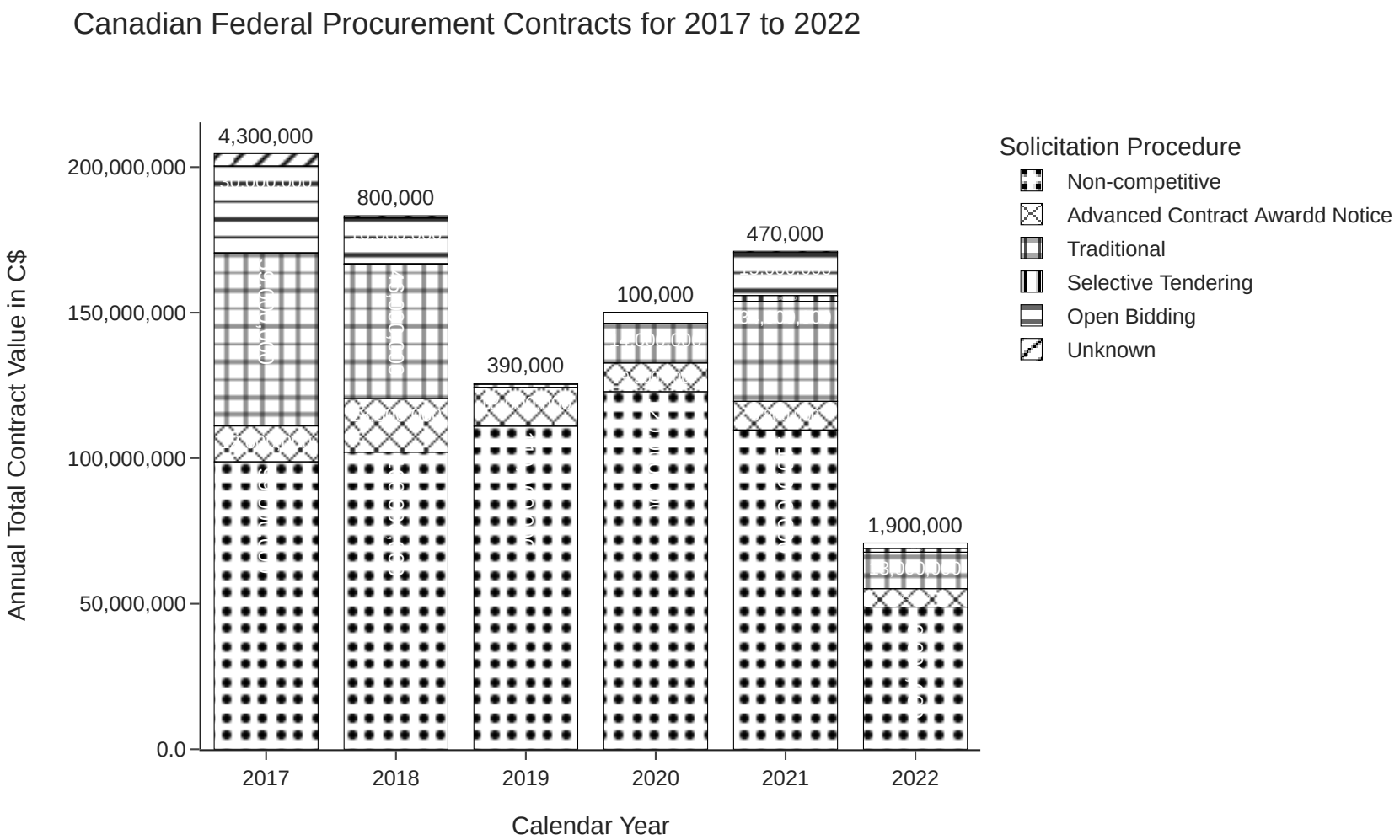
Bar – Three Series, Stacked

```
fig.update_layout(barmode = 'stack')
```

Bar – Three Series, Pattern



Bar – Three Series, Pattern

```
...

fig = px.bar(data_frame = df,
             x = 'year',
             y = 'contract_value',
             pattern_shape = 'solicitation_procedure',
             pattern_shape_sequence = ['.', 'x', '+', '|', '-', '/'],
             title = 'Canadian Federal Procurement Contracts for 2017 to
             text_auto=True,
             template="simple_white",
             labels = {
               'contract_value': 'Annual Total Contract Value in C$',
               'year': 'Calendar Year',
               'solicitation_procedure': 'Solicitation Procedure'})

fig.update_traces(marker=dict(color='black',
                              line_color='black',
                              pattern_fillmode='replace'))
```

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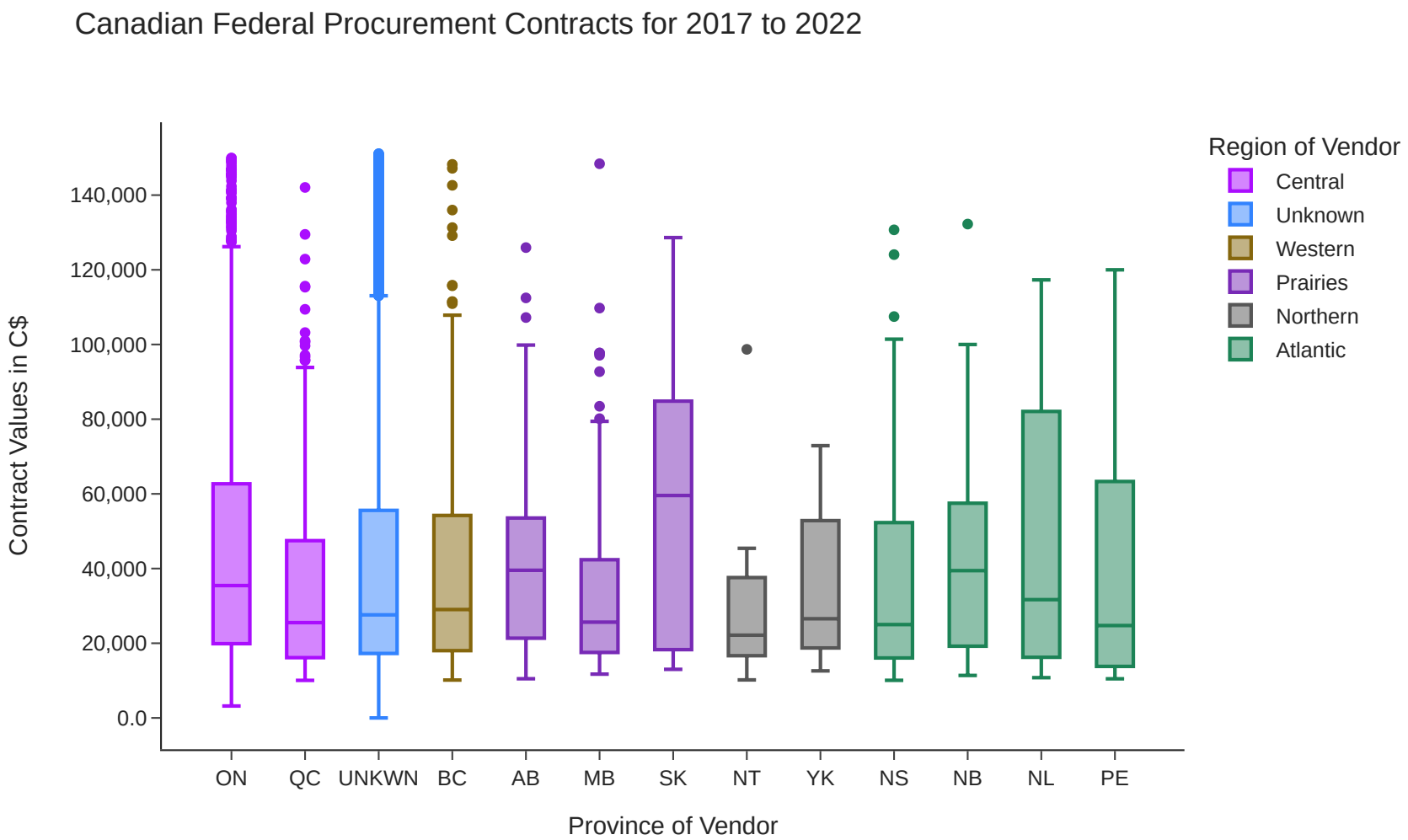
Box Plot



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Box Plot

```
...

fig = px.box(data_frame = df,
             x = 'vendor_province',
             y = 'contract_value',
             color = 'vendor_region',
             title = 'Canadian Federal Procurement Contracts for 2017 to
             color_discrete_sequence=px.colors.qualitative.Alphabet,
             template="presentation",
             labels = {'contract_value': 'Contract Values in C$',
                       'vendor_province': 'Province of Vendor',
                       'vendor_region': 'Region of Vendor'})

fig.update_yaxes(tickformat=',.2r')
fig.update_traces(width = 0.5)
```

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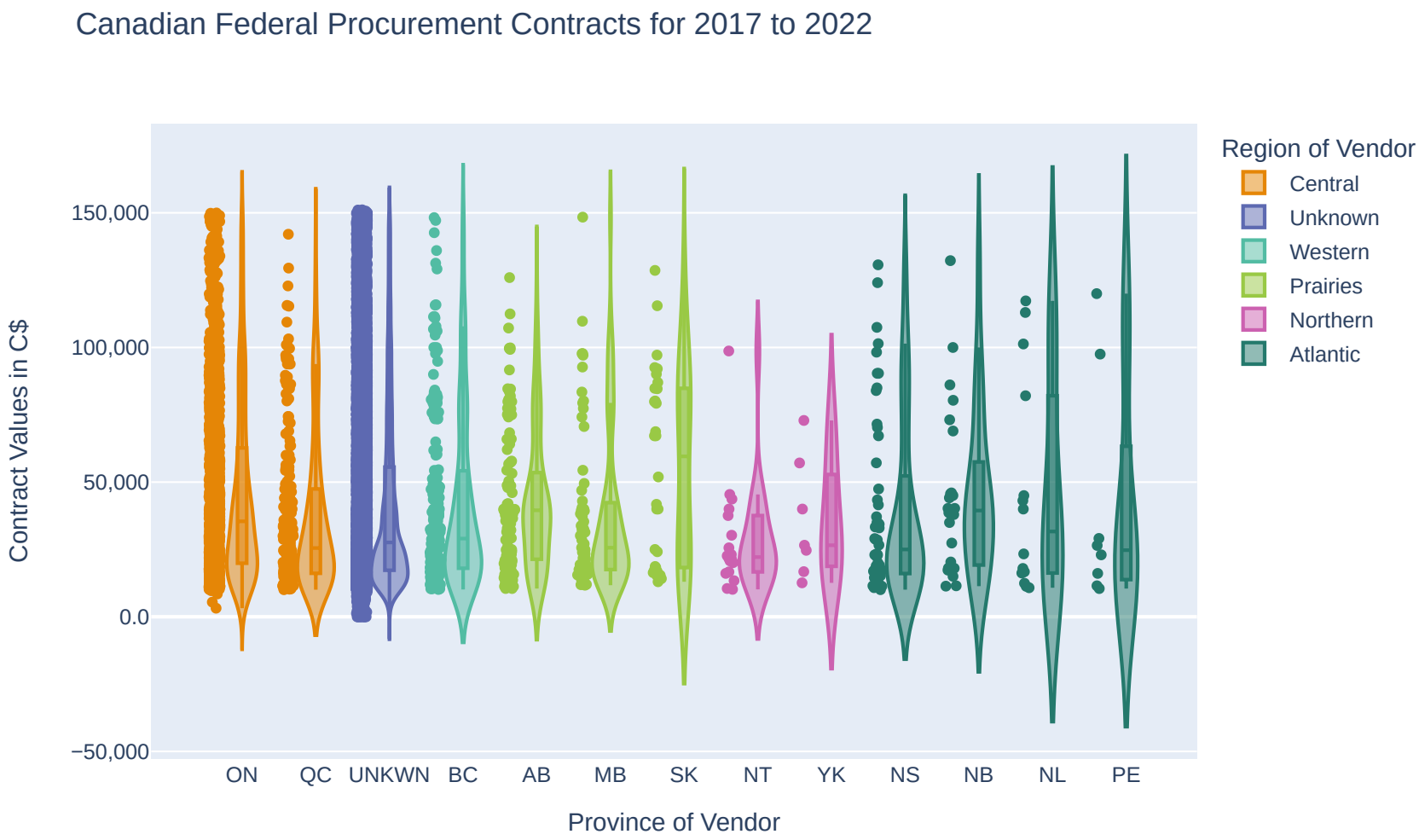
Violin Plot



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Violin Plot

```
fig = px.violin(data_frame = df,
          x = 'vendor_province',
          y = 'contract_value',
          color = 'vendor_region',
          points = 'all',
          title = 'Canadian Federal Procurement Contracts for 2017 to
          color_discrete_sequence=px.colors.qualitative.Vivid,
          box = True,
          labels = {'contract_value': 'Contract Values in C$',
             'vendor_province': 'Province of Vendor',
             'vendor_region': 'Region of Vendor'})

fig.update_yaxes(tickformat=',.2r')
fig.update_traces(width = 0.5)
```

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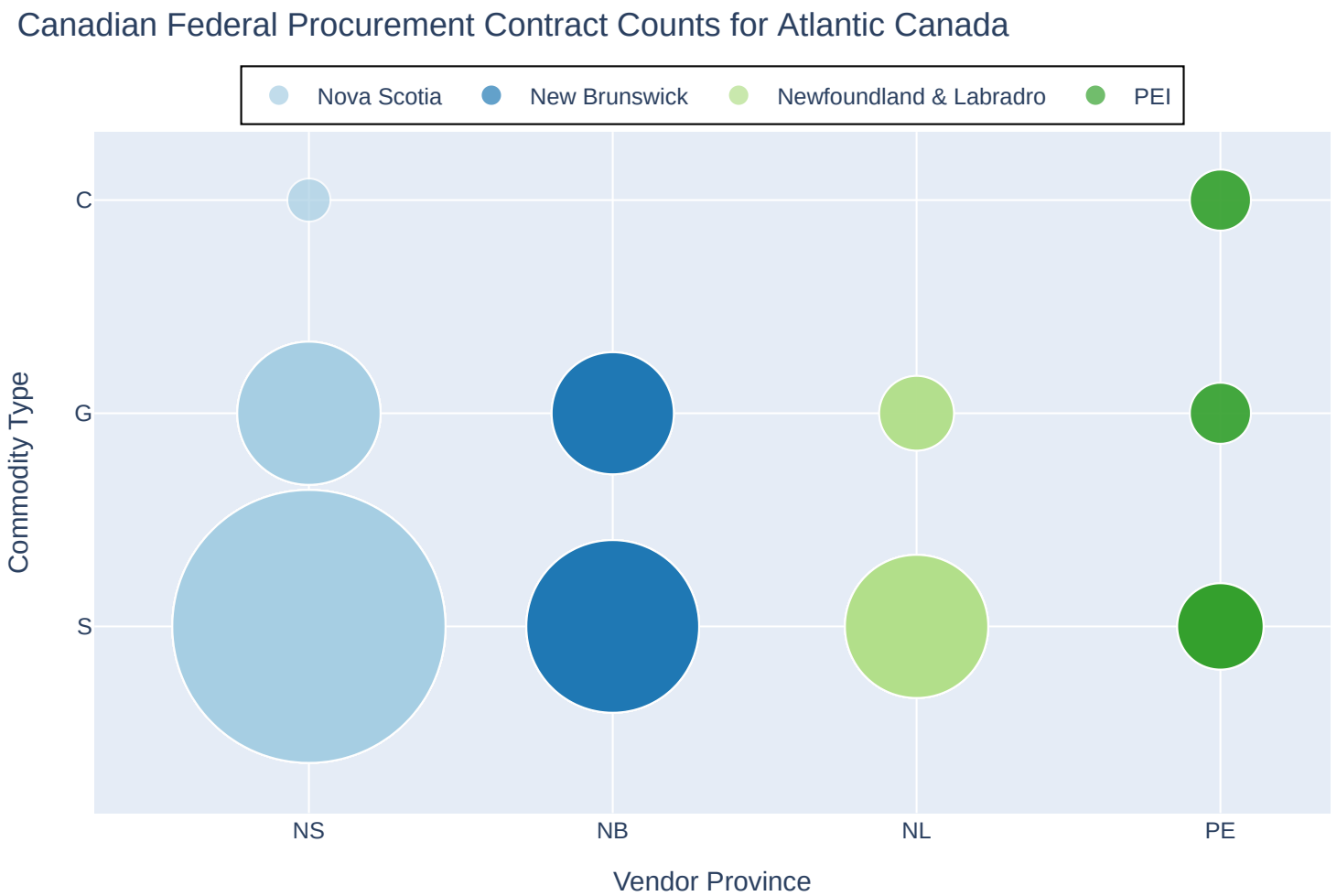
Counts/Bubbles



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Counts/Bubblest

```
df = contractsData[
      (contractsData['contract_date'] >= pd.to_datetime('2017-01-01'))
      (contractsData['contract_date'] <= pd.to_datetime('2022-12-31'))
      (contractsData['vendor_province'] != 'UNKWN') &
      (contractsData['vendor_region'] == 'Atlantic')]
df['count'] = df['vendor_province']
              .groupby([df['vendor_province'], df['commodity_type']])
              .transform('count')

df['commodity_type'] = df['commodity_type'].astype(str)
df['vendor_region'] = df['vendor_region'].astype(str)
df['vendor_province'] = df['vendor_province'].astype(str)
```

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Counts/Bubblest

```
fig = px.scatter(df,
            x='vendor_province',
            y='commodity_type',
            color='vendor_province',
            size='count',
            size_max=100,
            color_discrete_sequence=px.colors.colorbrewer.Paired,
            labels={'vendor_province': 'Vendor Province',
                    'commodity_type': 'Commodity Type',
                    'count': 'Count'},
            title='Canadian Federal Procurement Contract Counts for Atla
fig.update_layout(
      legend=dict(orientation="h",
                  y=1.01, yanchor="bottom",
                  x=0.5, xanchor="center"),
      legend_title_text=None,
      legend_bgcolor="white",
      legend_bordercolor="black",
      legend_borderwidth=1)
```

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Counts/Bubblest

```
newnames = {'G': 'Goods', 'S':'Services', 'C': 'Construction',
            'NS': 'Nova Scotia', 'NB': 'New Brunswick',
            'NL': 'Newfoundland & Labradro', 'PE': 'PEI'}

fig.for_each_trace(lambda t:
        t.update(name = newnames[t.name],
                 legendgroup = newnames[t.name],
                 hovertemplate =
                    t.hovertemplate.replace(t.name, newnames[t.name])))

fig.update_layout(legend= {'itemsizing': 'constant'})
fig.update_yaxes(categoryorder="array",
                 categoryarray=['Construction', 'Goods', 'Services'])
```

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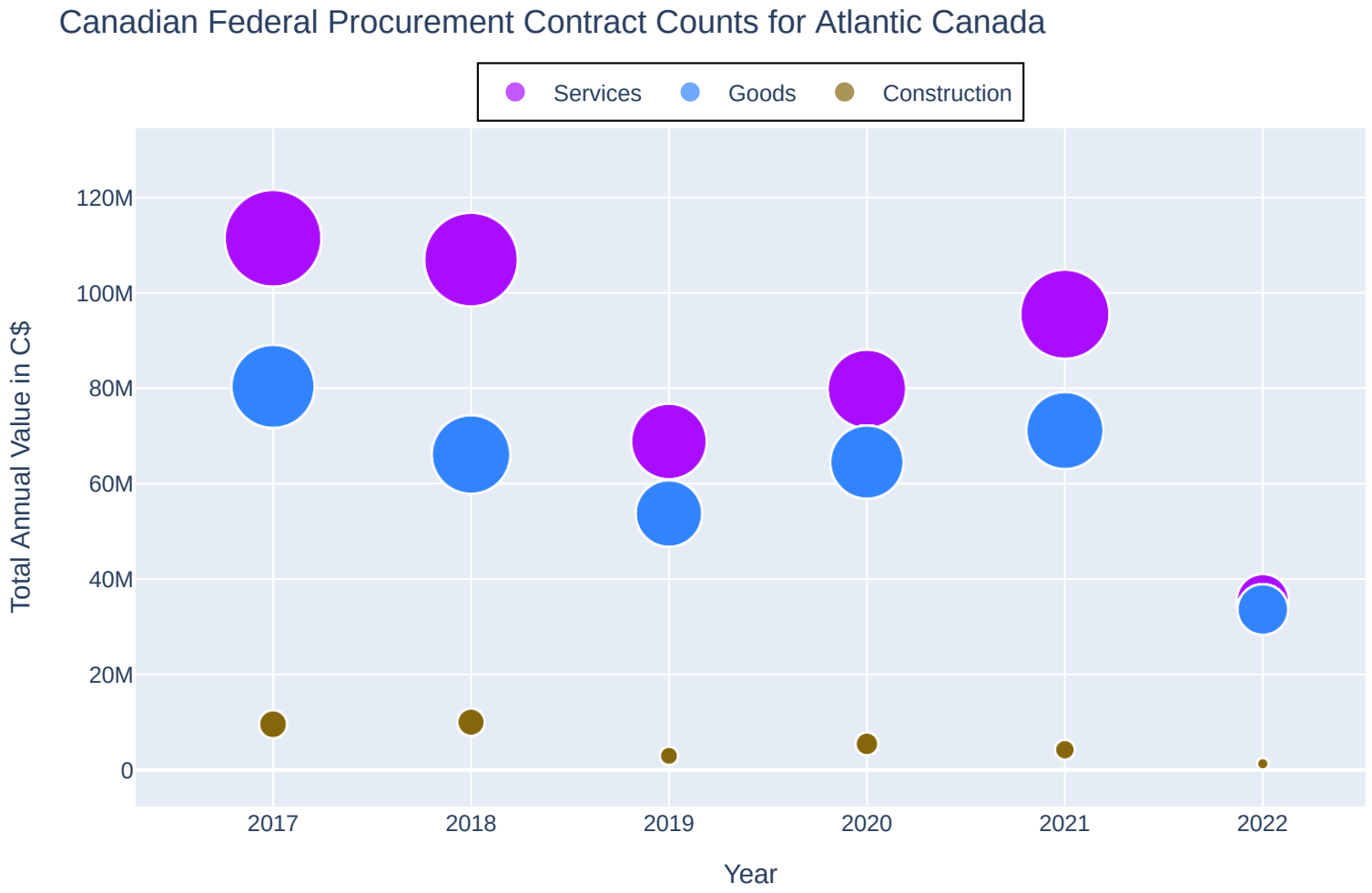
Bubble Chart



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Bubble Chart

```
df = contractsData[
        (contractsData['contract_date'] >= pd.to_datetime('2017-01-01')
        (contractsData['contract_date'] <= pd.to_datetime('2022-12-31')
        (contractsData['commodity_type'] != 'UNKWN')]

df['year'] = df['contract_date'].astype(str).str[0:4]
df['year'] = df['year'].astype(float)
df['count'] = df['vendor_province']
              .groupby([df['commodity_type'], df['year']])
              .transform('count')
df['total_value'] = df['contract_value']
                    .groupby([df['commodity_type'], df['year']])
                    .transform('sum')

df['commodity_type'] = df['commodity_type'].astype(str)
df['vendor_region'] = df['vendor_region'].astype(str)
df['vendor_province'] = df['vendor_province'].astype(str)
```

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Bubble Chart

```
fig = px.scatter(df,
            x='year',
            y='total_value',
            color='commodity_type',
            size='count',
            size_max=50,
            color_discrete_sequence=px.colors.qualitative.Alphabet,
            labels={'year': 'Year', 'commodity_type': 'Commodity Type',
                    'count': 'Count', 'total_value': 'Total Annual Valu
            title='Canadian Federal Procurement Contract Counts for Atl

fig.update_layout(legend=dict(orientation="h",
                              y=1.01, yanchor="bottom",
                              x=0.5, xanchor="center"),
                  legend_title_text=None,
                  legend_bgcolor="white",
                  legend_bordercolor="black",
                  legend_borderwidth=1)
```

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Bubble Chart

```
newnames = {'G': 'Goods', 'S':'Services', 'C': 'Construction',
            'NS': 'Nova Scotia', 'NB': 'New Brunswick',
            'NL': 'Newfoundland & Labradro', 'PE': 'PEI'}
fig.for_each_trace(lambda t:
       t.update(name = newnames[t.name],
                legendgroup = newnames[t.name],
                hovertemplate =
                   t.hovertemplate.replace(t.name, newnames[t.name])
       ) )

fig.update_layout(legend={'itemsizing': 'constant'})
```

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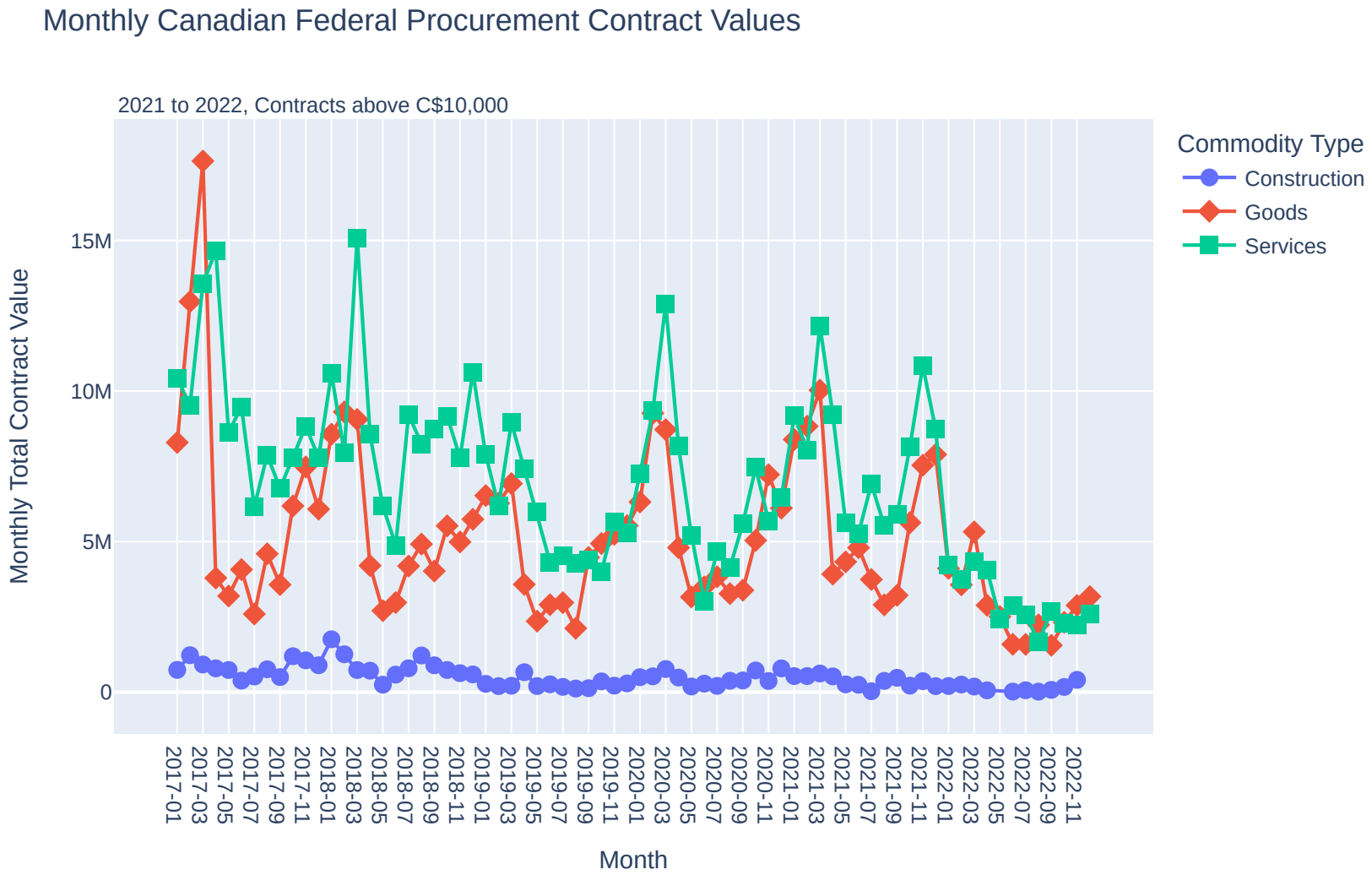
Line Chart



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Line Chart

```
...

grouped_df = df.groupby(['contract_month', 'commodity_type'])
                .agg(totalcount=('contract_value', 'count'),
                     totalvalue=('contract_value', 'sum'))
                .reset_index()

fig = px.line(grouped_df,
              x='contract_month',
              y='totalvalue',
              color='commodity_type',
              symbol='commodity_type',
              labels={'contract_month': 'Month',
                      'totalvalue': 'Monthly Total Contract Value',
                      'commodity_type': 'Commodity Type'},
              title='Monthly Canadian Federal Procurement Contract Val
```

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Line Chart

```
fig.update_xaxes(type='category',
                 categoryorder='category ascending',
                 tickformat="%b-%y")

fig.update_traces(marker=dict(size=10))

fig.for_each_trace(lambda trace:
      trace.update(name='Services' if trace.name == 'S' else
                   'Construction' if trace.name == 'C' else 'Goods'))

fig.add_annotation(text='2021 to 2022, Contracts above C$10,000',
                   showarrow=False,
                   xref='paper', x=0, xanchor='left',
                   yref='paper', y=1.05)
```

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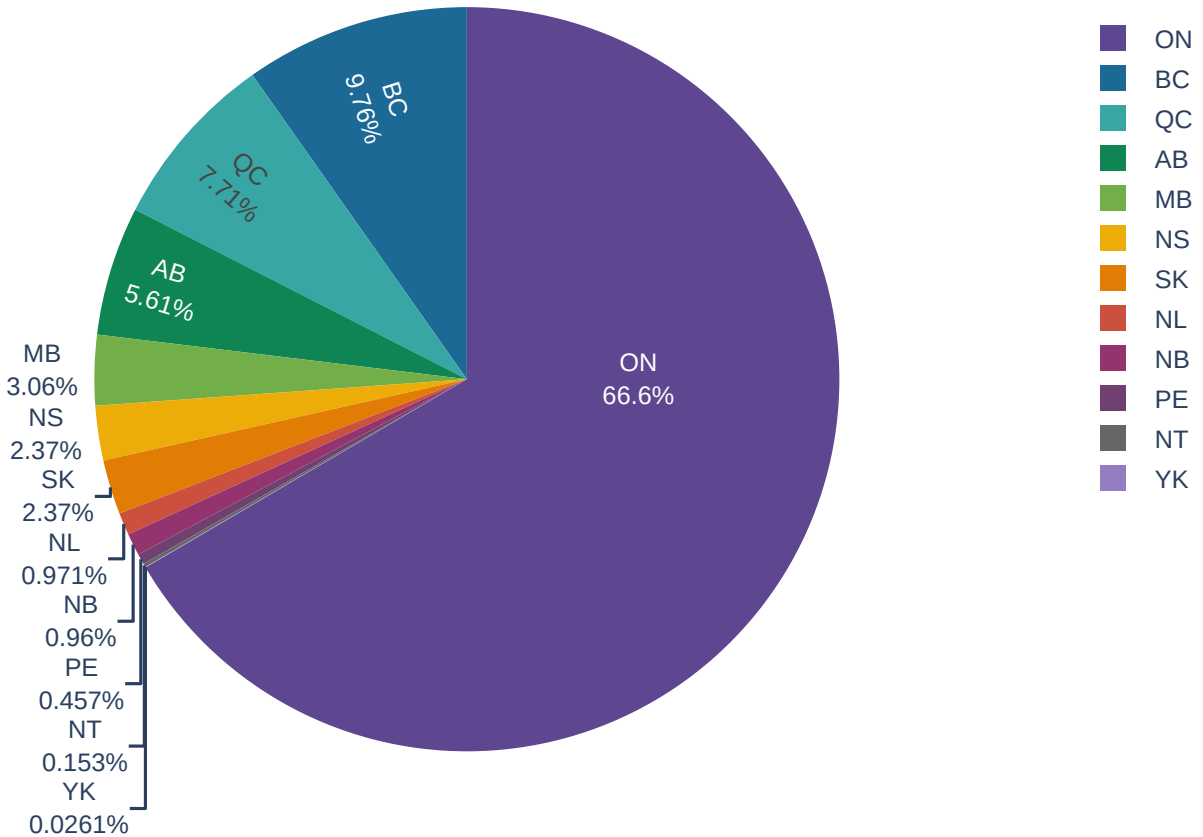
Pie Chart

2022 Canadian Federal Contract Award Values by Province



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Pie Chart

```
grouped_df = df.groupby(['vendor_province'])
               .agg(totalvalue=('contract_value', 'sum'))
               .reset_index()

fig = px.pie(data_frame=grouped_df,
             values='totalvalue',
             names='vendor_province',
             color_discrete_sequence=px.colors.qualitative.Prism,
             labels={'vendor_province': 'Province of Vendor',
                     'totalvalue': '2022 Annual Total Contract Value'}
             title = '2022 Canadian Federal Contract Award Values by P

fig.update_traces(textinfo='percent+label',
                  insidetextorientation='radial')
```

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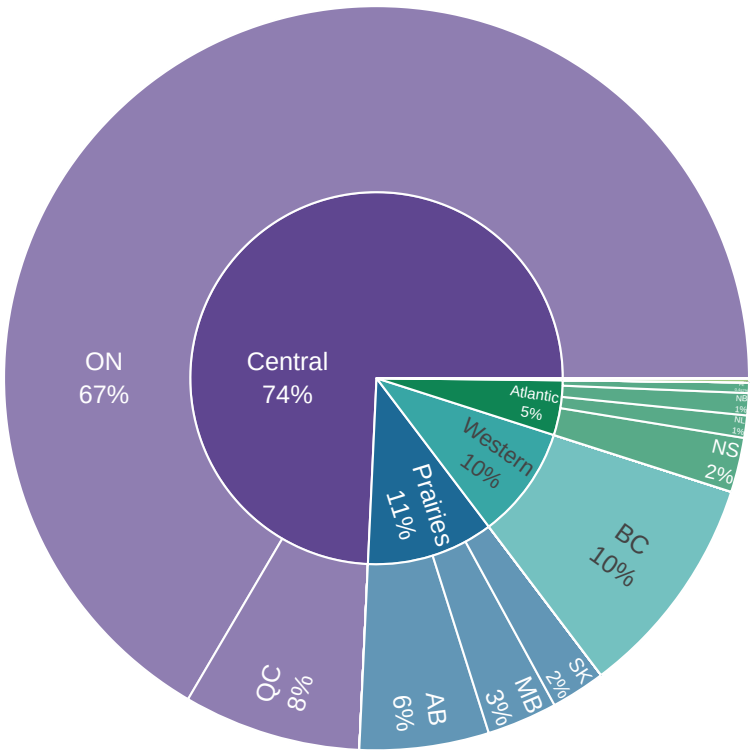
Sunburst Chart

2022 Canadian Federal Contract Award Values by Province



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Sunburst Chart

```
grouped_df = df.groupby(['vendor_region', 'vendor_province'])
               .agg(totalvalue=('contract_value', 'sum'))
               .reset_index()

fig = px.sunburst(data_frame=grouped_df,
             path=['vendor_region', 'vendor_province'],
             values='totalvalue',
             names='vendor_province',
             color_discrete_sequence=px.colors.qualitative.Prism,
             labels={'vendor_province': 'Province of Vendor',
                     'totalvalue': '2022 Annual Total Contract Value'}
             title = '2022 Canadian Federal Contract Award Values by P

fig.update_traces(textinfo='label+percent entry',
                  insidetextorientation='radial')
```

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Treemap Chart

2022 Canadian Federal Contract Award Values by Province

Treemap Chart

```
grouped_df = df.groupby(['vendor_region', 'vendor_province'])
               .agg(totalvalue=('contract_value', 'sum'))
               .reset_index()

fig = px.treemap(data_frame=grouped_df,
           path=[px.Constant('Canada'),
                 'vendor_region',
                 'vendor_province'],
           values='totalvalue',
           names='vendor_province',
           color_discrete_sequence=px.colors.qualitative.Prism,
           labels={'vendor_province': 'Province of Vendor',
                   'totalvalue': '2022 Annual Total Contract Value'},
           title = '2022 Canadian Federal Contract Award Values by Pro

fig.update_traces(textinfo='label+percent entry')
```

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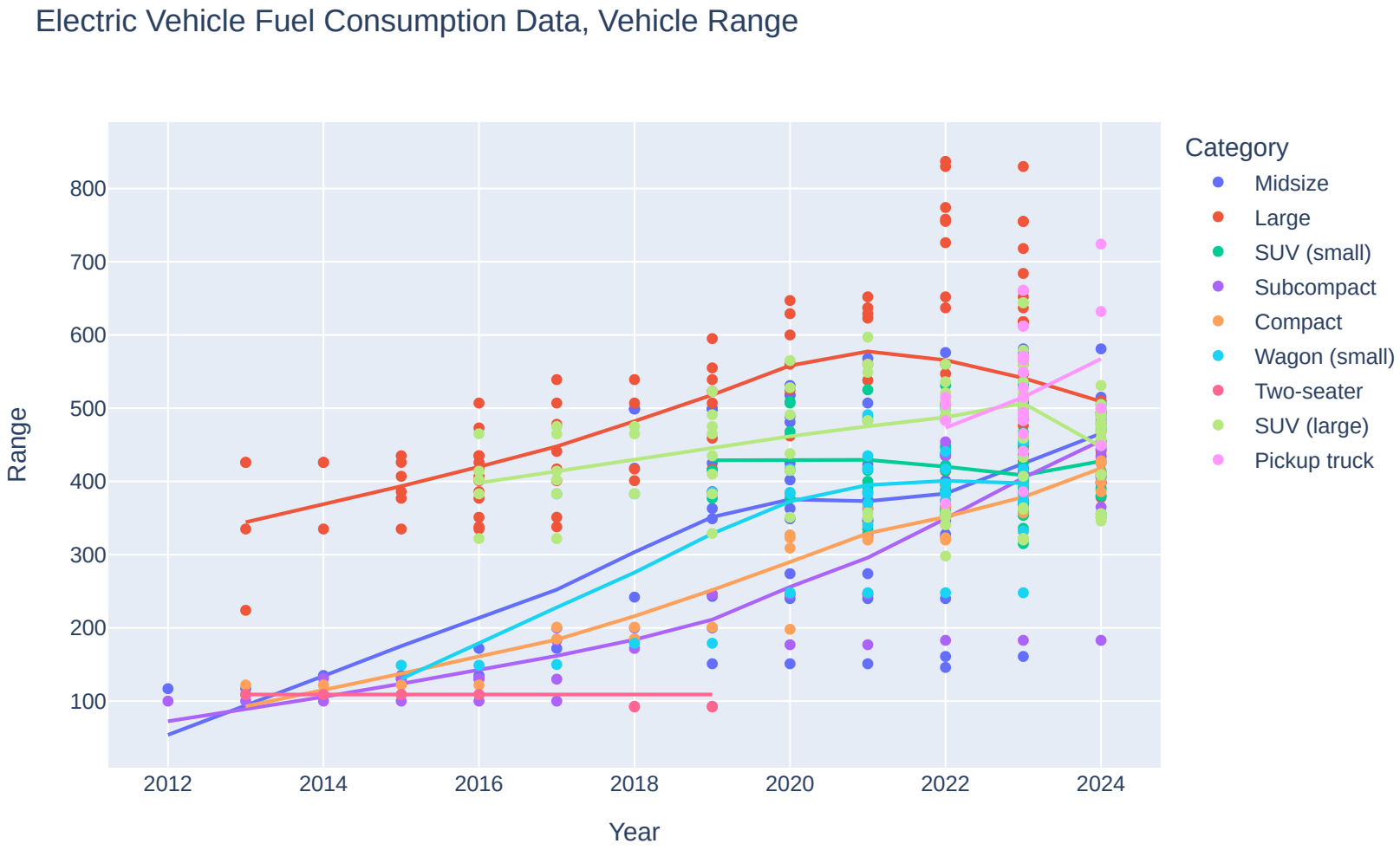
Trendline Plot



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Trendline Plot

```
fig = px.scatter(fuelData,
            x='Year',
            y='Range',
            color='Category',
            title='Electric Vehicle Fuel Consumption Data, Vehicle Rang
            trendline='lowess',
            trendline_options=dict(frac=0.6666))

...
```

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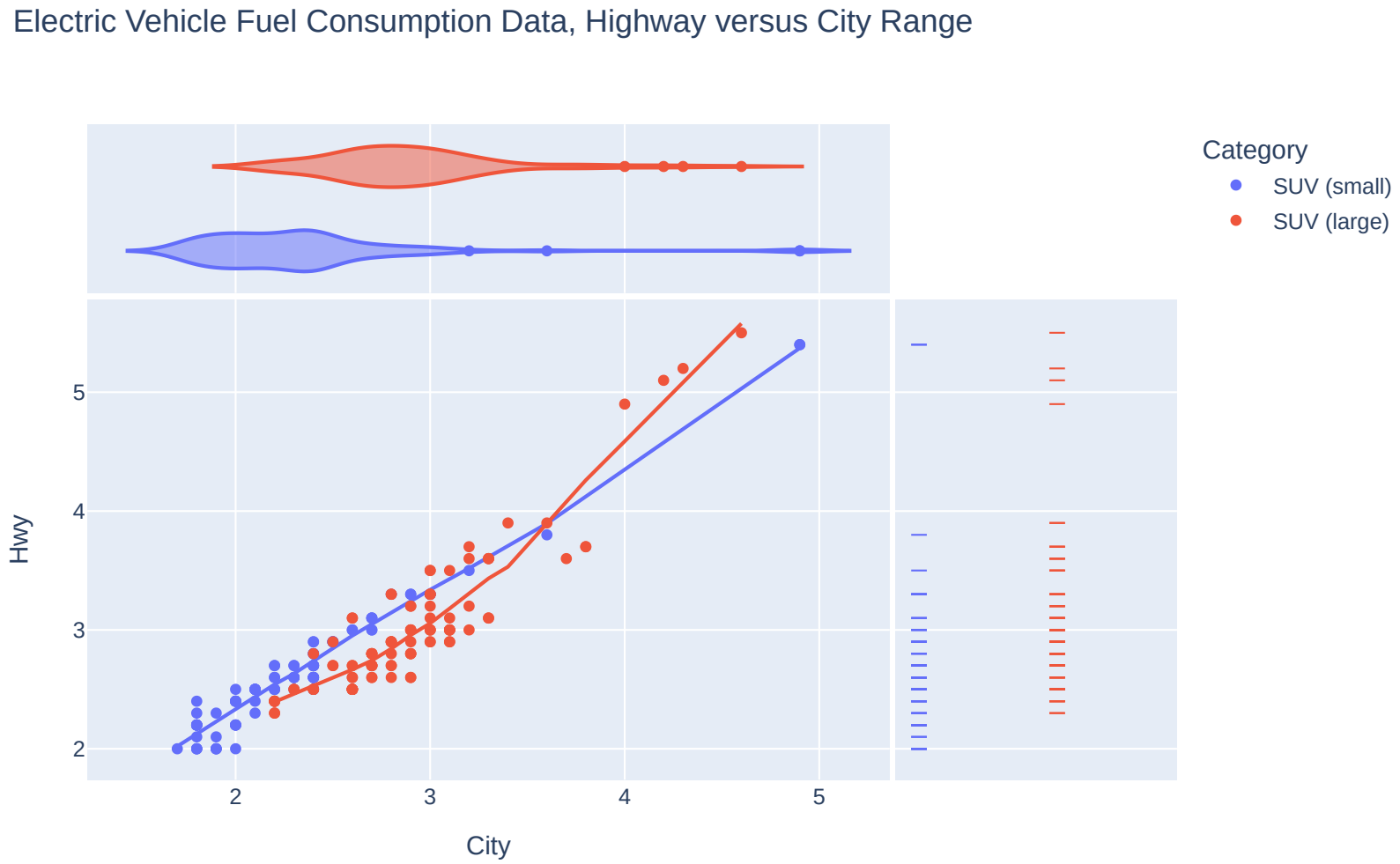
Trendlines and Marginals



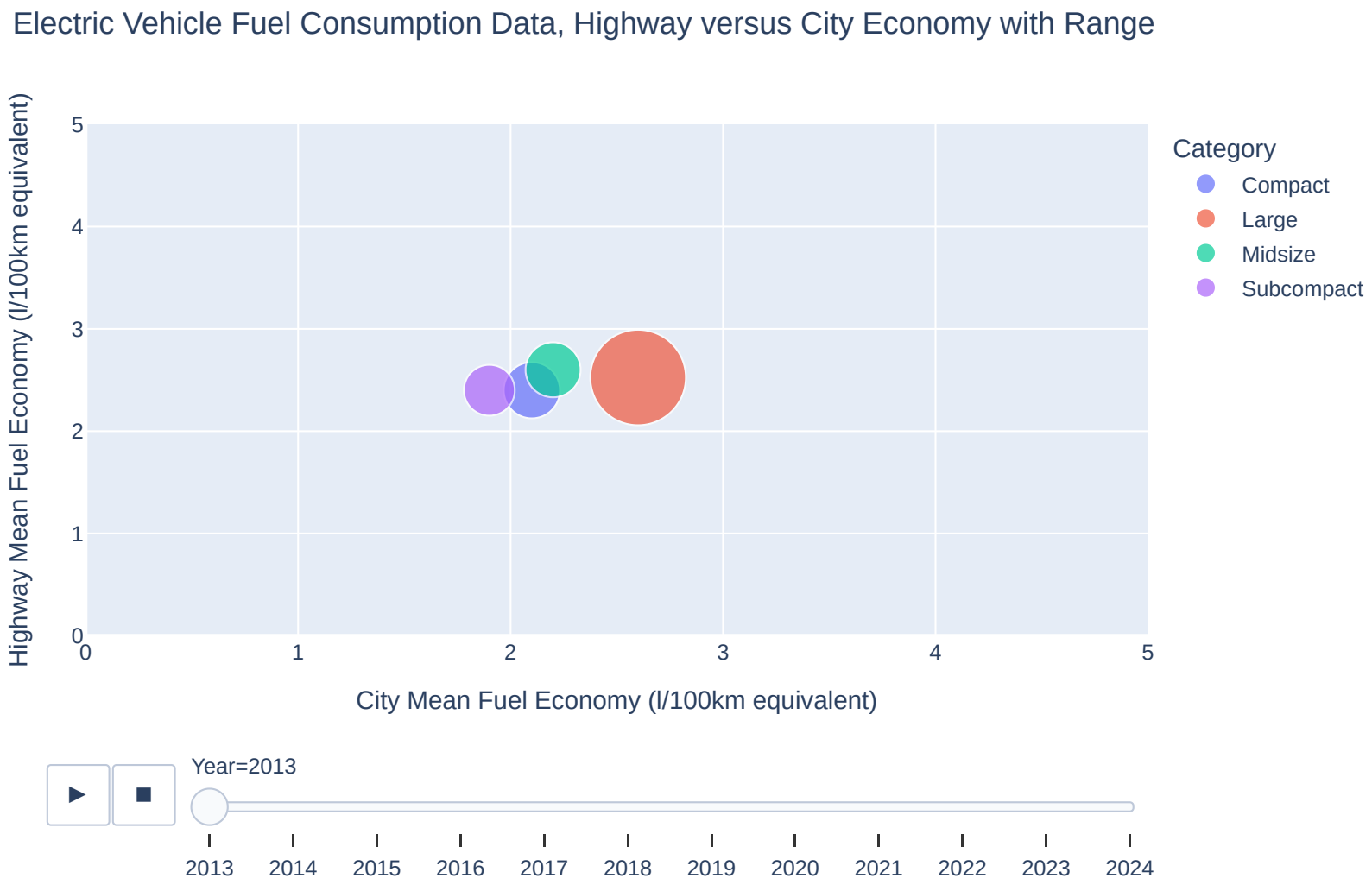
Trendlines and Marginals

```
...

df = fuelData[fuelData['Category'].isin(['US', 'UL'])]
fig = px.scatter(df,
            x='City',
            y='Hwy',
            color='Category',
            title='Electric Vehicle Fuel Consumption Data, Highway vers
            trendline='lowess',
            marginal_x='violin',
            marginal_y='rug',
            trendline_options=dict(frac=0.6666))

...
```

Bubbles, Interactive



Interactive Demo

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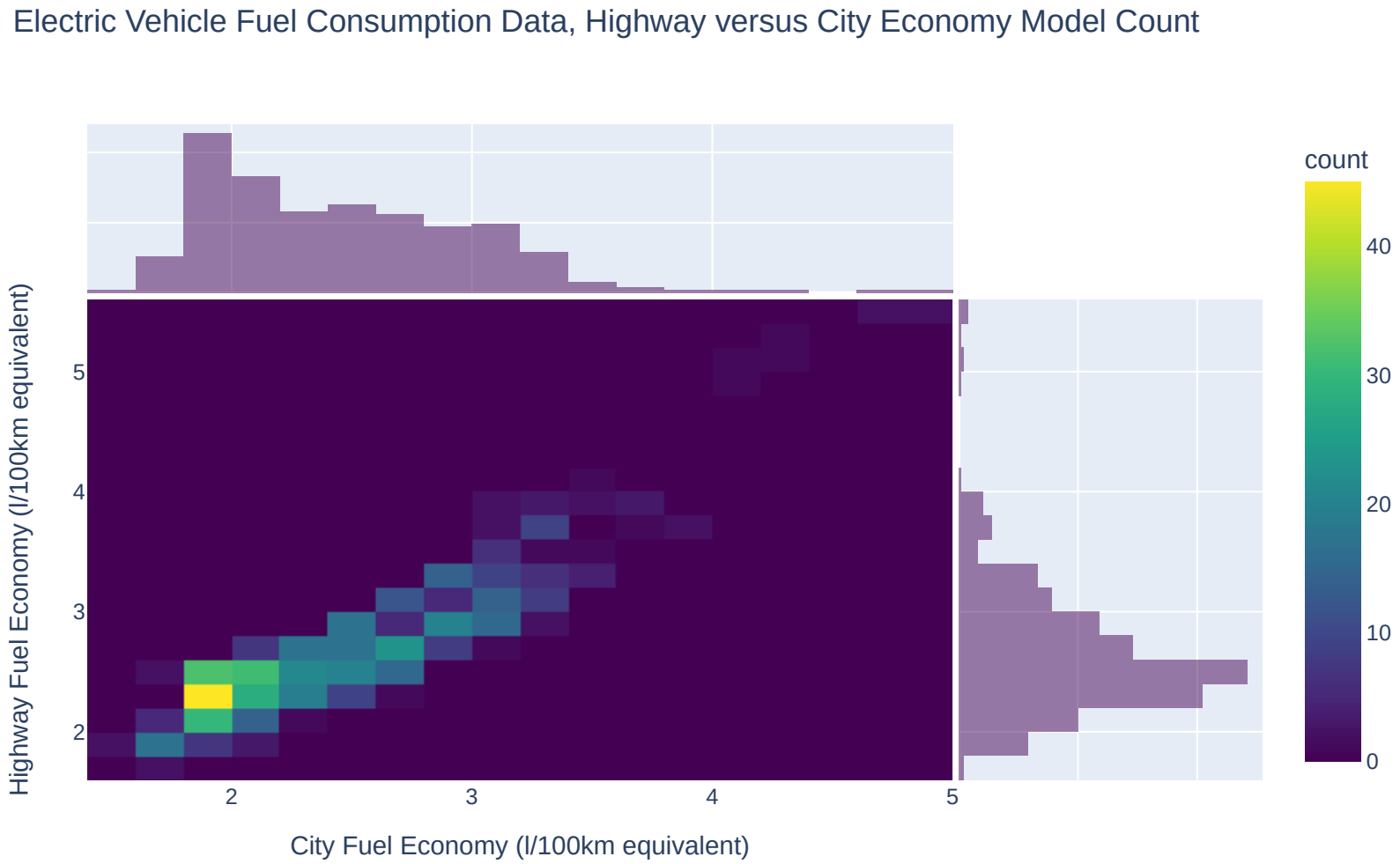
Bubbles, Interactive

```
df = fuelData
df = fuelData[(fuelData['Category'].isin(['S', 'M', 'L', 'C', 'UL']))
              & (fuelData['Year'] > 2012)]
grouped_df = df.groupby(['Category', 'Year'])
              .agg(range=('Range', 'mean'),
                   meanHwy=('Hwy', 'mean'),
                   meanCity=('City', 'mean'))
              .reset_index()

fig = px.scatter(grouped_df,
           x = 'meanCity',
           y = 'meanHwy',
           color = 'Category',
           size = 'range',
           animation_frame = 'Year',
           animation_group = 'Category',
           range_x = [0, 5],
           range_y = [0, 5],
           title='Electric Vehicle Fuel Consumption Data, Highway vers
           template='presentation',
           labels={"range" : "Range",
                   "meanHwy": "Highway Mean Fuel Economy (l/100km equi
                   "meanCity": "City Mean Fuel Economy (l/100km equiva
                 size_max = 50)
```

Heatmap with Marginals



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Heatmap with Marginals

```
df = fuelData

fig = px.density_heatmap(df,
            x = 'City',
            y = 'Hwy',
            nbinsx=20,
            nbinsy=20,
            color_continuous_scale=px.colors.sequential.Viridis,
            marginal_x="histogram",
            marginal_y="histogram",
            title='Electric Vehicle Fuel Consumption Data, Highway vers
            labels={"range" : "Range",
                    "Hwy": "Highway Fuel Economy (l/100km equivalent)",
                    "City": "City Fuel Economy (l/100km equivalent)"})
```

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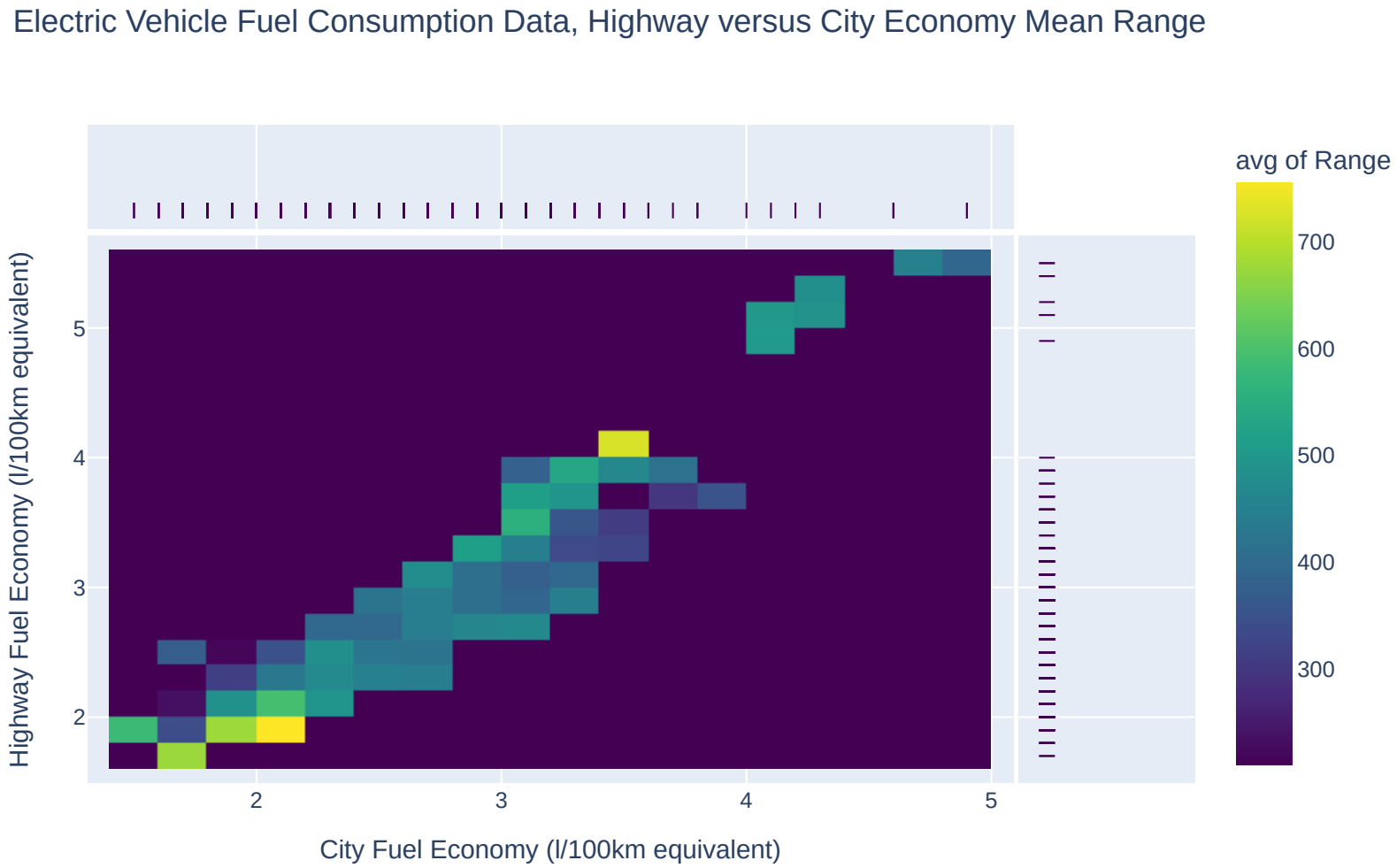
Heatmap with Marginals



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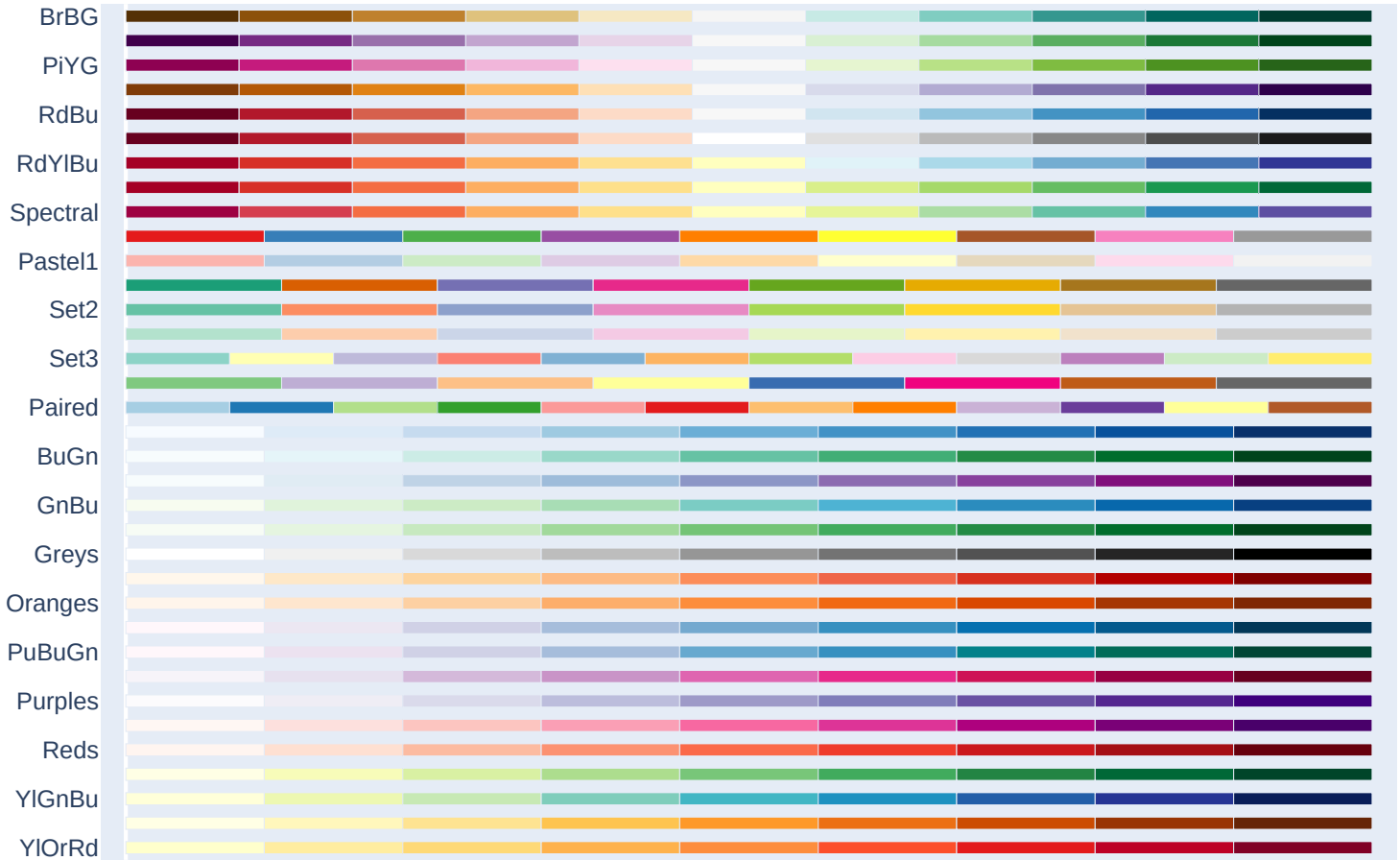
Heatamp with Marginals

```
df = fuelData

fig = px.density_heatmap(df,
            x = 'City',
            y = 'Hwy',
            nbinsx=20,
            nbinsy=20,
            color_continuous_scale=px.colors.sequential.Viridis,
            marginal_x="rug",
            marginal_y="rug",
            title='Electric Vehicle Fuel Consumption Data, Highway vers
            labels={"range" : "Range",
                    "Hwy": "Highway Fuel Economy (l/100km equivalent)",
                    "City": "City Fuel Economy (l/100km equivalent)"})
```

Colorbrewer Color Swatches

plotly.colors.colorbrewer



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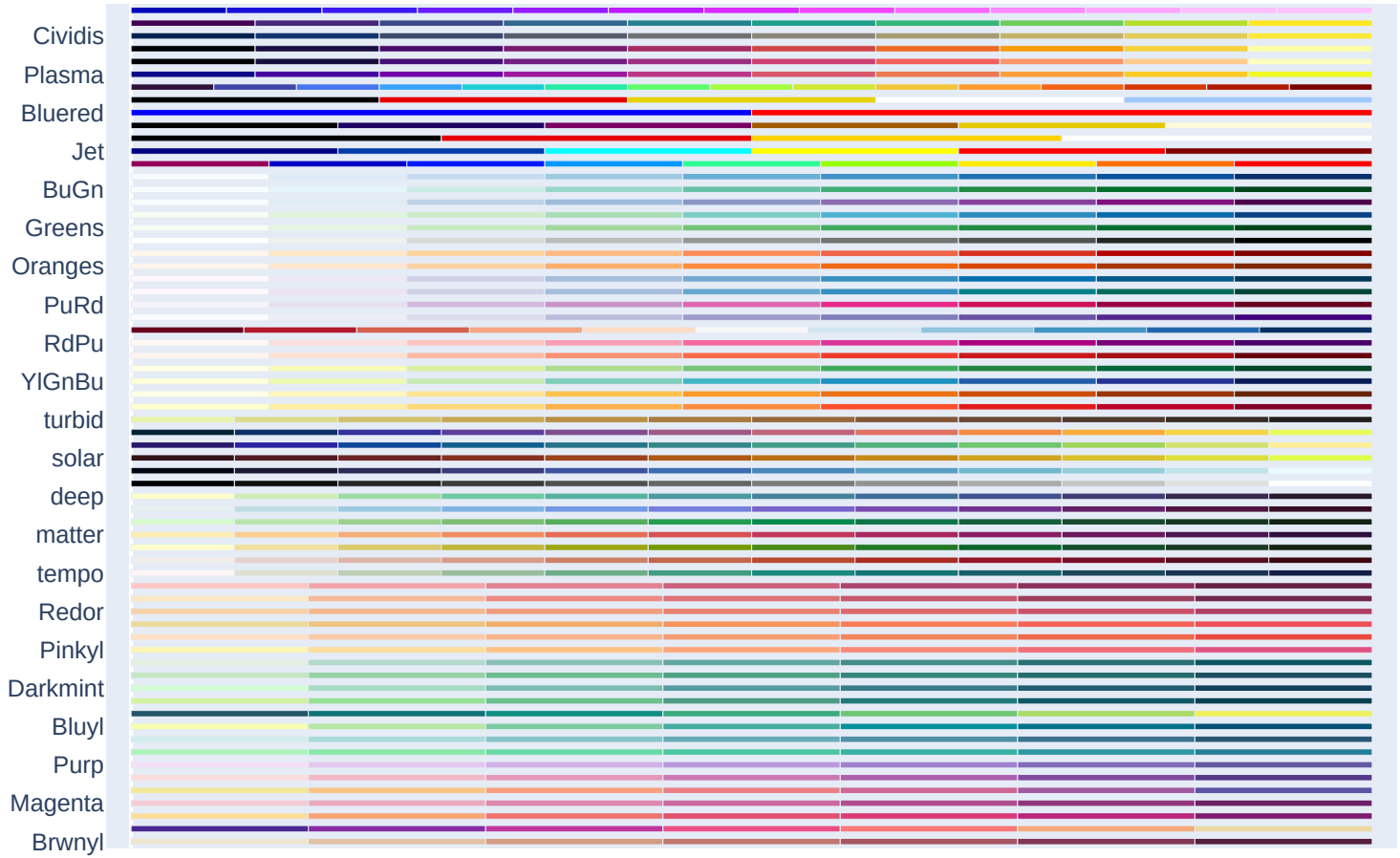
Discrete Color Swatches

plotly.colors.qualitative

Sequential Color Swatches

plotly.colors.sequential



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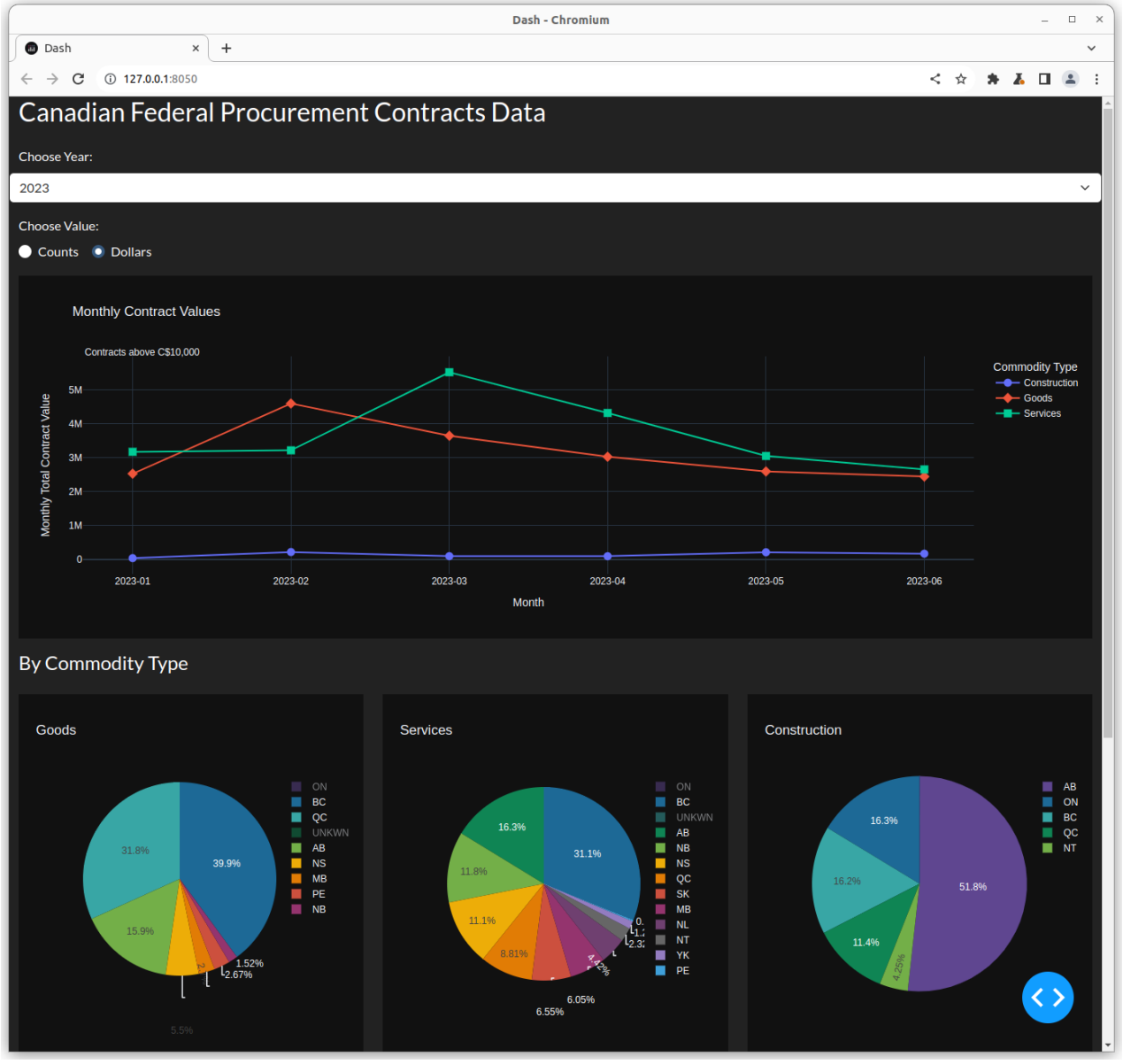
Dashboards – Live Demo



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http://joerg.evermann.ca/
DataVisualization.zip