Integrated Programme for Better Air Quality in Asia (IBAQ Programme)

CITY SOLUTIONS TOOLKIT:

EMISSIONS INVENTORIES: DATA VISUALIZATION OF EMISSIONS INVENTORY RESULTS

BACKGROUND INFORMATION

Communicating accurate and effective air quality data presentations is key to the development of well-informed air quality management (AQM) solutions. Albeit the process is not straightforward, stakeholders should be familiarized with the steps of interpreting data, including the identification of the level of air pollutants through measurements, and its sources, through an emissions inventory (EI). Emissions inventory data can be quite complex depending on the degree of data collection and analysis. It is important that the information is presented in the simplest way possible, through graphs and maps that can help the audience interpret the data and understand the context behind the numbers. Although the calculation process may be tedious, the data should always be understandable across all sectors, especially to policy and decisionmakers.

The most effective means of communication and data presentation for emission inventory is through an attractive visual reference such as time trends and spatial distribution. Data visualization offers an approach that can help in making the numerical data more understandable and wide-reaching. There are numerous available data visualization programs and tools that are accessible online which can create various types of data presentations. However, the best gauge of the effectiveness of a visual is when it moves stakeholders to action.

The focus of this module is not on the aesthetics, but instead on providing guidance on how to come up with data visualization that is clear and comprehensible without compromising data integrity and accuracy. The module gives guideline on effective emission inventory data visualization and useful rule-of-thumbs based on the experience of Clean Air Asia (CAA) in working with cities.

In this module you will find:

- Guidance on how EI data can be presented through effective visualization techniques;
- A summary of considerations in deciding which kind of visualization to use and how it should be communicated; and
- Examples of EI data visualization which can serve as reference for AQM practitioners.

THE METHODOLOGY

Once final calculations are done for the EI (See module on Development of source and emissions database), a dedicated personnel for data visualization would not take more than five days to perform the task. Professionals under communications and design, in collaboration with the individuals involved in data calculation are best equipped with the skills to do data visualization. It is emphasized that the data visualization process must always be aligned with the communication plan of the city. A detailed guidance on communication planning is provided in the module on Steps to develop a communications plan for cities.

The data visualization process generally includes the following steps: 1) understanding the data, 2) identifying how the data will be presented, 3) choosing the appropriate format for data presentation, 4) identification of tools for data visualization, and 5) communicating the visuals. The detailed discussion of prescribed steps will be discussed on their respective sections

1. Understanding the data

Before any graphics are created, the responsible individual must ensure that the following points are taken into consideration, as these are the same questions that we want the target users to understand through the visual interpretation of the EI data:

(1) What are the main categories of sources of pollutants?
(2) What is the main source of pollutant in a particular area?
(3) How much pollutants are emitted by the specific source identified?
(4) What is the extent of the study in terms of geographic scope and pollutant coverage?

2. Identifying how the data will be presented

Presentation of EI data can be through the following (Clean Air Asia, 2019):

(1) Highest shares per pollutant, to show where each air pollutant comes from
(2) Highest shares per source, for ease of management (i.e. general categories would be area, stationary, mobile, then all specific source types per each category is explained)
(3) Spatial map of the study area
   a. Can show which specific locations have higher emissions and thus can be prioritized
   b. Can show possible vulnerable locations (e.g. hospitals, schools, etc.) by overlaying data

3. Choosing the appropriate data presentation format

There are many emission source sectors to study when conducting an EI. Each sector has different qualities with regards to its pollutants and how it is emitted. The following are general visual presentations labelled according to their sector and type of data presentation (Wilton, 2001).

- **Fact sheets** – usually reduced to a few pages summarizing highlights of the EI. This is focused on using graphics in communicating the information and is often the most effective way of presenting EIs to the public.
- **Online sites** – providing a summary of EI data online can be effective in areas where access to the Internet is guaranteed. EI data found on this platform are usually presented using graphics with its details and summaries. Links for related data can also be found on these sites.
- **Summary reports** – these kinds of reports are reduced versions of a complete technical report. A summary report can be customized for a target audience that would require the results but not interested in all details of the project.
- **Inventory reports** – these are the complete technical reports which are considered as main EI output. It has complete information and detail.
- **Back-casting report** – when a previously done EI is repeated but using a new method, this is called “back-casting.” In an inventory report, a supplementary back-casting report can be added where data from previous years are re-analyzed with the same method used in the current EI reported.
- **Technical appendices** – appendices contain the detailed explanation of the methodologies used and the assumptions made in doing the EI.

4. **Identification of tools for data visualization**

There are numerous available tools for data visualization in the market, and the preference to use one over the other depends on the complexity of the data visualization needed. Microsoft Excel should be able to provide the basic needs for simple emission calculations and visualization for EI results. Other software like R and Origin can also be used to create graphs, while GIS can be used for creating spatial maps of emissions. Python and MATLAB can be used for more complex analysis and visualization. Adobe Illustrator, on the other hand, is helpful for creating visually engaging graphics for use in infographics and other materials. In summary, Microsoft Excel should be able to provide all basic needs for simple emission calculations and visualization for emission inventory results.

Below are some of the tools that are helpful in data visualization. Links are provided for more detailed information

(1) **Microsoft Excel** – A basic data processing and management program from Microsoft that has a suite of features from doing statistical analysis to visualization like charts and graphs.

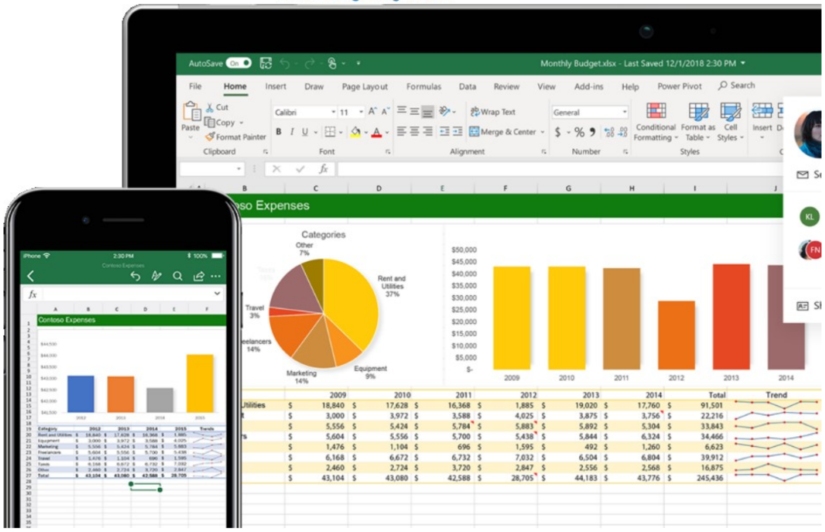


Image source: Microsoft
https://products.office.com/en/excel

(2) **R (and R Studio)** - R is a programming language for statistical calculation. R Studio, on the other hand, is an Integrated Development Environment (IDE) that helps users to develop programs in R. Integrated development environments are basically programs to produce other software.

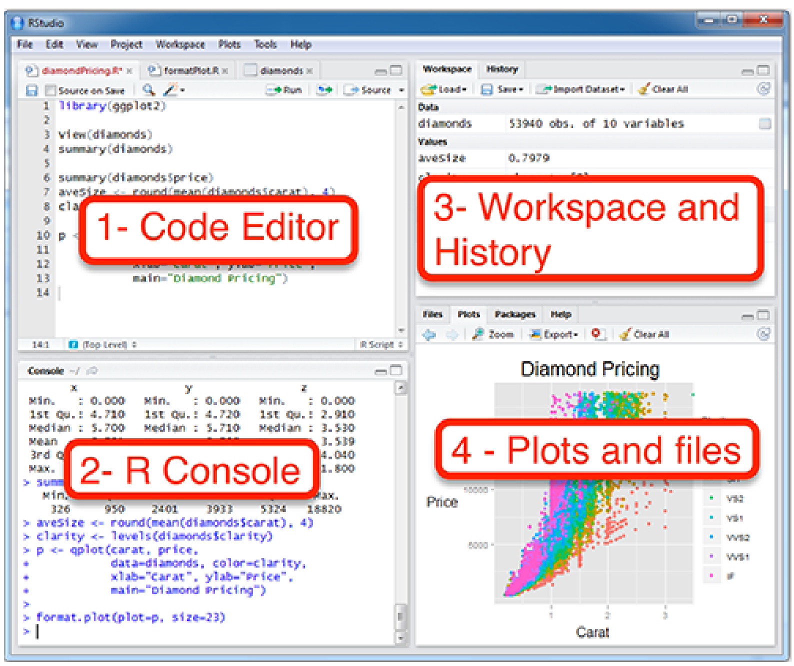


Image source: STHDA
R: https://www.r-project.org/ R Studio: https://rstudio.com/products/rstudio/download/

(3) **Origin** – Another graphing and analysis program with multiple ways to visualize data and graphing types. May require a learning curve to use because the primary users are scientists and engineers.

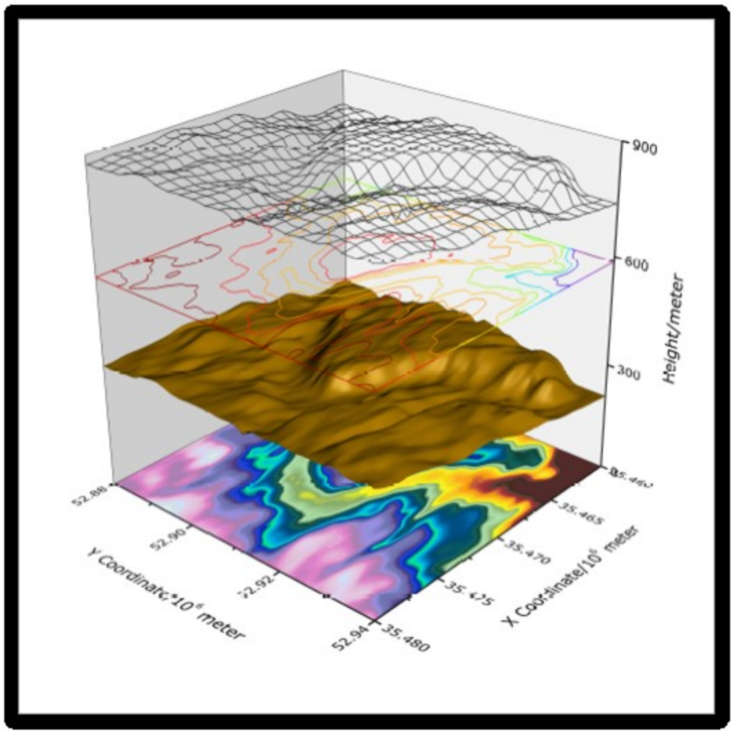


Image source: OriginLab
https://www.originlab.com/index.aspx?go=PRODUCTS/Origin

(4) **QGIS** – The advantage of QGIS is its open source status, i.e., users can access and use it for free compared to other Geographic Information Systems software like ArcGIS. This kind of software is able to integrate multiple ‘layers’ of data to employ more in-depth analysis about a geographic location.

Integrated Programme for Better Air Quality in Asia

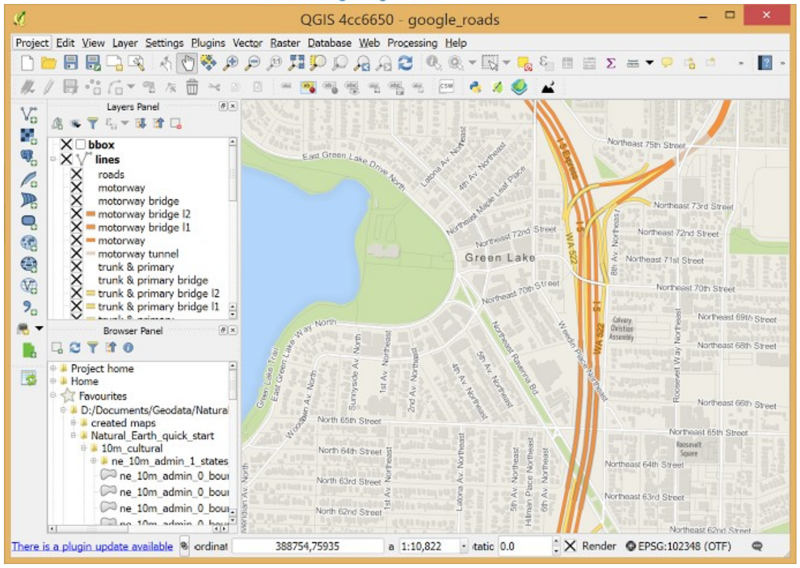


Image source: QGIS.org
https://www.qgis.org/en/site/

(5) **ArcGIS** – Developed by Esri, it is a software suite that creates maps and integrates other location-based data. It can also analyze data and combine other tools for more complex processes. This is a worldwide accepted program which most groups and stakeholders use for official reports and documents.

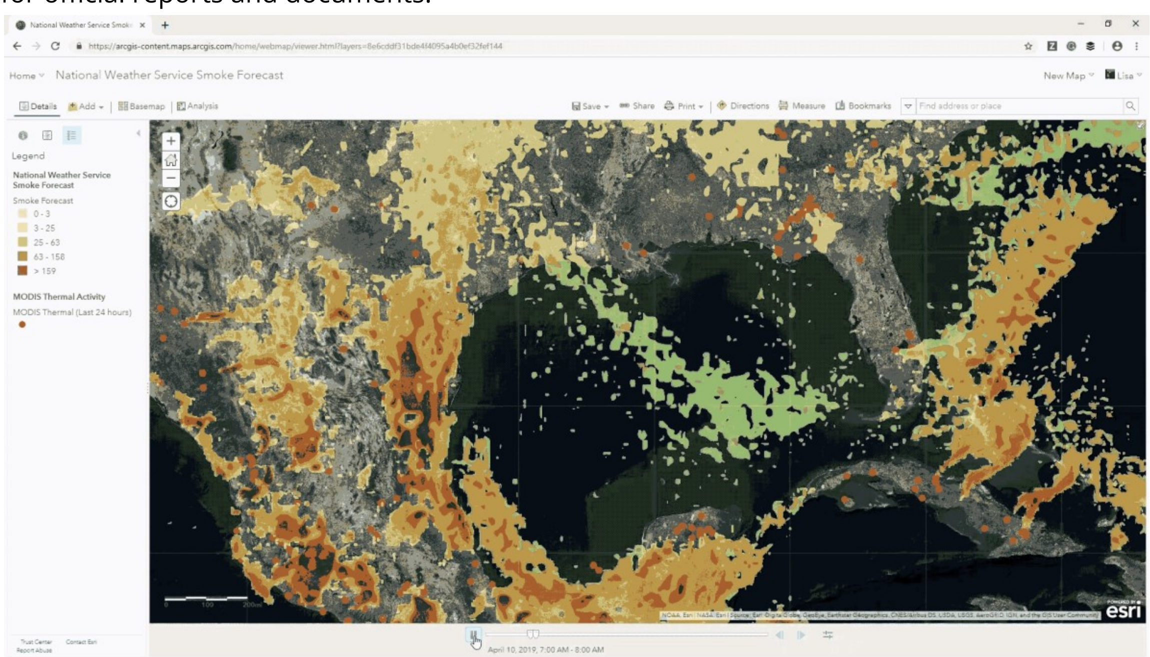
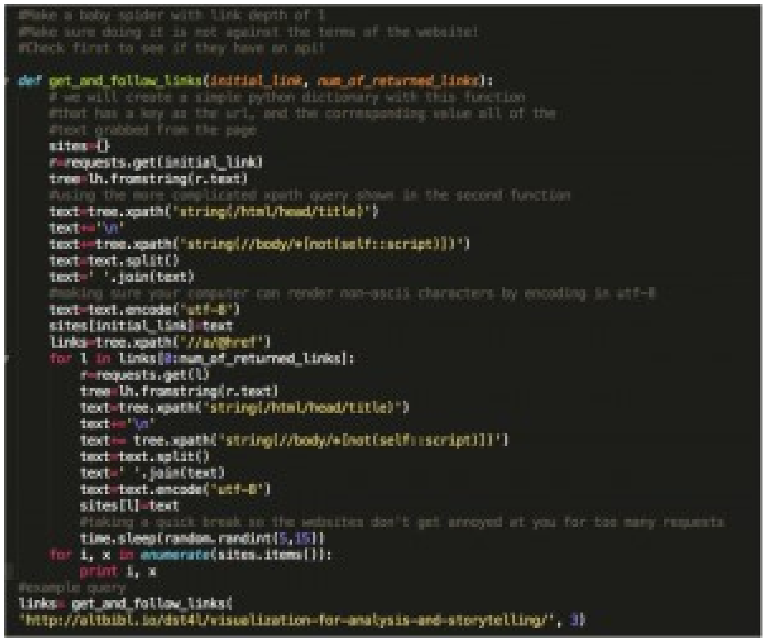


Image source: Esri
https://www.esri.com/en-us/arcgis/products/arcgis-pro/overview

(6) **Python** – Python is an open source, free to use and distribute programming language that can integrate many applications for analysis and data visualization. Training is required but after learning the language, the software can integrate other programs to process data uniquely which can't be done on a standalone basis.



```
#Make a baby spider with link depth of 1
#Make sure doing it is not against the terms of the website!
#Check first to see if they have an api!

def get_and_follow_links(initial_link, num_of_returned_links):
    # we will create a simple python dictionary with this function
    #that has a key as the url, and the corresponding value all of the
    #text grabbed from the page
    sites={}
    r=requests.get(initial_link)
    tree=lh.fromstring(r.text)
    #using the more complicated xpath query shown in the second function
    text=tree.xpath('string(/html/head/title)')
    text+='\n'
    text+=tree.xpath('string(//body/*[not(self::script)])')
    text=text.split()
    text=' '.join(text)
    #making sure your computer can render non-ascii characters by encoding in utf-8
    text=text.encode('utf-8')
    sites[initial_link]=text
    links=tree.xpath('//a/@href')
    for l in links[0:num_of_returned_links]:
        r=requests.get(l)
        tree=lh.fromstring(r.text)
        text=tree.xpath('string(/html/head/title)')
        text+='\n'
        text+= tree.xpath('string(//body/*[not(self::script)])')
        text=text.split()
        text=' '.join(text)
        text=text.encode('utf-8')
        sites[l]=text
        #taking a quick break so the websites don't get annoyed at you for too many requests
        time.sleep(random.randint(5,15))
    for i, x in enumerate(sites.items()):
        print i, x
#example query
links= get_and_follow_links(
'http://altbibl.io/dst4l/visualization-for-analysis-and-storytelling/', 3)
```

Image source: Cosmolearning
https://www.python.org/

(7) **MatLab** – MatLab is designed to analyze data, create models and develop other programs. MatLab is one of the more powerful programs that can be scaled up for cluster computing. It is used by experts from the academe, engineers, and industry.

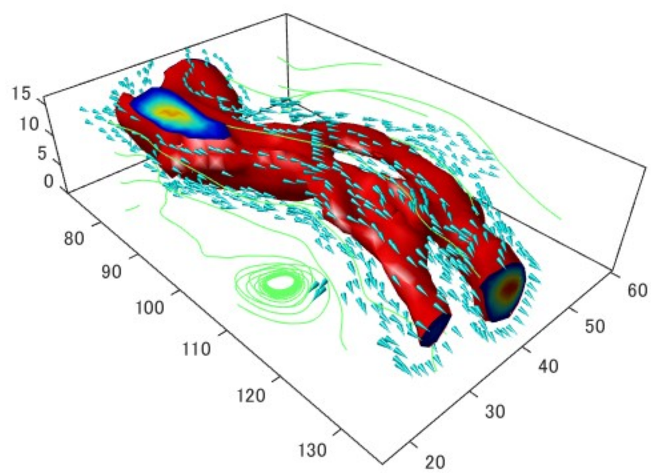


Image source: MathWorks
https://www.mathworks.com/products/matlab.html

(8) **Adobe Illustrator** – This program focuses on vector graphics. It is used for editing graphics of a project and is not capable of programming or analyzing data. It is purely a graphics editing software with a variety of features and capabilities.

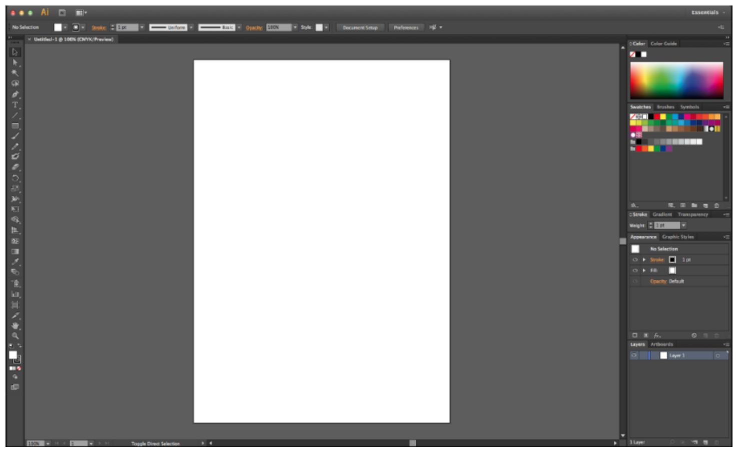


Image source: ICT Unit 1
https://www.adobe.com/sea/

5. Communicating the visuals

Communicating the results of an EI to the public can be in the form of public presentations, through fact sheets, pamphlets or summary documents, sources in the internet and media campaigns.

There are several considerations to take when preparing the campaign materials:

1) Public presentations and media campaigns should contain the following:

- Overview of air quality issues
- The role of the emissions inventory in determining sources of emissions to air.
- Implications of the results for future AQM decisions

2) Technical accuracy is paramount but should be presented in a comprehensible manner. Use of plain language in materials is recommended.

3) Use of simple pie charts, graphs, maps, and photographs that can be provided in both electronic or hardcopy form is prescribed.

4) To verify the completeness of the campaign materials, the following key questions must be answered by the output:

- What is the purpose of the work?
- What does it mean to me and the public?
- How does it impact decisions and policy?

Once these questions are clearly answered by the material, then it is good to go.

EXAMPLES AND APPLICATIONS

Beig et al.'s 2017 paper on reactive nitrogen species demonstrates examples of graphs and plots on EI:

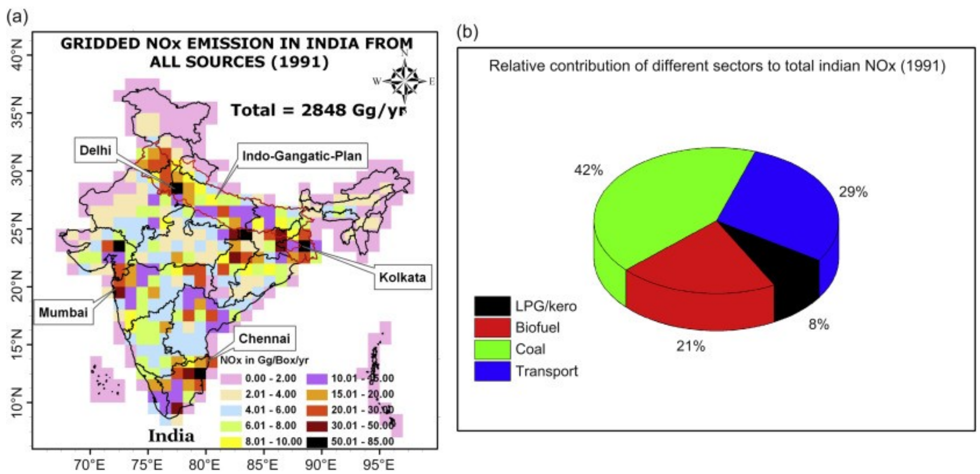
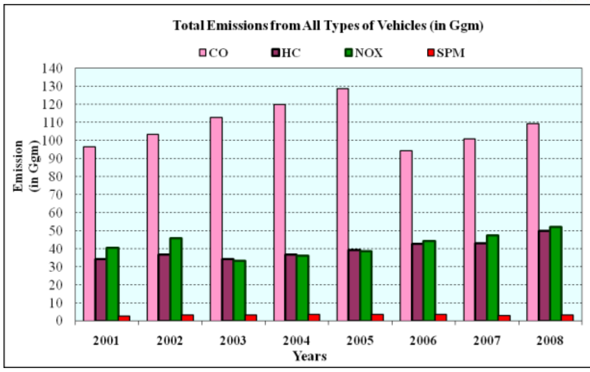
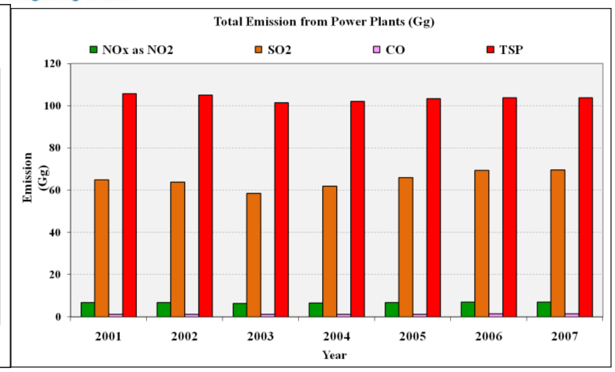


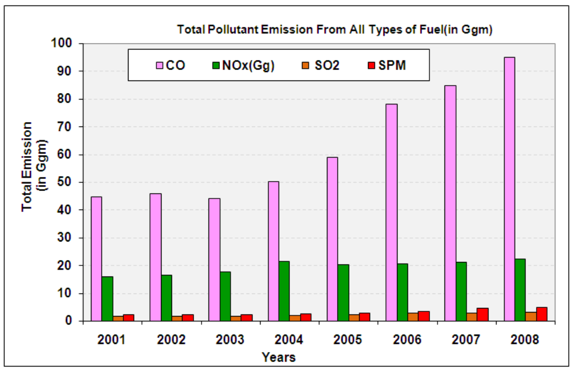
Figure (a) shows a spatial map of India, where the different colors per grid represent the level of NOx emissions. On the other hand, figure (b) shows one of the simplest graphs used in data visualization. The pie chart clearly identifies the sources of NOx, and the sizes of each pie segment is proportional to the contribution of each source. Pie charts are some of the simplest yet effective tools in conveying emission contribution. Although a bit more complex, spatial maps offer a clearer picture of which geographical regions should be prioritized for action.

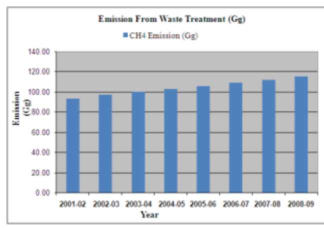
Use of charts: As presented below for various sector, using charts is the most straightforward way to show comparisons of total emissions over a period of time. Note the proper use of colors and refer to an expert to validate the results. The colors should be distinguishable from each other on a white background.

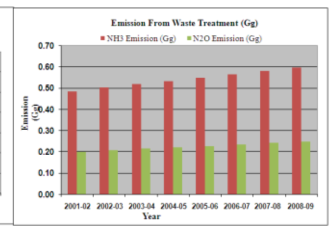




Emissions from Transport and Powerplants (Energy) Sectors







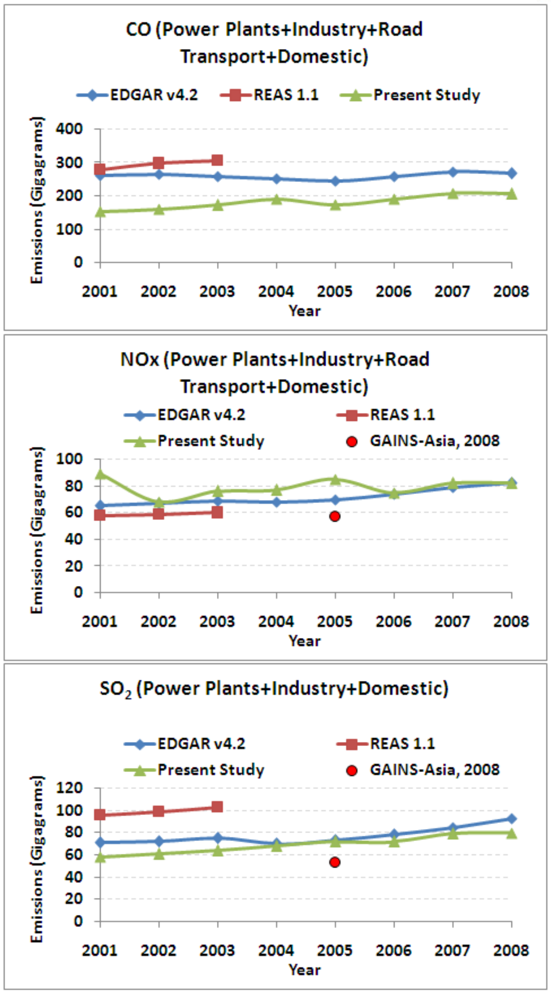
Emissions from Domestic sector and Waste Treatment (Mohan et al, 2012)

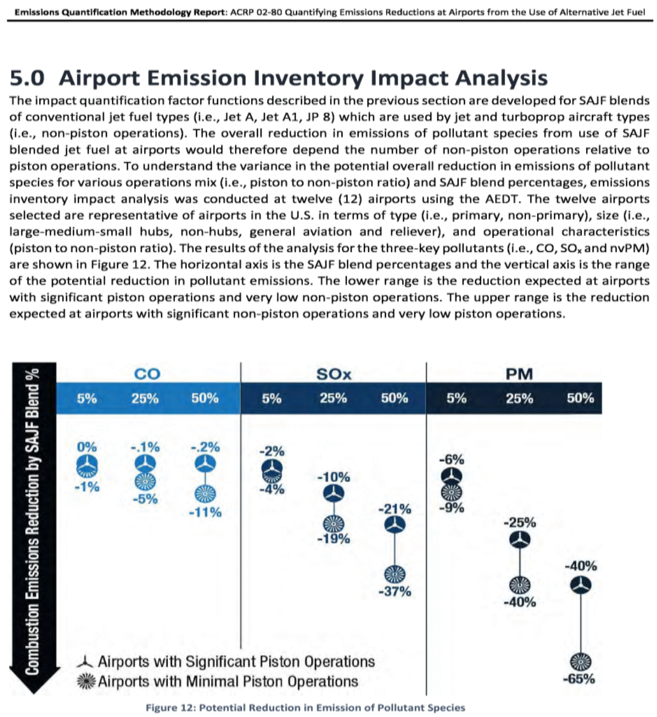
Emissions from powerplants as shown below uses a **Table** which can be satisfactory for technical reports. Care must be taken not to populate the document with too many tables without complementary visual charts or figures.

Sl. No.	Thermal Power Plants	Consumption in 000T							
		2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
1.	**Badarpur**	3767	3818	3554	3605	3732	3768	3739	4104
2.	**I.P. Stn.**	695	650	495	639	789	934	946	982
3.	**Rajghat**	612	542	671	629	541	503	529	736

Coal Consumption for year 2001 – 2008 for all three thermal power plants (Mohan et al, 2012)

Line graphs can also show comparisons and trends. Previous data from other inventories can be used for comparison, as shown in the image on the left below:





Emissions Quantification Methodology Report: ACRP 02-80 Quantifying Emissions Reductions at Airports from the Use of Alternative Jet Fuel

5.0 Airport Emission Inventory Impact Analysis

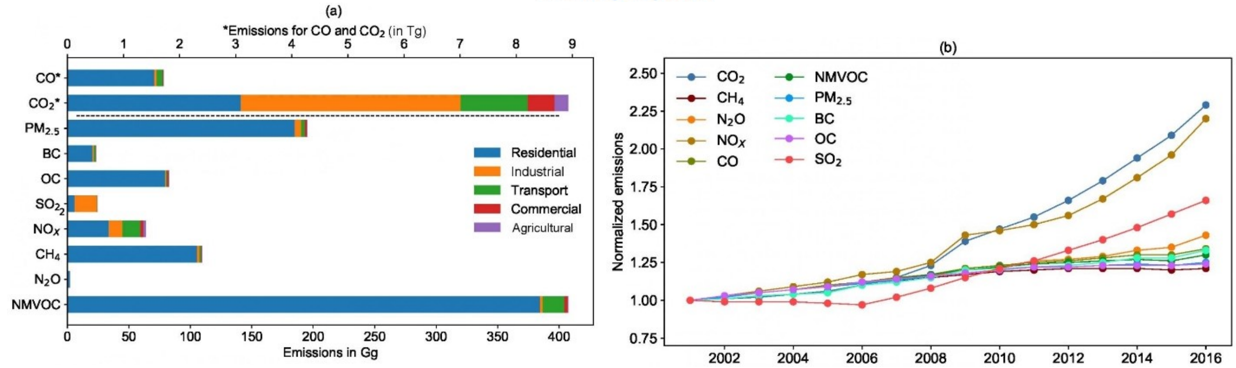
The impact quantification factor functions described in the previous section are developed for SAJF blends of conventional jet fuel types (i.e., Jet A, Jet A1, JP 8) which are used by jet and turboprop aircraft types (i.e., non-piston operations). The overall reduction in emissions of pollutant species from use of SAJF blended jet fuel at airports would therefore depend the number of non-piston operations relative to piston operations. To understand the variance in the potential overall reduction in emissions of pollutant species for various operations mix (i.e., piston to non-piston ratio) and SAJF blend percentages, emissions inventory impact analysis was conducted at twelve (12) airports using the AEDT. The twelve airports selected are representative of airports in the U.S. in terms of type (i.e., primary, non-primary), size (i.e., large-medium-small hubs, non-hubs, general aviation and reliever), and operational characteristics (piston to non-piston ratio). The results of the analysis for the three-key pollutants (i.e., CO, SO_x and nvPM) are shown in Figure 12. The horizontal axis is the SAJF blend percentages and the vertical axis is the range of the potential reduction in pollutant emissions. The lower range is the reduction expected at airports with significant piston operations and very low non-piston operations. The upper range is the reduction expected at airports with significant non-piston operations and very low piston operations.

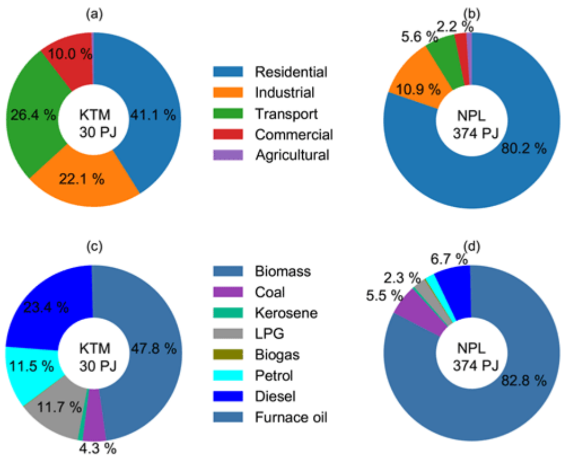
Figure 12: Potential Reduction in Emission of Pollutant Species

(Mohan et al, 2012) (NASEM, 2019)

The image on the right is a more creative way of presenting EIs, also known as **Infographics**. This is good for factsheets and short presentations where symbols and images are shown. Consultation with an expert in communication is suggested.

In Sadavarte et al.'s 2019 paper on the national EI for Nepal, the graphs below show (a) a simple bar graph that can directly show which pollutants are emitted in the highest levels, and from what sector it comes from; and (b) a time-based or temporal trend for each of the emissions from 2002 to 2016.

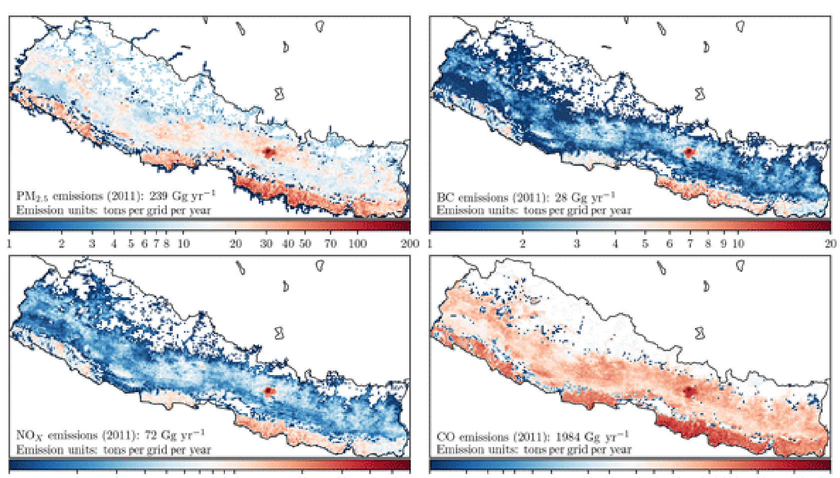




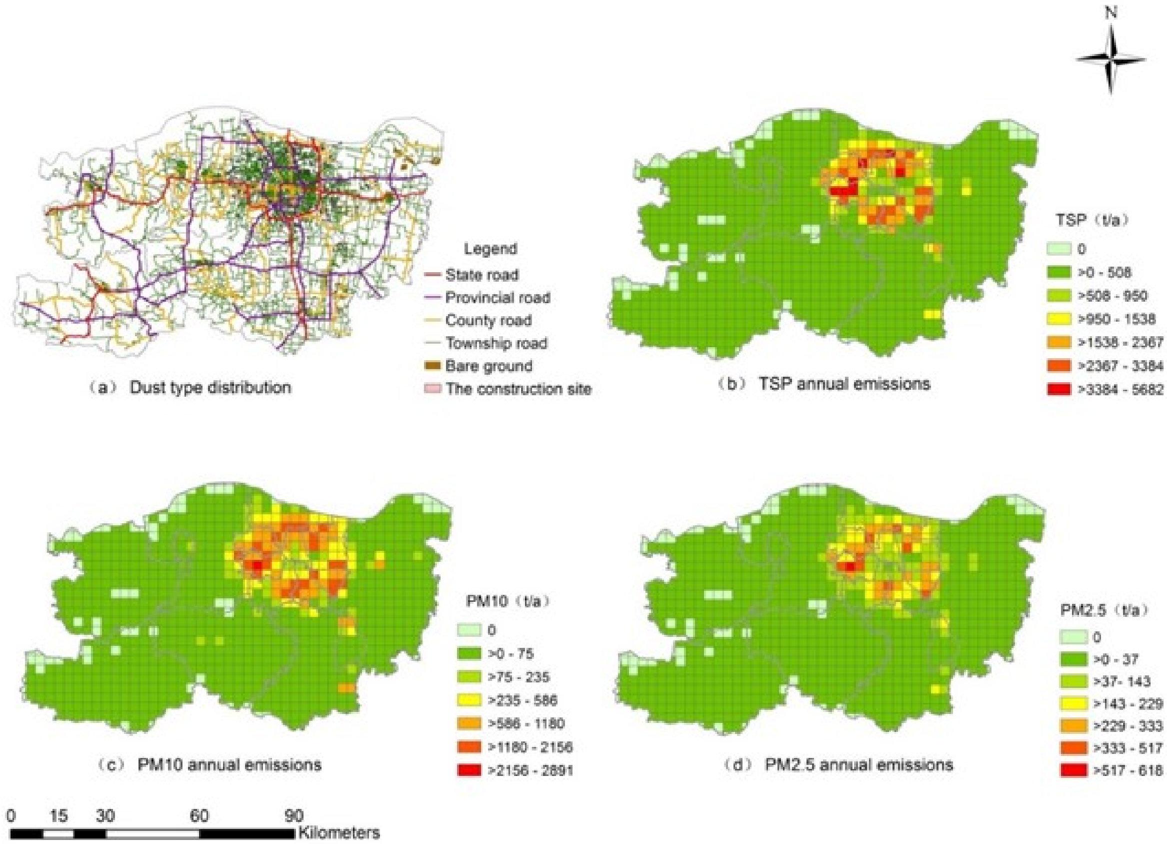
Another example is how energy consumption comparison at sectoral level for different locations (Kathmandu Valley and Nepal) and for different fuels at a particular year (2011) is illustrated using a variation of the pie chart, which is called a doughnut chart (Sadavarte et al, 2019)

(Note: Make sure to choose the right combination of colors that can be easily differentiated from one another.)

GIS and other visual tools: As EIs become more sophisticated, more analysis can be made using applications that are available online through smartphones and computers. Shown below are a few examples.



Spatial distributions of PM2.5, BC, NOx and CO emissions for year 2011 in Nepal (Sadavarte et al, 2019).



Spatial distribution of TSP, PM10 and PM2.5 due to dust sources, with major contribution from construction, followed by road and soil dust source, also shown in GIS maps (Yang et al., 2020).

GIS is a powerful tool to showcase EI data and to follow it up with modeling. As seen above, the use of GIS software can generate the visualization materials where various layers of data (e.g. geographical boundaries, emissions data, pollution sources) are superimposed geographically. This kind of analysis and presentation is the way forward for both technical output and public consumption because it can tell the whole story without showing so much numbers.

Software and apps are being developed so that companies and organizations have an easier time complying with AQM standards. One of which is VelocityEHS, a comprehensive cloud software solution with the following features:

- Real-Time Monitoring and Calculation
- Hybrid Calculation Engine
- Major Source Emissions Compliance
- Fully Customizable and Exportable Reporting
- Theoretical Emissions Modelling
- TRI Reporting Automation

Software such as these facilitate the development of EIs, but proper validation of the program should be done and experts in the field should be able to verify the performance of these tools.

At the end of the day, the type of data visualization to be done should be dependent on the availability of data and its level of detail. Other few reminders in doing data visualization include:

(1) Ensuring proper and complete data labels, including legends;
(2) Inclusion of accurate units especially for levels of pollutants;
(3) Identification of time frame of analysis; and
(4) Ensuring readability of information in terms of font face, size and color combinations (patterns are preferred especially if printouts cannot be in color print)

There are many more innovative examples of how to visually present EI data and results. The general objective must be maintained that the purpose of presenting data in a more visual manner is to make it more accessible for people and that the output improves decision making for AQM in the city.

WAY FORWARD

Air quality management practitioners should endeavor to continue to improve techniques on data visualization to make air quality information more visual and easier to comprehend by targeted stakeholders. As more stakeholders understand the value of EIs for AQM, more effort and resources can be dedicated to improving air quality action. Non-government and civil society organizations can help bridge science communicators and technical staff who conduct the EI process. A collaboration between the local government and the public should facilitate a feedback process to assess the effectivity of the data visualization and communication process.

It must be noted, however, that the presentation of data is still as good as how the data was collected and analysed, and how the actual EI development process has been conducted. These processes must be continuously improved, leading to a more comprehensive database that is understood by all stakeholders (See module on Development of source and emissions database).

REFERENCES:

Beig, G., Maji, S., Panicker, A.S., &Sahu, S.K.(2017) Sources of Reactive Nitrogen, Environmental and Climate Effects, Management Options, and Policies. 2017, Pages 403-426 https://doi.org/10.1016/B978-0-12-811836-8.00025-2

Mohan, M., Bhati, S., Ggunwani, P., & Marappu, P. (2012) Emission Inventory of Air Pollutants and Trend Analysis Based on Various Regulatory Measures over Megacity Delhi. Air Quality: New Perspective. eBook (PDF) ISBN: 978-953-51-5307-8 DOI:10.5772/45874

National Academies of Sciences, Engineering, and Medicine. 2019. *ACRP Web-Only Document 41: Alternative Jet Fuels Emissions: Quantification Methods Creation and Validation Report*. Washington, DC: The National Academies Press. https://doi.org/10.17226/25548.

Sadavarte, P. and Rupakheti, M. and Bhave, P. and Shakya, K. & Lawrence, M.(2019) Nepal emission inventory -- Part I: Technologies and combustion sources (NEEMI-Tech) for 2001—2016. Atmospheric Chemistry and Physic 19.20: 12953-12973 URL: https://www.atmos-chem-phys.net/19/12953/2019/ DOI 10.5194/acp-19-12953-2019

VelocityEHS (https://www.ehs.com/wp-content/uploads/2016/12/VEHS_Solution-Sheet_Air-Emissions.pdf)

Wilton, Emily. (2001) Good Practice Guide for Preparing Emission Inventories. Ministry for the Environment. Sustainable Management Fund. The Crown, New Zealand. Last Accessed: https://www.mfe.govt.nz/sites/default/files/emissions-good-practie-guide.pdf

Yang et al. (2020). Emission Inventory and Spatial Distribution of Particulate Matter from Dust Sources in Zhengzhou City, China. Accessed from https://www.researchsquare.com/article/rs-10808/v1