GLOBAL ENERGY SYSTEMS NAVIGATOR:
AN INTERACTIVE MAP OF ENERGY AND CARBON FLOWS

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The Global Energy Systems Navigator is an interactive map of the flows of carbon and exergy – the useful portion of energy – through global human energy systems. It is an educational tool for anyone interested in better understanding the complex mechanisms by which we convert natural energy resources into end-uses. The data were collected from dozens of reference sources such as International Energy Agency and UN databases, scientific journals, and government reports.

ORIGINS

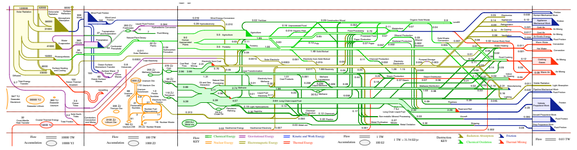
CARRIERS AND TRANSFORMATIONS

The data that make up the navigator are of two types:

- Carriers: mediums through which exergy and carbon flow
- Transformation: processes that convert one carrier into another

STATIC VISUALIZATION

Sankey Diagram: developed at Stanford University



Strengths:

- Displays the entire system in a single view
- Complexity and interconnectedness of the system are apparent
- Relative magnitudes are perceptible

Weaknesses:

- Presentation must be very large to be legible
- Limited ability to “drill down” and explore the data
- Layout is arbitrary and drawn by hand
- No room for additional metadata

INTERACTIVE VISUALIZATION

Design Goals:

- Dynamic, intelligent computer-generated layout
- Explore broadly and “drill down” for more information
- Limit the scope of data at any given time
- Presentable on the web on standard displays
- Relative magnitudes are perceptible

We have constructed an interactive web-based visualization that combines a node-and-end view and quantitative stacked bar graph view.

APPROACH

NAVIGATION BAR

Presents all carriers and transformations in a searchable, filterable list.

- Mouse hovering over list items highlights the corresponding node and its connections in the network view.

NETWORK VIEW

Presents the data broadly. Users can explore the data’s interconnectedness.

- Carriers and transformations appear as nodes, connected by edges.
- Carrier nodes are circles. Transformation nodes are small bar graphs of the transformation’s exergy efficiency.
- Nodes are arranged so that primary resources appear to the left and final end-uses appear to the right.
- Mouse hovering highlights node connections and displays a detailed description of the chosen node.

METHODS

We achieve a good layout by basing the nodes' X positions on a weighted average of its minimum and maximum depths in the network and the depths of its neighbors. The initial Y positions are random.

Next we start a physics simulation using three forces:

1. A spring force along edges that bring nodes close to their neighbors.
2. An repel force which reduces overlap of adjacent nodes.
3. A framing force which acts on nodes as they get close to the borders.

DETAILS VIEW

Presents quantitative view of an item with its inputs and outputs on either side.

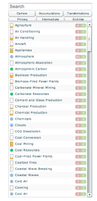
- Hovering reveals that item’s value of exergy and carbon as well as a detailed description of its role in the energy system.
- Clicking on an input or output item refocuses the view to center on it, revealing its carbon and exergy inputs and outputs.

METHODS

- A stacked bar graph visualizes the proportion each input and output contributes to the central item’s total exergy or carbon.
- Animation is used to refocus the view onto a new central item.

RESULTS

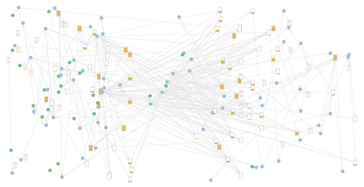
NAVIGATION BAR



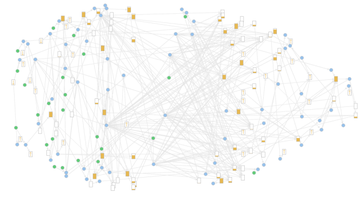
- Real-time search filters nodes to match the query.
- Buttons filter by item type (e.g. carrier, transformation) or by position in the system (e.g. primary resource, end-use).
- Tool-tips display item’s carbon/exergy on mouse hover.
- Each time is tagged with the number of inputs and output.

NETWORK LAYOUT

Using a combination of weight averages of minimum and maximum node depth and physics simulations, we achieve an effective layout of nodes.



LAYOUT BASED ON WEIGHTED AVERAGE OF MINIMUM AND MAXIMUM DEPTHS IN THE NETWORK.



LAYOUT WITH SUPPLEMENTAL PHYSICS SIMULATIONS.

DETAILS VIEW

- Central item’s exergy/carbon magnitude defines the scale of the graph.
- Inputs and outputs are displayed as stacked on either side in proportion to the central item.
- Clicking on an input/output refocuses the graph and makes that item central.
- Carriers are blue. Transformations are orange.
- Tool-tips display the item’s carbon and exergy on mouse hover.

FUTURE WORK

MULTIPLE DATA ENCODING IN NETWORK VIEW

Though the network view is designed to present the data broadly, we believe more data could be encoded in the shapes, sizes, and even relative positions of the nodes without causing distraction.

REDUCED EDGE OVERLAP IN NETWORK LAYOUT

The network layout could be improved by applying algorithms to reduce edge overlap and increase the proximity of connected nodes.

PATH HISTORY

These data could be further explored by recording and comparing the efficiency properties of various paths through the network. Users could, for example, compare the carbon footprints of powering automobiles with gasoline vs. electricity produced from solar power.

BETTER INTEGRATION

Smoother transitions between the network and details views are needed to help users perceive them as part of a single interactive visualization.

USER TESTING

As a tool intended for lay audiences, studies in usability would help determine our designs address the needs of our target users.

COLLABORATORS

Data for this project were collected at the Global Climate and Energy Project at Stanford University.

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