Proceedings of the IASTED International Conference
Power and Energy (PE 2013)
November 11 - 13, 2013 Marina del Rey, USA

VISUALIZING ENERGY DATA AND SEEING THE WHOLE PICTURE OF ENERGY IN GUATEMALA

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ABSTRACT
Taking several visualizations produced by the Lawrence Livermore National Laboratory for US country-wide energy use as examples, we explored the possibility of designing and assembling a custom visualization of the energy data provided by the Ministry of Energy – the national energy agency – of Guatemala. We found that energy data is consistently collected and regularly published in Guatemala but the reports seldom include graphics and analysis that tell the full story of energy for each time lapse with little to none consideration for the lay reader. In this paper we present preliminary results about the designed visualizations and explain the procedure followed to construct and validate each one of them. As the project evolved we found that the need for this type of representations of energy data is felt not only in our country but in most of Latin America. Efforts to fulfill that need were identified and coordination with them has started.

KEY WORDS
Energy Flow Analysis, Energy Data Visualization, Energy Flow Diagram, Guatemala.

1. Introduction

The Ministry of Energy and Mines – MEM – in Guatemala (http://www.mem.gob.gt) is the central agency for collecting energy data in the country. It has legal powers to request data from all types of energy operators, generators, transporters, distributors, of all sizes and technologies. As many agencies of its type in Latin America, it follows the guidelines of the Latin American Energy Organization or OLADE (http://www.olade.org) by their Spanish initials, to format and present the data in public reports. The guidelines are contained in documents like the "Manual de Estadísticas Energéticas Año 2011" ("Energy Statistics Manual Year 2011") [6] edited by OLADE for all of its associated countries.

Along with MEM there are other agencies that collect and report data on energy: the National Commission for Electric Energy or CNEE (http://cnee.gob.gt) that oversees the National Interconnected System, the electric grid of generators, transporters, distributors and related stakeholders, the Wholesale Energy Market Administrator or AMM (http://www.amm.org.gt) an association of private producers of energy whose members sell most of electric energy used in the country, and some academic institutions and NGOs related to environmental protection interested in providing information to the public to increase awareness on the potentially harmful practices of some processes linked to energy [1].

Nevertheless, the most complete and consistent information for the energy sector is that provided by MEM.

The Institute of Science and Technology for Development of the Universidad Rafael Landívar in Guatemala (http://www.incytde.org), known as InCyTDe from its name in Spanish, recently took the mission of examining the energy sector of the country and one of the first tasks was to analyze the available data provided by the aforementioned agencies.

Quite soon two facts were found: first that the most complete report for the country was the Energetic Balance Sheet [15] and second that the information provided by such report was hard to understand and lacked visual representations that could convey the whole situation easily even to the trained eye.

In this paper we present the results of an effort to design and validate a visualization of the available data on energy in the country aimed to provide a more understandable and complete picture of the sector to the public. It is organized as follows: in section 2 we discuss the Energetic Balance Sheet of the country; section 3 portrays the Energy Flow Diagrams, the type of visualization selected for the work; section 4 describes the process of design and validation; section 5 explains what we found in the process; and section 6 presents our conclusions and plans for future work.

2. The Energetic Balance Sheet

The OLADE guidelines [6] are used to compile country energy data into a standard report called the "Balance Energético" or "Energetic Balance Sheet" – EBS. The importance of this report is well stated in the abstract of the Energy Statistics Manual mentioned before: "Este trabajo presenta los conceptos básicos necesarios para la recopilación y manejo de las estadísticas del sector energético, orientados de manera específica a la elaboración de balances energéticos en términos de

DOI: 10.2316/P.2013.806-036

ACTIVIDADES	PETR	CRBN	HYDR	GEOE	LEÑA	BCAÑ	Total Primarias	ELEC	GLP	GAS	KER
Producción	6,679.87	0.00	2,276.27	1,027.43	27,369.01	4,022.07	41,374.66	0.00	0.00	0.00	0.00
Importación	0.00	2,059.21	0.00	0.00	929.32	0.00	2,988.52	14.37	2,231.52	6,155.28	542.08
Exportación	5,934.02	0.00	0.00	0.00	0.00	0.00	5,934.02	207.84	0.00	0.00	0.00
Variación Inventario	-252.37	3.13	0.00	0.00	0.00	0.00	-249.24	0.00	-423.22	104.73	38.68
OFERTA TOTAL	**493.48**	**2,062.34**	**2,276.27**	**1,027.43**	**28,298.33**	**4,022.07**	**38,179.92**	**-193.47**	**1,808.30**	**6,260.01**	**580.76**
Refinerias	-493.48	0.00	0.00	0.00	0.00	0.00	-493.48	0.00	0.00	4.58	1.71
Centrales Eléctricas	0.00	-2,062.34	-2,276.27	-1,027.43	0.00	-2,688.51	-8,054.55	4,646.21	0.00	0.00	0.00
Autoproductores	0.00	0.00	0.00	0.00	0.00	-1,333.56	-1,333.56	339.61	0.00	0.00	0.00
TOTAL TRANSFORMACION	**-493.48**	**-2,062.34**	**-2,276.27**	**-1,027.43**	**0.00**	**-4,022.07**	**-9,881.59**	**4,985.81**	**0.00**	**4.58**	**1.71**

Figure 1. Excerpt from the main table in the Energetic Balance Sheet for the year 2005. This was the first EBS published online by the MEM. For the complete report see [15].

energía final y a la generación de indicadores económico-energéticos y de impacto ambiental."[1]

The Energetic Balance Sheet or Energy Balance Table [22] is thus a well-established, standardized report that can be expected to be published by the national energy agency in most countries of Latin America, [2], [20] and [23] are some examples.

In the case of Guatemala to the verifiable extent allowed by the Ministry of Energy official website, it has been published annually since 2005 (see Figure 1), almost with no change in format and number of sections (see Figure 2), making it a trustable source of official data on energy for the country [15].

3. Energy Flow Diagrams

Energy Flow Diagrams – EFD – are visual representations of energy data that show in a single chart how much energy has been produced by every source available in the country or region of interest. It then shows the amounts that are transformed into electricity and where every form of energy is consumed. The diagram is read from left to right and uses arrows and colors to guide the reader in following the path the different types of energy traverse from primary source to consumers. In many cases it can be considered an especial type of Sankey diagram [14], [21].

The incurred losses of energy in production, transport or transformation processes are also accounted for in the EFD and aggregated in a special category.

Such a visualization tool appears as the right format to convey what can be called "the full story of energy" for a country or region during a period of time. Instead of depicting only segments related to production or to transformation or to consumption, like traditional bar or pie charts do, it rejoins all the relevant summary data and builds an inherently consistent representation that answers the questions individual charts would only partially respond. People looking to find where the nation or region stands regarding energy production and consumption can figure out very quickly after analyzing the corresponding EFD [11].

It is no wonder then why several countries have started employing it for reporting energy data and in some cases even disaggregating the data to craft reports limited to specific regions or time intervals [3], [4], [8], [10], [12].

On the other hand, creating an EFD can be a tricky task that requires data manipulation skills and graphic design abilities, along with deep knowledge of energy topics such as technology, economics, and social dynamics.

Even with the whole set of data and skills available, the amount of time needed to come up with the appropriate design of the diagram can be significant.

There are some efforts in progress to apply computing power to automatically generate the diagram but the results are still uncertain [19].

4. Designing an Energy Flow Diagram for Guatemala

After verifying to a rational extent that there was no report being delivered or planned for delivery in the near future, similar or equivalent to the energy flow diagram for Guatemalan energy data, the InCyTDe assembled a team to plan, design and validate the first visualization of that type for the country.

The process, a work in progress, includes four steps:

1. Test the feasibility of creating an energy flow diagram based on one of the available energetic balance sheets assessing the sufficiency of the data contained in the report by actually creating a first version.
2. Assess and improve the clarity and completeness of the generated visualization by presenting and discussing every version produced with individuals and groups in the energy field.

[1] "This work presents basic concepts needed for compiling and handling statistics in the energetic sector, specifically towards the production of energetic balance sheets in terms of final energy and the generation of economic-energetic and environmental impact indicators."

En siguiente cuadro se muestra el Balance Energético Nacional consolidado para el año 2010, en KBEP.

ACTIVIDADES	PETR	CRBN	HYDR	GEOE	LEÑA	BCAÑ	Total Primarias	ELEC	GLP	GAS	KER	DOIL	FOIL	COQE
Producción	4,331.9	0.0	2,981.1	1,679.1	37,253.0	8,019.6	54,264.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Importación	0.0	2,878.7	0.0	0.0	0.0	0.0	2,878.7	224.5	2,666.9	7,653.1	560.9	8,947.2	4,056.1	625.4
Exportación	3,693.0	0.0	0.0	0.0	0.0	0.0	3,693.0	86.1	760.0	235.1	0.0	216.0	64.2	0.0
Variación Inventario	-144.8	-400.2	0.0	0.0	0.0	0.0	-545.0	0.0	-24.2	-126.5	12.5	453.4	-134.0	340.5
OFERTA TOTAL	**494.1**	**2,478.5**	**2,981.1**	**1,679.1**	**37,253.0**	**8,019.6**	**52,905.5**	**138.4**	**1,882.7**	**7,291.5**	**573.4**	**9,184.5**	**3,857.8**	**965.9**
Refinerias	-494.1	0.0	0.0	0.0	0.0	0.0	-494.1	0.0	0.0	0.4	3.1	167.9	0.0	0.0
Centrales Eléctricas	0.0	-2,478.5	-2,963.8	-1,679.1	0.0	-5,613.7	-12,735.1	5,055.1	0.0	0.0	0.0	-11.0	-2,922.5	0.0
Autoproductores	0.0	0.0	-17.3	0.0	0.0	-2,405.9	-2,423.2	455.0	0.0	0.0	0.0	0.0	-145.0	0.0
TOTAL TRANSFORMACION	**-494.1**	**-2,478.5**	**-2,981.1**	**-1,679.1**	**0.0**	**-8,019.6**	**-15,652.5**	**5,510.1**	**0.0**	**0.4**	**3.1**	**157.0**	**-3,067.6**	**0.0**

BALANCE ENERGÉTICO DE GUATEMALA
AÑO 2011

ENERGIA SECUNDARIA en KBEP

ACTIVIDADES	PETR	CRBN	HYDR	GEOE	LEÑA	BCAÑ	Total Primarias	ELEC	GLP	GAS	KER	DOIL	FOIL	COQE
Producción	3,966.74	0.00	3,233.94	1,522.42	37,253.01	12,424.03	58,400.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Importación	0.00	2,878.72	0.00	0.00	0.00	0.00	2,878.72	316.86	2,729.97	7,144.48	557.47	9,154.37	4,465.59	1,184.99
Exportación	3,504.33	0.00	0.00	0.00	0.00	0.00	3,504.33	119.58	806.72	153.14	0.00	168.76	60.56	0.00
Variación Inventario	108.67	-395.56	0.00	0.00	0.00	0.00	-286.89	0.00	93.89	106.43	-428.40	-2,260.94	2,899.60	-107.85
OFERTA TOTAL	**571.07**	**2,483.16**	**3,233.94**	**1,522.42**	**37,253.01**	**12,424.03**	**57,487.64**	**197.28**	**2,017.14**	**7,097.78**	**129.07**	**6,724.67**	**7,304.63**	**1,077.14**
Refinerias	-571.07	0.00	0.00	0.00	0.00	0.00	-571.07	0.00	0.00	0.71	4.40	238.11	0.00	0.00
Centrales Eléctricas	0.00	-2,483.16	-3,216.63	-1,522.42	0.00	-8,696.82	-15,919.03	5,262.36	0.00	0.00	0.00	-56.47	-2,771.38	0.00
Autoproductores	0.00	0.00	-17.31	0.00	0.00	-3,727.21	-3,744.52	425.47	0.00	0.00	0.00	0.00	-145.04	0.00
TOTAL TRANSFORMACION	**-571.07**	**-2,483.16**	**-3,233.94**	**-1,522.42**	**0.00**	**-12,424.03**	**-20,234.63**	**5,687.83**	**0.00**	**0.71**	**4.40**	**181.64**	**-2,916.43**	**0.00**

Figure 2. Excerpt tables from EBS for years 2010 (above) and 2011 (below). The differences in format are mainly in typeface and colors. The complete reports can be consulted in [15].

3. Iterate the design and its evaluation creating reports for different years using data from energetic balance sheets.
4. Coordinate with national and international energy agencies in order to incorporate the energy flow diagrams into wider efforts related to energy data management and reporting.

At this point in the project we have advanced up to the iteration of the design and evaluation (point 3) and have started to identify and contact agencies working with energy data (point 4). In the following paragraphs we summarize the actions performed in each of the stages of the project.

4.1 Feasibility Assessment

The first step in the process was to identify a source of energy flow diagrams that could provide models and examples. Several web sites from energy agencies were revised. We found that the EFDs produced by the (Lawrence Livermore National Laboratory – LLNL https://www.llnl.gov/) – were abundant and cover several cases of use of this type of diagrams [13].

Using a Microsoft Excel worksheet to import the data from the EBS corresponding to the year 2010, all the needed figures were calculated and prepared to feed the chart.

In Guatemala the main primary sources of energy reported in the EBS for 2010 [16] are: wood (48.62%), oil and derivates (31.60%), biomass from sugar cane bagasse (10.47%), hydro energy (3.89%), coil (3.23%), and geothermal (2.19%).

Biomass from sugar cane, hydro, coil and geothermal, all of them completely, and a portion of derivates of oil are used to generate electricity. Wood is burned at homes and industry for cooking and heating.

The final uses of energy are distributed in industry, residential, commerce and services, transport, and other minor categories. Energy losses are also included in the EBS but require special calculation.

After several trials and calculations in the Excel worksheet we were able to map the categories in the LLNL EFDs to those reported in Guatemala and to reorganize the classification to account for categories not present in either side. The data was ready for charting.

The aim of this first step was to get results quickly with the tools available without much elaboration. Microsoft PowerPoint was the software at hand that provided the basic diagram elements. The first version of the EFD was ready (see Figure 3).

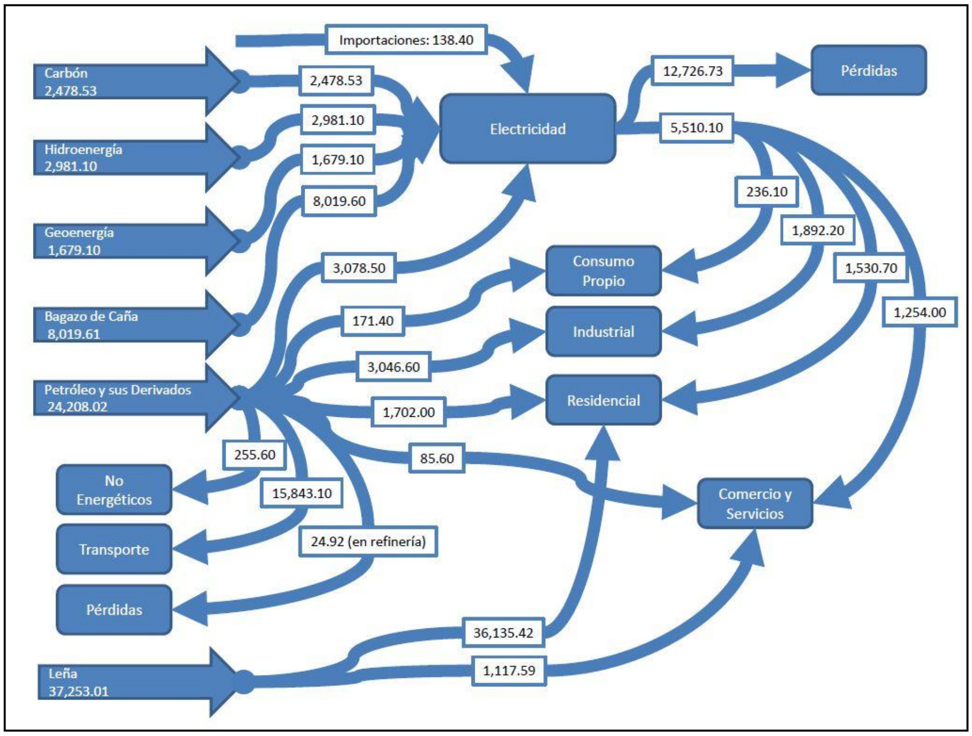

Figure 3. Initial version of the EFD built to verify that enough data was available.

4.2 Evaluation Meetings

In order to validate the design several questions were asked: is the current format of the EBS adequate enough to explain the state of energy in the country? Are people able to explain where the country obtains energy from using the EBS? Where does it use it? How much it transforms before final usage? If an EFD is presented along with an EBS does it help to clarify the information? Is the EFD enough to tell the whole story of energy for the country?

To answer those questions we decided to meet with diverse groups of people with different levels of expertise in the energy field. The data from the EBS would be discussed asking and answering questions about its significance to assess the degree to which attendants could understand it. Their reactions to the data had to be noted and registered. Then the designed EFD would be introduced with a new round of questions and answers to complement the validation.

If the EFD by itself would have been identified by participants as a better tool to deliver the information on energy, then we could proceed to iterate the design to include refinements identified during the meetings or suggested by participants.

Three meetings of this type were held, the first with the staff of the InCyTDe, 6 researchers, 4 of them not involved in this project. The versions of the EFD for the 2010 EBS data were presented in that meeting with interesting results. The clarity and understandability of the data conveyed by the EFD was much better than that of the EBS, according to the comments the participants made. In the portion of the meeting where only the EBS was used several concepts and numbers had to be explained and reviewed back and forth in order to answer questions like what is the main primary energy source for 2010? What is the amount of energy losses in transformation? How is wood used and why is it comparable to oil and derivates?

The feedback from that first meeting was used to refine the design in preparation for the next meeting, which was held at the MEM offices in Guatemala City.

Mr. Felipe Robles, the engineer in charge of statistical data management and energetic markets at MEM, met with us to review the design. We started reviewing how MEM collects and stores information about energy in the country. We were able to see the new web platform being deployed by OLADE to facilitate recording the data and getting reports. When the EFD was shared the result was again satisfactory. In fact it was seen as complementary to the OLADE platform. An important portion of time during that meeting was employed to discuss energy losses and the extent to which the calculated figures were valid. This point was very important because energy losses are not directly reported in the EBS but have to be calculated from differences between output and input energy or consumption and offering. The discussion led us to an important result: sugar cane bagasse amounts and the way they are reported has to be reviewed to establish the real contribution this source was making, or at least make it more clear how that source was being reported.

The third evaluation reunion was held with two energy specialists from the Institute for Agriculture, Natural Resources and Environment – IARNA, (http://www.infoiarna.org.gt/) – of the Rafael Landívar University. An interesting event at this meeting was that one of them told us that precisely when we showed the

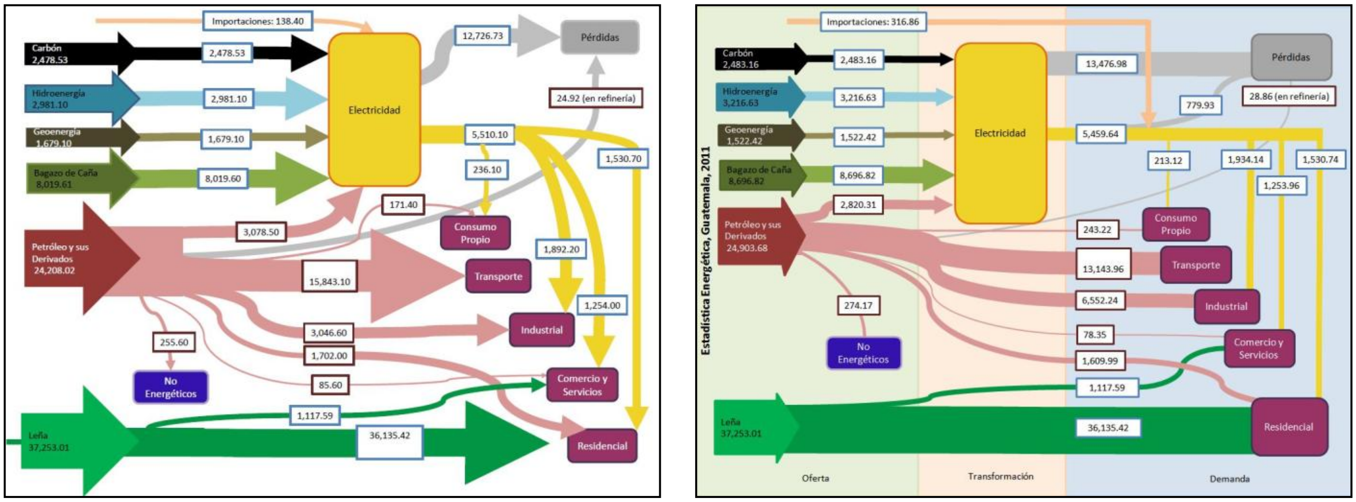

Figure 4. Two stages of design: first version (left), second version (right). Both versions were used during validation meetings and contain the same basic information than the first version (Figure 3). Comments and suggestions were taken into account for each transition.

EBS and one of the EFDs from LLNL, he thought: "I wish we could have something like that for Guatemala". The comment was very revealing for us because, coming from an energy specialist with several years in the field, it confirmed that EFDs did not exist for the country and that they are actually needed.

This last round of evaluation was also very informative to us regarding figures for wood.

According to the specialists there is more accurate data in the reports from other government agencies. Wood use is an important topic of research in Guatemala because it reflects several social problems including access to grid electricity, deforestation, illegal cutting of trees, among others. There are several institutions involved in the study of the problem.

Their suggestion led us to consider the inclusion of data from other sources.

Also, it was pointed out that comparative data between the hydro source and the sugar cane bagasse could be misleading, since the numbers for the latter were much higher than for the former, but the general notion in the country is that hydro provides in fact much more electricity than bagasse.

The difference can be explained when the efficiency of both sources is considered: hydro is much more efficient and in fact responsible for a bigger percentage of the generation of electricity but there was no way to tell that from the EFD as it was at that point.

The topic of energy losses emerged again in this meeting. Because we also presented EFDs from LLNL, the participants asked to compare how they were dealing with losses in their chart. It was suggested that instead of referring to them as "energy losses" the word "rejected energy" used by LLNL could be a better choice.

At the moment of writing this manuscript we have two meetings more planned and pending to be held, using the same methodology. The results of the first three were promising.

4.3 Iteration of Design

The first versions of the EFD were based on the data from the 2010 EBS [16]. During the design iterations the data from 2005 and 2011 was used. This provided the opportunity to experiment with the design, make some corrections, and incorporate suggestions from the evaluation meetings. Also design ideas from EFDs from other countries, [2] and [23], were considered.

The resulting designs were compared and assessed based on the feedback collected from the previous stage. They will be used in the next rounds of validation meetings.

The main changes and variations to try are related to how numeric data is presented, the way in which percentages could be included, the extent to which relative heights of rectangles or the weight of connecting lines has to be exact to correctly transmit the information to the reader, how is it better to show energy loss data, and others.

Colors and shades were also an important redesign issue, not only for aesthetic considerations but because there is a certain association of some colors to particular forms of energy, and that association needs to be taken into account.

From the second iteration of design an effort was made to make more explicit the division of the flow in three stages: generation, transformation, and consumption (see Figure 4). Two options were tried: using different background color for each stage and dividing the stages with lines. The lines option was considered better because the resulting design was cleaner and caused less perception problems; it was also friendlier with people with color blindness (Figure 5).

The plans to further improve the design include the addition of some form of interactivity aimed to users seeing the EFD on line. It could be that for example, when the user hovers the mouse over a certain portion or

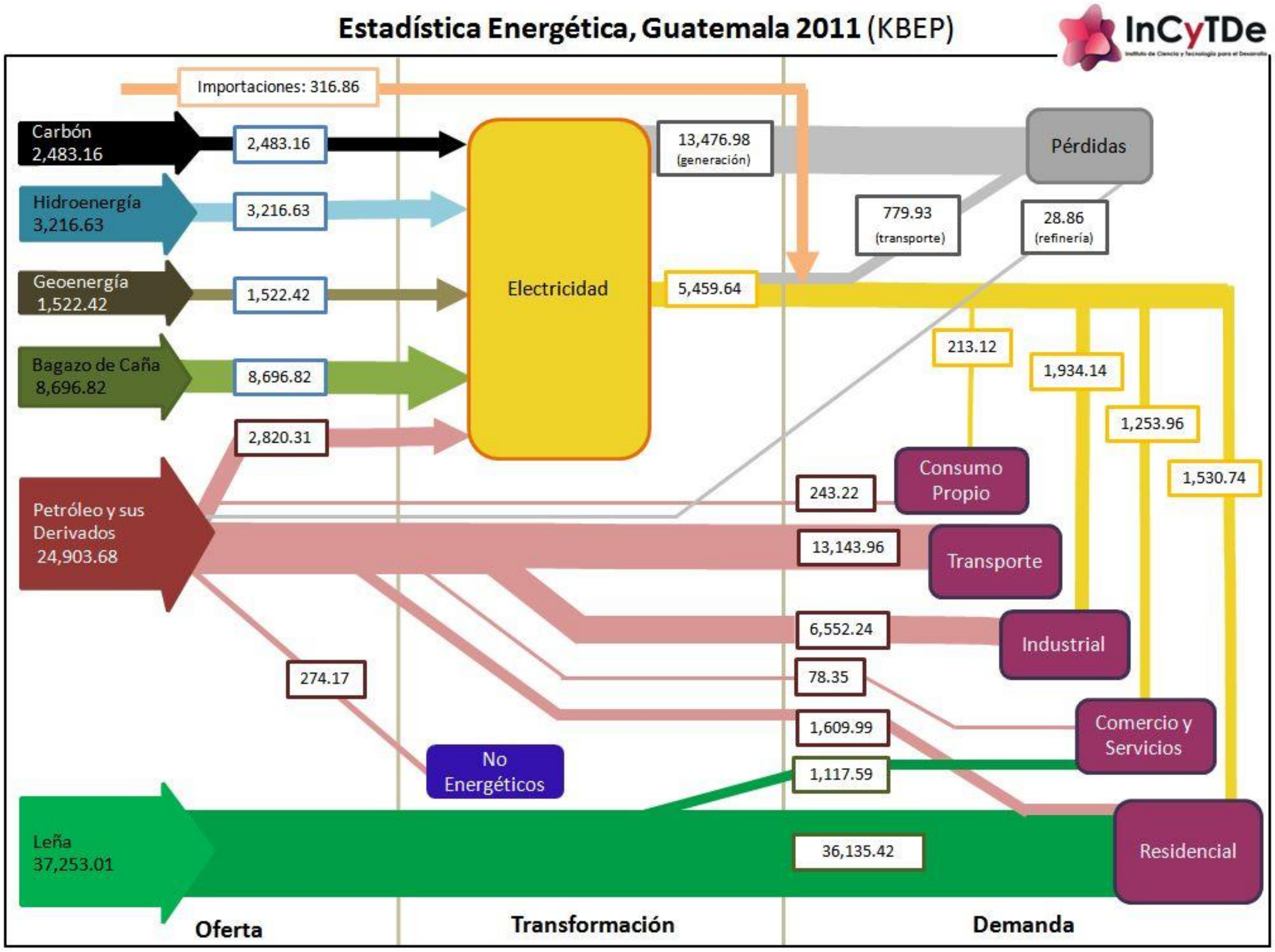

Figure 5. Current working version of the EFD at the moment of writing this manuscript.

number a small window could pop-up with explanations, complementary charts, or links.

4.4 Sharing and Networking

This stage of the project requires the identification of local and foreign energy agencies and organizations, and share with them the design as a work in progress.

Several products have to be prepared for such diffusion: a detailed account of the design process and the design validation, a manual for the preparation of EFD based on EBS, a list of the EFDs available at InCyTDe, on-line in the web site or shareable via email, and others.

Up to now we have identified two important energy agencies that we plan to address: OLADE and its project to provide a data collecting and reporting platform to all of its associates [17], [18], and the Energy Innovation Center – EIC – the energy division of the InterAmerican Development Bank – IDB [9].

The EIC is currently developing applications to automatically create EFDs for countries based on the data they provide.

In both projects, OLADE and EIC, there are important collaboration opportunities that have to be explored.

5. Findings

The whole experience of designing and validating the visualization was full of insights and discoveries. The validation made through meetings with specialists proved to be productive. Several improvements and suggestions were recorded in notes during the process. Here we list the most relevant for the energy field.

5.1 Energy Losses or Rejections

Energy losses are a complicated subject in the reports of any country. They usually account for an important portion of the production and are widely variable depending on energy technology, measurement method, and even reporting requirements. For our country and in this work, it was a constant source of discussions and questioning. For example, in the case of sugar cane bagasse, the losses reported were high, in some cases higher than those of energy produced by oil and derivates or coil. We could only conjecture that such high losses are a product of how the initial energy contents of sugar cane bagasse are calculated.

To standardize report figures in the EBS all energy inputs are converted to Barrels of Oil Equivalent – BOE – which provide a common unit of energy content. That standardization is in fact useful to prepare the EFD. If the conversion is not made properly there is a risk of accounting for more or less energy than there is actually available. We suspect that is the case of sugar cane, but at this stage we have not devised a method to verify that extent.

Similar concerns were found with other sources including wood, which is very important in our country, hydro and geothermal.

Anyhow the subject of energy losses – or rejected energy as is called in some reports – is very sensitive and one thing the EFD does efficiently is show the amounts and where the losses are occurring. The laws of thermodynamic provide explanations of why losses are an inherent part of energy production, transformation and consumption, but it is also inherent and natural for humans to object to any loss.

5.2 Energy Flow Diagram Complexity

EFDs are easier to understand than traditional numerical data sheets even when combined with different types of charts. Their strength as explaining charts derives from their simplicity in presentation.

On the other hand, designing and preparing an effective EFD that provides a coherent and true description of the energy state is not easy and not straightforward. Several trade-offs have to be made by the creator. Exactitude is probably the most common one. Size of boxes and weight of lines, that is supposed to convey information on relative amounts, has to be traded for readability if the exact size or weight would produce an almost invisible element. Colors have to be harmonized, numbers and percentages have to be included in the EFD when images are not enough, elements have to be moved around to make space for relevant information, and so on.

It is very difficult to believe that EFDs can simply be produced automatically and delivered to the public without human edition.

5.3 Convergence of Efforts

During the execution of the project we confirmed several times the need for more accessible information regarding the energy sector. That need is being addressed by several agencies, some at the local realm and some others internationally.

We identified three which are particularly well suited to seek collaboration for this project: the Ministry of Energy – MEM – in Guatemala, the OLADE in Latin America and the EIC, the energy division of the Inter-American Development Bank – IDB.

The MEM is very willing to provide information and staff to participate in our design validation rounds, also it is currently starting the implementation process of a platform developed by OLADE to capture and report energy data. They are planning to produce the next EBS for Guatemala using this new tool. We expect that our design and validation effort can be used as an input to include EFDs in the platform.

EIC at IDB has an ambitious project to provide an information tool to automatically generate EFDs based on data provided by their associated countries. Again, we expect to provide our results to contribute to that project.

5.4 Energy Production and Use in Guatemala

While preparing EFDs it is necessary to examine carefully energy data for the country. As a consequence several insights about energy production, transformation and use that may have gone unnoticed before, become apparent.

In the case of Guatemala the most prominent fact is its high dependency on wood for heating and cooking. Wood is usually reported in other countries as part of biomass fuels together with sugar cane bagasse and similar products. In the case of Guatemala there are important differences between sugar cane and wood. The former is produced and used in a highly industrialized process; it is a sub product in the production of sugar. Wood is basically collected and used in rural areas picked directly by its final consumers with a moderate to high impact on the environment. Sugar cane bagasse is completely destined to electricity production while no wood is used for that purpose. The data provided by the MEM about wood, although official and trustable, has to be contrasted and complemented with that of other agencies to provide a more accurate image of this resource.

Geothermal energy is also a source that needs careful attention. In 2010 it amounted for 2.19% of all energy produced and in 2011 it raised to 2.65%. According to some reports [5], [7], the country has the natural resources to produce up to 1GWe from geothermal sources, which would be enough for all its electrical needs. How the country makes progress towards taking advantage of all that energy potential remains to be seen.

6. Conclusion

In this paper we have discussed our design and validation efforts to create visualizations for the energy data of Guatemala. Preliminary results from this work in progress have been presented.

We have verified that the available data in the country is sufficient to construct visualizations in the Sankey diagrams format, specifically energy flow diagrams or EFD. The technical difficulties and complexity of design and construction of such diagrams have been analyzed along with its power to convey properly the information from the energy sector up to what we have called “the full story of energy”. This capacity has been tested during our project.

A relevant by-product that we have obtained is that the preparation of the EFD along with the in-deep analysis of the energy sector of the country that it requires, has led us to insights and has pointed to research topics in several areas. Again, this result can be deduced from the comprehensiveness with which EFDs permit to analyze energy.

In the near future we plan to continue iterating design and validations rounds until we achieve an EFD that is clear and easy to read for technicians and lay persons.

We have identified several on-going efforts to improve management and reporting of energy data both at the local and at the international ambits. Our plan is to collaborate with those and provide the products of this project as inputs for them.

Acknowledgements

We want to thank the following institutions for the collaboration, suggestions and insights they provided, during the stages of this project: Ministry of Energy and Mines of Guatemala – MEM, Energy and Climate Partnership of the Americas – ECPA, the Institute for Agriculture, Natural Resources and Environment – IARNA, and the Energy Innovation Center – EIC.

References

[1] A. Koberle, Energizar a Guatemala: Propuesta de un Plan de Electricidad Sostenible, International Rivers, Berkeley, CA, 2012.

[2] A. Molina Soto, Balance Energético Nacional 2010. Ministerio de Ambiente, Energía y Telecomunicaciones, Dirección Sectorial de Energía, San José, Costa Rica, 2012.

[3] A.J. Simon, & R.D. Belles, Estimated State-Level Energy Flows in 2008, United States. Lawrence Livermore National Laboratory (LLNL), Livermore, CA, 2011.

[4] C.A. Smith, R.D. Belles, & A.J. Simon, 2007 Estimated International Energy Flows (No. LLNL-TR-473098). Lawrence Livermore National Laboratory (LLNL), Livermore, CA. 2011.

[5] F. Asturias, & C. Grajeda, Geothermal resources and development in Guatemala – Country update. *Proceedings World Geothermal Congress*, Bali, Indonesia, 2010, 7 pp.

[6] F. Garcia, *Manual de Estadísticas Energéticas*, OLADE, 2011.

[7] F.A. Asturias, Status update of geothermal development in Guatemala, Presented at “Short Course on Geothermal Development and Geothermal Wells”, UNU-GTP and LaGeo, Santa Tecla, El Salvador, March 11-17, 2012.

[8] G. Berry, & W. Daily III, Energy Flowchart Scenarios of Future U.S. Energy Use Incorporating Hydrogen Fueled Vehicles. Report from Lawrence Livermore National Laboratory (LLNL), Livermore, CA, 2004.

[9] Inter-American Development Bank, Energy Innovation Center. Retrieved September 4, 2013, from http://www.iadb.org/en/topics/energy/energy-innovation-center,6861.html, 2013.

[10] K. Amoo-Gottfried, & D.O Hall, A biomass energy flow chart for Sierra Leone, *Biomass and Bioenergy*, 16(5), 1999, 361-376.

[11] K. Nuttbohm, L. Fischer, L. Muckenfuss, & S. Baiboks, Visualising sustainability communication with Sankey diagrams–a viable approach?, Environmental Informatics and Industrial Environmental Protection: Concepts, Methods and Tools, Berlin, Germany, 2009, 53-59.

[12] K.A. Senelwa, & D.O. Hall, A biomass energy flow chart for Kenya, *Biomass and Bioenergy*, 4(1), 1993, 35-48.

[13] Lawrence Livermore National Laboratory, Energy Flow. Retrieved September 1, 2013, from https://flowcharts.llnl.gov/, 2012.

[14] M. Schmidt, The Sankey diagram in energy and material flow management, *Journal of Industrial Ecology, 12*(1), 2008, 82-94.

[15] Ministerio de Energía y Minas República de Guatemala, Balances Energéticos. Retrieved September 4, 2013, from http://www.mem.gob.gt/viceministerio-del-area-energetica-2/direccion-general-del-area-energetica/balances-energeticos, 2012.

[16] Ministerio de Energía y Minas, Dirección General de Energía, Informe Balance Energético 2010. Guatemala, 2011.

[17] Organización Latinoamericana de Energía, SIER. Retrieved September 4, 2013, from http://www.olade.org/proyecto/sier, 2013.

[18] Organización Latinoamericana de Energía, Sistema de Información Energética Regional – SIE – Regional. Retrieved September 4, 2013, from http://www.olade.org/proyecto/sie, 2013.

[19] P. Riehmann, M. Hanfler, & B. Froehlich, Interactive sankey diagrams, *IEEE Symposium on in Information Visualization*, Minneapolis, MN, 2005, 233-240.

[20] *Práctica de País en las Estadísticas de Energía* (Viceministerio de Minas y Energía, Paraguay, 2012).

[21] R.E. Scherr, H.G. Close, S.B. McKagan, & S. Vokos, Representing energy. I. Representing a substance ontology for energy. *Physical Review Special Topics-Physics Education Research*, 8(2), 2012.

[22] S.C. Bhattacharyya, *Energy economics: concepts, issues, markets and governance* (London UK: Springer-Verlag London Limited, 2011).

[23] Subsecretaría de Planeación Energética y Desarrollo Tecnológico, Balance Nacional de Energía 2010. México, 2012.