Modeling Energy System Investment Planning Infrastructure for State of Iowa

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List of Definitions

- **NETSCORE21**: The 21st Century National Energy and Transportation Infrastructures Balancing Sustainability, Costs, and Resiliency (NETSCORE-21) research project. The goal of this project is to formulate optimal infrastructure designs in terms of future power generation technologies, energy transport and storage, and hybrid-electric transportation systems, with balance in sustainability, costs, and resiliency.

- **NETPLAN**: Multiobjective optimization software used to model the electric and the transportation system. NETPLAN's goal is to identify future investment decisions for Iowa that most effectively achieve objectives in costs, emissions, and resiliency. The software was developed and used by NETSCORE21 project team.

- **ISU**: Iowa State University.

- **GUI**: Graphical user interface.

- **KML**: Keyhole Markup Language used to show geographic annotation and visualization for use with Google Earth.

- **CSV**: Comma Separated Value file used to store text and numbers in plain textual form that can be read in text editor.

- **MMcf/d**: Million cubic feet per day
Introductory Materials

Project Goal

The electric and transportation systems in Iowa are highly interdependent. A small factor change in the transportation system can have drastic changes in the electric system, and vice versa. For example, if the price of oil increases substantially a demand for electric vehicles will be established. Electric vehicles will increase the load on the power stations, and therefore changes to the existing system will be required.

This relationship forms the basis of our project. We will be showing the interdependence of the two systems as well as the investment planning strategies.

Once Iowa’s base data is collected we will be using the NETPLAN software to analyze various scenarios that could occur over the next forty years. The output of NETPLAN will only be a prediction, but the detail of our base data will increase the accuracy of our predictions.

Once we have successful simulations of our investment planning we will develop an interactive public website to visualize our results. The user will be allowed to view the current infrastructure, using GoogleEarth, and run their own simulations using our base data. We will allow the user to alter certain parameters (such as emissions, costs and demand) and view the changes to the existing system. The results will be displayed in charts and tables which the user will be able to download.

Acknowledgement

Our team would like to thank Dr. McCalley, Venkat Krishnan, and Joseph Slegers for their continuing help and guidance on our project. We would also like to thank Eduardo Ibanez for his input on our NETPLAN simulations, and the rest of the Netscore21 team whose presentations added additional perspective to our project.
System Design

Concept Sketch

The concept sketch will be discussed in three parts. Each on representing a rectangle, starting from left to right.

The first rectangle, labeled website page, represents the user’s interaction of the website. The current infrastructure of the state is shown with Google Earth. The user will have access to a GUI where they will be able to alter parameters of the electric or transportation systems. The middle rectangle, ISU server, will be the execution of the analysis using the change of parameters by the user. Once NETPLAN analyzes the simulation it will convert the results and send them to the website. The rightmost rectangle, website page, will display the results of the NETPLAN simulation and the changes to the infrastructure of Iowa. The output will be displayed using GoogleEarth, charts, and tables. The concept sketch is shown below in figure 1.

![Concept Sketch Diagram](image)

**Figure 1: Concept sketch**

Functional decomposition

The energy consumption primarily occurs in two ways: electric and transportation, as shown in figure 2. In our design we represent the two systems in term of nodes and arcs...
to identify the relation between them. Figure 3 shows the transportation node map for state of Iowa.

![Energy Consumption Diagram](image1)

**Figure 2: Energy Consumption**

![Transportation Node Map](image2)

**Figure 3: Transportation node map**

- **Transportation**
  The transportation system is an extensive network within the state of Iowa. The highway, railroad, and river routes will be combined to form a single interdependent system. Each type will have its own node and arc system. The nodes will represent the parameters such as traffic and cargo demand. The arcs connecting the nodes will represent distances, emissions, traffic flow, etc.
The node and arc systems will be visually represented using GoogleEarth. This data will also be compiled into codes which will be used by NETPLAN to analyze the systems as a whole. Each parameter of the system will be written into its own file to be used by NETPLAN. These files will include:

- Emissions - vehicles, locomotives, and river barges.
- Demands - vehicles, locomotives, barges, cargo.
- General Information - distances, efficiency, cost, maintenance.
- Investment - new technology to replace existing system.

NETPLAN will analyze the transportation system data with respect to the current conditions and change of parameters specified by the user. NETPLAN will be able to predict any upgrades to highways or rails, or the establishment of newer technology, such as electric rail.

The analyzed data from NETPLAN will be displayed on the website where the user can download the predicted investments needed to meet the projected demands.

**Electric**

The electric system contain two network: generation and transmission where we include all of the transmission lines that are above 115kV, power plants that are above 100 MW in capacity and natural gas pipelines with capacity greater than 20 MMcf/d. Each power plant will be a node that gives its capacity, emissions, efficiency, type of plant, etc. Each transmission node will be located at the main intersections between multiple lines. These nodes will be connected with arcs that run between generation nodes and transmission nodes and also running between two transmission nodes. The arcs will show parameters such as distance, efficiency, losses, flow, etc.

These nodes and arcs will be displayed visually through GoogleEarth. This will be sent through NETPLAN using a collection of files that contain a list of all the nodes and arcs with all the parameters that go along with them including:

- Capacity – MW capacity of each power plant
- Type of generator – What the power plants use to generate energy (coal, natural gas, wind, etc.)
- Cost – Shows the cost of a new generator for each type in $/MW of capacity.
- Load – Gives the amount of load for each section
- Emissions – Shows emissions of each generator
- Efficiency – Gives the efficiency of each generator
- Losses – tells the amount of losses between each transmission node
These files will then go through NETPLAN and show the users the predicted output of the grid in 40 years. This will be customizable by the user and tell them if new transmission lines or power plants need to be built. This will all be shown through GoogleEarth and other images on a website.

**System Analysis**

The analysis software we have chosen to use is NETPLAN. This software is being developed at Iowa State University. This software is currently being used by Netscore21, which is creating a highly detailed and national version of our project. Several other programs were presented to us, required our team to determine which software best suited our needs. The three were NETPLAN, CARVER2, TRAGIS, NEMS, and MARKAL/TIMES.

NEMS (National Energy Modeling System) is modeling software which can be used to represent an energy or transportation system. This software is effective in evaluating the systems, but not in identifying policy in the system.

MARKAL/TIMES is an optimization software. This software would be effective in our design if the software could model transportation and transmission. Our project requires the relationship between energy generation/transmission and motorized transportation.

Oak Ridge National Laboratory creates the Tragis software. This software did not allow the user to obtain investment strategies once the data was analyzed. This software was transportation based, but was created in conjunction with the U.S. Department of Energy. This software would be useful to model the current and future systems, but effective enough for our required website.

CARVER2 software would also be highly focused on the transportation system within Iowa. This software was designed for security reasons and will show the effects of certain routes being shut down. An example would be a terrorist attack on a bridge. This software shows the risk involved and the ability of the system to function due to a failure.

The NETPLAN software combines both energy and transportation systems into a single interdependent system which can be analyzed effectively. Using this software we are able to alter any parameter of the system and view how the system will react and what investments need to be made to meet the demand of the new system. Using this software will allow the user to run countless scenarios and create a profile of the best investments over the next forty years. This software does not give exact guidelines to investment planning instead it gives a general result of the best technology to meet the needs of the system. For our purpose, the overall functionality of NETPLAN exceeded the other types of software.
Design Requirements

The design wills only required working computer with internet connection and internet browser. The computer should have at least 800 megahertz (MHz) processor speed and 512 MB of system memory.

Technology platforms/choices

The different technologies that will be used to show the output of NETPLAN are GoogleEarth and Graphical User Interface (GUI). The client and the group that created the software last year chose these. These were chosen because it needs to be accessible and usable to any user on any type of machine. GUI was chosen to show the graphical outputs showing things such as load growth or amount of power generated from each type resource. GoogleEarth was chosen because it can be used on any internet browser and operating system and was well know by the group. This will be used to show how the present and the predicted grid will look.
Detailed Design

System Architecture

The system architecture is shown in figure 4. The data will be presented in KML and CSV file that will be used in NETPLAN. The visualization part will be present it by Google Earth map and chart.

Design Process

Our senior design team will collect data of Iowa’s energy infrastructure and transportation. The data will be represented as points were formatted in Excel spreadsheets. We write software that where data will pass through and produce KML files. Then These KML files will stored on ISU’s server ready to read by the Google
Earth implementation in our project’s website. Transmissions lines will not display as points, but will mapped out with Photoshop and save as KML file on ISU sever as well.

**Figure 5:** KML file use to display energy infrastructure in Google Earth map

**Figure 6:** Manually data input to the server

**Figure 7:** Converted data from the server to the project’s website with Google implementations display.
Website layout

- **Google Earth:** The page will display Google Earth map to visualize existing energy infrastructures in the state of Iowa such as power plants, electric transmission lines, major highways, gas pipelines, …etc. Figure 8 show Google Earth map used by previous year team.

![Figure 8: Google Earth view of energy infrastructure in Iowa](image)

- **Node Maps:** Include all the maps used to evaluate the energy sectors such as transmissions, generations, highways, national gas pipes, and rivers.

- **Energy Molding:** Here the users can choose different investment scenarios and run NETPLAN also where the result will be display it, see figure 9. The selection menu will include:
  - **Load Growth:** Users can choose a percentage that the load will grow each year.
  - **Type of Generation:** Users can choose how the power is generated for example wind, coal, solar, etc.
  - **Emissions:** Users can limit the amount emission produced by the power plants and transportation.
  - **Price:** User can choose the price of gas and electricity.
  - **Investment:** User can add different type of energy source such as power plant and highway.

- **Help:** The page will provide information about using the website and troubleshooting.
- **Feedbacks:** The users can comments and provide other suggestions.

Figure 9: User interface will be used to run NETPLAN

**Design Constraint**

The website will have a limited space that specified by ISU rules, also the website will use ISU server which may create some difficulty in term of firewall and security if it used by internet client. NETPALN is newly developed software and have some limitation that may cause some difficulty when it run form multiple website browsers.

**Testing and Evaluation Plan**

- **Design:** The website will be checked and test from any design errors that could effect the ability of the users to navigate through the website. The design errors include but not limit to links, tabs, formatting and visibility.

- **Technical:** The team will ensure the website will meet all the desirable performance such as loading speed. Since the website will run and display the simulation result of NETPLAN form ISU server it important to be in shortest time as possible (~5 seconds) for the users that have at least internet speed of 1.5 Mbps.
The software NETPLAN should be run from Mac or Windows computer. Otherwise the team will identify any problems could occur when using the website and inform the users by the reason for that error and the solutions using error message or help tab.

- **Users Related:** The website will contain help tab to provide additional information and detailed explanation to the users. There will be error message to explain any invalid input enter it by the users such as but not limit to numbering format.

- **Output Results:** The website will display the result of each input scenario to net plans in at least three formats: table, chart, and map. For all these different scenarios the output results should be accurate and consistent. The team will verify all the results and make sure they all meet the best investment choice and feasibility.

- **Evaluation:** After the initial testing by the team, the advisor and the clients will be asked to provide their evaluation of the website. Then the team will have at least three testing trails group that include professors and graduate students chosen from NETSCORE21 project to provide their feedback. The evaluation criteria will include but not limit to:
  - **Functionality:** Is the website met all the functional requirements like navigation, links… etc.?
  - **Usability:** Is the information provided in the website are useful? Is they are clear?
  - **Completeness:** Is there anything needs to be added? Is there something needs to be removed or need more explaining?
  - **User-Friendliness:** Is the website friendly to use in term of design and formatting.

Also there will be feedback tab has form on the website for any user that would like to provide some comments or suggestion.
Closure Materials

Closing Summary

The final design and the website will be deliver in December 2011 and will be used as part of NETSCORE21 research project. The result of infrastructure investment will play very important rules in the decision making of energy investment for years to come.

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