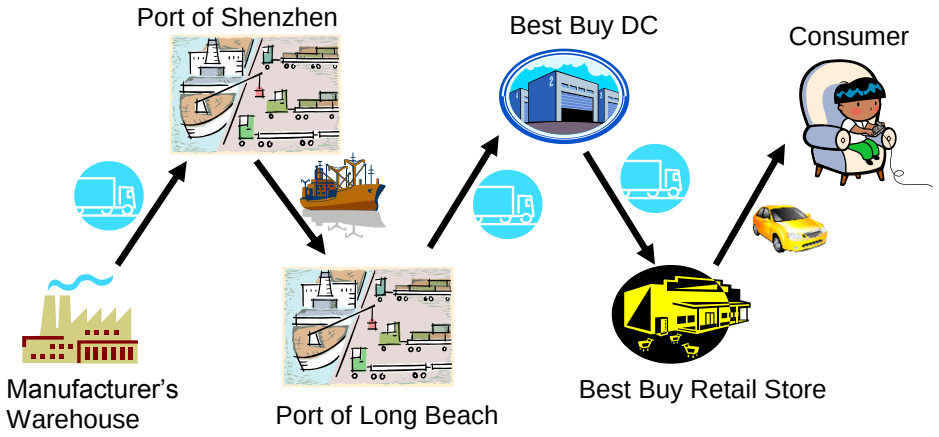
Case: Building a Model to Calculate Energy and CO_2 Emissions

Introduction: We shall use CargoScope to model the distribution of a Wii gaming console purchased for a lucky child in Pacifica, California. We will trace the journey back to the contract manufacturer's warehouse in China, calculating the energy usage and emissions along the way. Before starting to work online, it is useful to first draw the distribution network and state assumptions, especially as CargoScope does not allow for easy editing, such as inserting a forgotten node. The supply chain we consider now is that of the Wii after manufacture. Below is the *push* view of the supply chain.



Although Nintendo is headquartered in Japan, the Wii is assembled by contract manufacturers, as are most consumer electronics. Foxconn is the primary manufacturer, and they have a large factory in Shenzhen,[1] one of the fastest growing cities in China. The distance from the city to Shenzhen Port, CNSZX, is about 20 km. From there, the product will be shipped by large bulk carrier to the Port of Long Beach, USLGB, a distance of 10260 km.[2] The product is then trucked to Chino, one of Best Buy's main distribution centers[3], a small town 80 km inland. From Chino it is sent by truck to the retail store in Colma, 675 km away. The final link is that of the consumer from Pacifica, who we posit makes a special trip to the store 10 km away.

Although supply chains are often depicted as above with the consumer as the last step, we can also look at the network of relationships starting at the consumer's point of view and looking back towards the supplier, a viewpoint more aligned to a *pull* view of the supply chain. In building our model, we will first define the consumer and then define nodes further *upstream*. Other fulfillment paths may possible, such as ordering via an online retailer like Amazon, with home delivery via parcel carrier. But for now, we consider this as our *base case*. We may later make changes to our model to consider alternate scenarios.

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[1] See http://online.wsj.com/public/article/SB118677584137994489.html?mod=blog#articleTabs_comments for more information on Foxconn, which is also known as Han Hoi Precision Industries.

[2] See http://www.searates.com/reference/portdistance/ for ocean-based distances. Overland distances are obtained via Google maps, assuming highway routings.

[3] Company DCs and stores are often found by looking at corporate websites, such as www.bestbuy-jobs.com/

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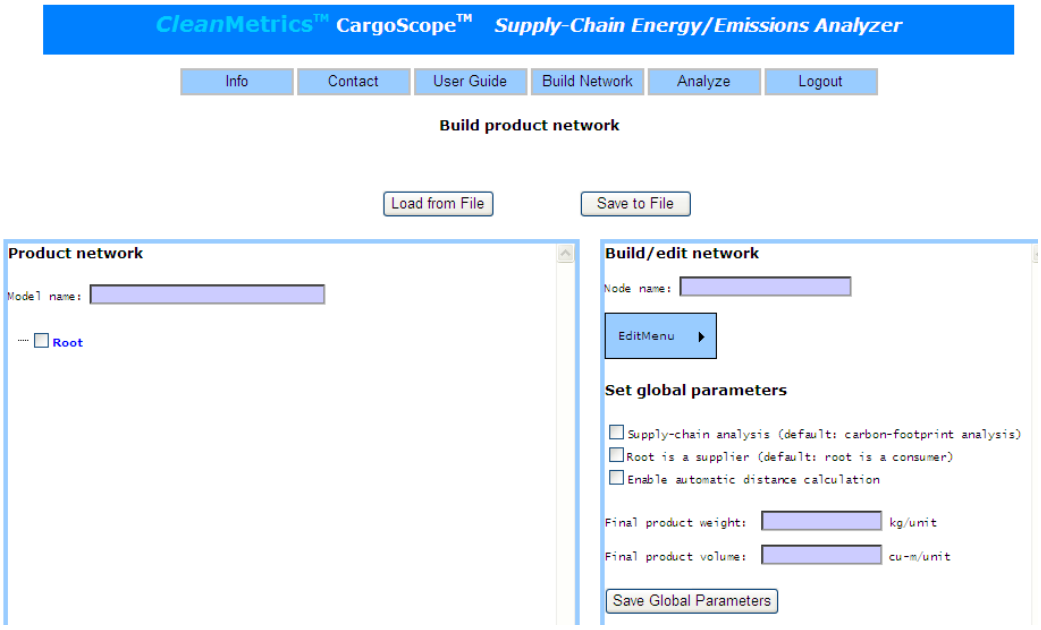
Set-up: CargoScope is an online tool that works with some, but not all, browsers:

- Firefox (any version)
- Internet 7
- Internet 8.0, but we will need to turn on the "Compatibility View" mode, which is usually a button to the right of the URL box.

Go to: http://www.cleanmetrics.net/cargoscope
The username is: CONTACT YOUR INSTRUCTOR FOR THIS
The password this term is: CONTACT YOUR INSTRUCTOR FOR THIS

Figure 1: Initial Loading Screen



Initializing the Model: While it is possible to access and modify existing models with the **Load from File** button, let us create a model from scratch.

- Name the model. At **Model Name** type `Wii to California`
- First, select the **Root** checkbox. Next, in the **Node Name** field type: `Pacifica Consumer.` Lastly, select rename node from the **Edit Menu**
- We will use default values (Carbon Footprint analysis, assigning the root as the consumer, and entering distances manually) so leave these checkboxes blank.
- At this point we define the product weight and volume, as these values will propagate to all subsequent nodes we create. For example, the Wii weights 7.5 lbs and is in a 15"x 10"x 4.5" box. CargoScope only works with metric (SI) units, so we will need to convert any English units; a Wii is 3.402kg and 0.0111 cu-m. As it is a sealed box with secure packaging, we shall assume that there is no extra packaging necessary during shipping. Next, click on the **Save Global Parameters** button. Given we are only considering the movement of a finished, packaged Wii, its weight and volume will remain constant throughout our model. *Caution: Be sure to enter the correct values for weight and volume before adding any nodes. If you make any changes to these parameters later, after other nodes have been set up, the changes will not propagate through the rest of the model automatically*.

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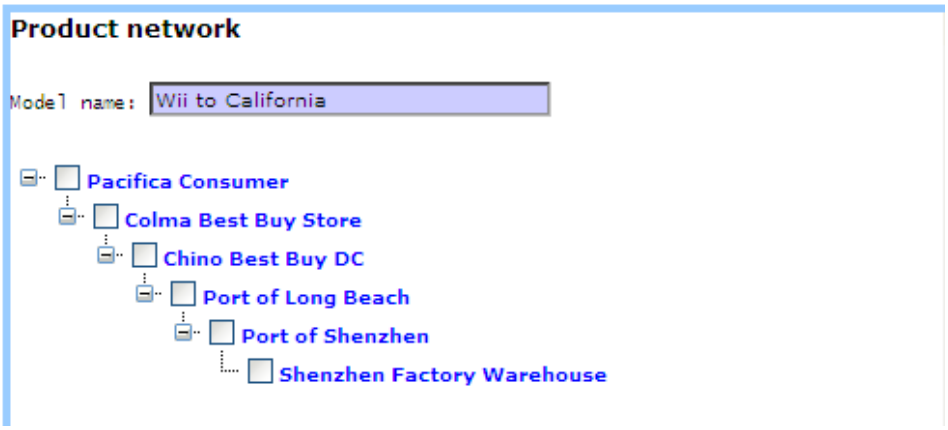
Adding Nodes:

- We add the next node, or "child." To do so, check the newly named root `Pacifica Consumer` on the left side. Next, in the **Node Name** field, type `Colma Best Buy Store` and then select Add Child from the **Edit Menu**
- This node can be further defined, either as a processing or storage node. We consider the emissions associated with transport and storage only, so we will not define any processing nodes for this case. Most energy usage associated with storage is for refrigeration and climate control. For now we assume consumer electronic goods can be stored at ambient temperature. For our base case model, we shall pay no attention to energy usage around storage, and we can thus ignore defining our storage nodes more completely.
- We repeat this process for next node, the Best Buy DC in Chino. After that we define the Port of Long Beach and, then, the Port of Shenzhen. The last node we enter is the factory warehouse at Shenzhen. Figure 2 is a picture of the nodes in our supply chain model. Notice it is a bottom-up, rather than top-down view.
- If you select a wrong node to which to add a child, you will get a different structure. You can fix mistakes by clicking on the misplaced child, and then go to the **Edit Menu**: Cut the child, then, after clicking on the node you would like to place the child under, click Paste. You can move entire "branches" of a network this way, as cutting a node will also cut any children.

Figure 2: The Wii Supply Chain



Defining the Transportation Links:

- A link between two nodes is created by selecting the node further upstream from the consumer. Check the node called `Colma Best Buy Store` on the left and then select Transport Properties from the **Edit Menu**.
- This results in a new window entitled **Set Properties for Transport Link**, as seen in Figure 3. First select the transport mode from the drop down. Many consumer vehicles and vehicle types are listed; for this scenario we pick the Honda Accord. We do not have a perishable product that needs refrigeration and, even if we had, it is a short drive form Colma to Pacifica in a temperate climate, so we can leave the temperature control selection with its default of None.
- Let us consider the distance next. Routing via Google Maps™ shows about a10 km drive from Pacifica to the nearest Best Buy, and this becomes our **Link Distance**. Our academic version of CargoScope has no automatic distance calculation, so the checkbox on the right has no effect.

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- Lastly, we must set our Utilization and Backhaul rates. While CargoScope defaults to 100% for both values, this is overly optimistic here.

  Utilization: If we were purchasing multiple items from Best Buy or other nearby stores, we would be utilizing more of the car's cargo space. However, our base scenario considers a dedicated trip for purchasing one Wii console. CargoScope shows that the Honda Accord has a cargo weight limit of 36.64 kg and a cargo volume of 0.2 cu-m. Given the dimensions and weight of the Wii, we could fit either 18 Wiis by volume or 11 Wiis by weight. Thus we utilize only about 1/11th (9%) of the car's cargo capacity (by weight).

  Backhaul: Non-zero values for backhaul are appropriate only if the other part of the trip is used to transport items. For example, imagine we could pay for our Wii with homegrown vegetables from our garden in Pacifica! Alas, in reality, most dedicated consumer trips to the store have a backhaul rate of 0%, as we are bringing nothing to the retailer that requires our car's cargo space.

Figure 3: Transportation Link between Consumer and Store

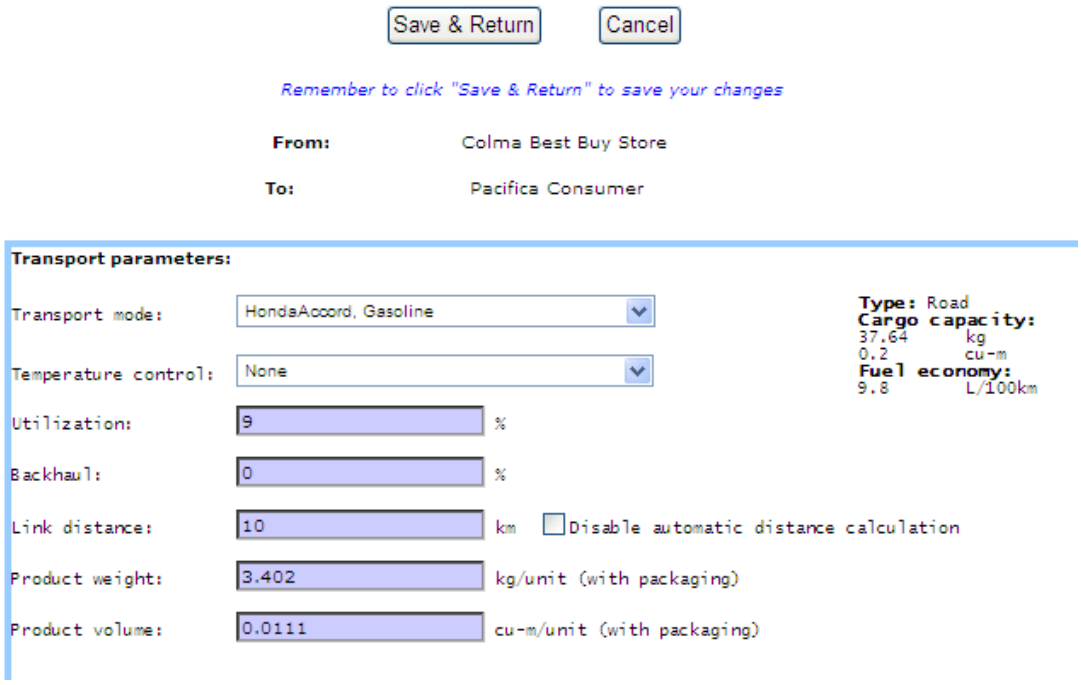

Figure 3 shows what we have entered. We do not overwrite the product weight or volume that was defined earlier. Also notice that metric fuel economy is expressed in Liters/100km (9.8 L/100k = 24 m.p.g.) which is the inverse of how fuel economy is defined in English units. Lastly be sure to push the **Save & Return** button.

We now define the properties for the remaining transportation links.

- The next link is that between Best Buy's store in Colma and the Chino distribution center (DC), 675 km away. We assume Best Buy uses a Midsize Diesel Truck for this route. Given that Best Buy has many stores in the Bay Area and that the trip is long and expensive, it seems reasonable to expect Best Buy will load their truck efficiently, not only with Wiis but also other products stocked by the DC, and they may also use the truck to send returns back to the DC for processing.

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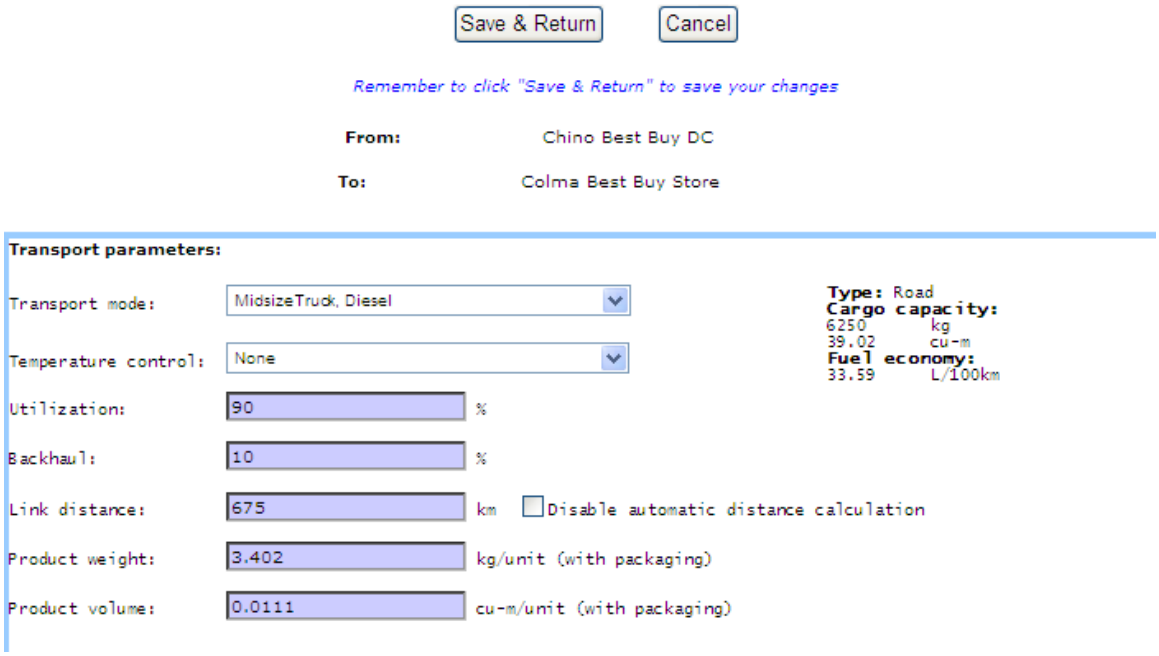
Thus we assume a high (90%) utilization and some (10%) backhaul. We can see this link below in Figure 4:

Figure 4: Transportation Link between the Store and DC

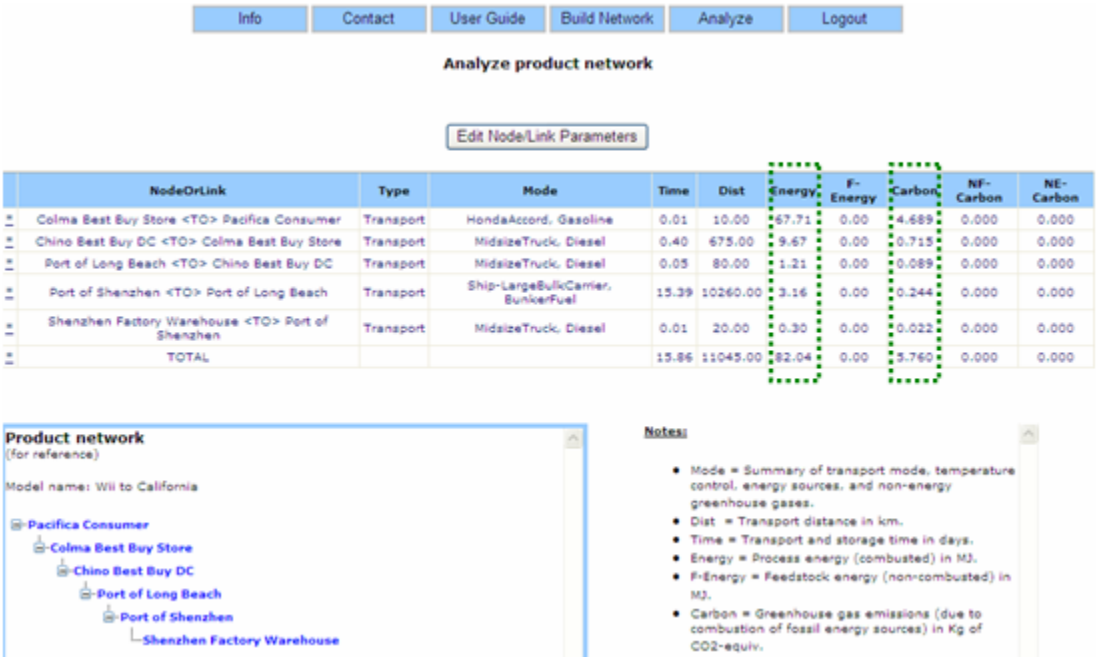


- The next link is the relatively short one from the Port of Long Beach to the Chino DC, 80km away. We assume a similar midsized truck is used and repeat our high (90%) utilization rate. It's unlikely that any product returns to China, so we expect no backhaul on our trip to the port.
- Next, we define the link of 10,260 km between the Port of Long Beach and Port of Shenzhen, via Large Bulk Carrier. While it is likely that Wiis travel by container, pure container ships are not listed as an option in CargoScope. CargoScope does not display fuel economy or capacity figures for ocean, air or rail modes. Also, do not enter in Utilization or Backhaul rates, as CargoScope assumes ocean, air, and rail carriers will be able to fill all available space efficiently on all trips. *Although it appears it is possible to change these values, CargoScope will ignore any inputs for Utilization or Backhaul rates for Ocean, Air, or Rail transport modes. Leave these rates at their default rates of 100% when you select any of these three transport modes.*
- Our final link is a short one, from the Port of Shenzhen back to the factory warehouse, only 20 km away. We continue to assume use of a non-temperature controlled midsized truck, a high (90%) utilization rate, and no (0%) backhaul.

Analysis: We are done with our model definition for now. Before we continue, push the **Save to File** button near the top in Figure 1. *Caution- saving the model every few minutes is always a good idea as CargoScope will not save work remotely. If we navigate away from the website, shut down the browser or just wait too long, we will lose any unsaved work.*

We can always get back to this screen by pushing the **Build Product Network** button at the top. Next to that is the **Analyze** button. Assuming we have followed directions, we should get something that looks like Figure 5, although green boxes have been added to highlight the relevant output columns.

Figure 5: Analysis Results



	NodeOrLink	Type	Mode	Time	Dist	Energy	F-Energy	Carbon	NF-Carbon	NE-Carbon
*	Colma Best Buy Store <TO> Pacifica Consumer	Transport	HondaAccord, Gasoline	0.01	10.00	67.71	0.00	4.689	0.000	0.000
*	Chino Best Buy DC <TO> Colma Best Buy Store	Transport	MidsizeTruck, Diesel	0.40	675.00	9.67	0.00	0.715	0.000	0.000
*	Port of Long Beach <TO> Chino Best Buy DC	Transport	MidsizeTruck, Diesel	0.05	80.00	1.21	0.00	0.089	0.000	0.000
*	Port of Shenzhen <TO> Port of Long Beach	Transport	Ship-LargeBulkCarrier, BunkerFuel	15.39	10260.00	3.16	0.00	0.244	0.000	0.000
*	Shenzhen Factory Warehouse <TO> Port of Shenzhen	Transport	MidsizeTruck, Diesel	0.01	20.00	0.30	0.00	0.022	0.000	0.000
*	TOTAL			15.86	11045.00	82.04	0.00	5.760	0.000	0.000

Each row has a link, with these links appearing in the order they were defined. CargoScope displays the mode and distance, and then estimates time spent in transit for links (or uses our value for storage time for nodes). As we are only looking at logistics (movement and storage) and ignoring manufacturing, the F-energy, NF-Carbon and NE-Carbon columns will be blank and can be ignored. The only output columns of interest to us are the ones boxed in green: the Energy (expressed in Mega Joules) and Carbon emitted (expressed in kg of CO_2 equivalent.) Most of the transit modes burn fossil fuels, so energy usage and carbon emissions will be highly correlated. A final row provides totals for the product. Figure 5 shows CargosScope estimates that transporting a Wii from the manufacture's warehouse to a Pacifica home requires 82 MJ for that Wii, resulting in emissions of 5.76 kg CO_2e.

Notice that the link with the longest distance is not the most energy or carbon-intensive. In fact, over 80% of the energy and emissions result from the short but special purpose trip by the consumer to pick up the Wii from the store. The next biggest component is trucking the Wii between the DC and retail store. Although the distance between China and the US is large, a fully utilized ocean vessel results in very little energy and emissions per Wii.

If we wish to revisit our model more closely, we can select a row by clicking on the * at the very left and then pushing the **Edit Node/Link Parameters** button. For example, we might want explore changing our mode or utilization rates for the DC to store trip. This will take us back to Figure 4. If we make any changes, we need to push the **Save & Return** button to bring us back to the Analyze screen with new results. To save these changes to our model for real, go to **Build Network** and then press the **Save to File** button. Otherwise, such edits will not be saved. If you wish to experiment with making changes to the model (as is suggested by the following exercises) it is advisable to keep a base case file and save your changes to different files.

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Questions

1) How would we change the model if the consumer fully utilizes all cargo space on the trip to the store? What if the consumer has a small hybrid car instead of a Honda Accord? What if the consumer stops at the store on the way to or from work, making a round trip detour of only 2 km (model as a trip distance of 1 km with 0% backhaul)? Which of these variants results in the most emissions reduction?

2) If we were to use a Heavy Diesel Truck instead of a Medium Diesel Truck between the retailer and the DC, but keep all other parameters unchanged, will we save energy and reduce emissions? What if using larger trucks results in a significantly lower utilization rate of 60%? What if utilization drops to 35%? What might be some other supply chain impacts of switching truck size?

3) What would happen if we air-freight the Wii between Shenzhen and Los Angeles instead of sending it by ocean freight? (You may ignore the minor model inaccuracies that occur because airports and ports are not located exactly in the same place), Despite the increased expense and energy usage, when might companies opt to use air-freight instead of shipping cargo by sea?

4) If it turned out that Wiis dwell in the Chino DC for two months, and that DC needs to have temperature control, how might we add this to our model? (Hint: Use the **Edit Menu** to define the Storage Properties for the Chino DC. Then, when taken to the screen that is called **Set properties for storage node** do the following: for **Energy Source** pick US-Pacific, for **temperature control** pick Cooler, for **Volume Capacity** enter 10 cu-m, for **Utilization** enter 100%, and for **Time in Storage** enter 60 days.) *How does this impact our energy usage and emissions?*

Briefly address each of the following questions in your write-up.

A. Are long distance supply chains necessarily more energy intensive than shorter distance ones? What other factors seem to be influential?

B. Do there seem to be any obvious or straightforward ways to reduce transportation energy usage and emissions in this supply chain? If so, who should be responsible?

C. Is it appropriate to include the link between the consumer and the retailer? How much influence does Nintendo, Best Buy or any other firm have over consumers' driving habits?

D. Should we consider a different frame for this model? When might it be appropriate to include manufacturing activities or component and packaging suppliers? What facets of the supply chain do we have more control over than others? How will this help us in determining what to analyze?

E. Imagine that Nintendo is considering putting a carbon label on the Wii. What are some factors they should consider? Does such carbon labeling make sense to you?

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