Refinery to Retail Supply Chain Tracking and Energy Balance Using Big Data Application and Development of Monitoring Framework Using Contemporary Techniques

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Abstract*:As part of the overall supply chain of oil and gas industry, originating right from exploration onshore/offshore all the way upto retail distribution, finding out the energy balance is an important criteria to measure efficiency of the supply chain.Thus far, the effort has been to track the crude transportation to refineries and then the volume of oil distributed to terminals and retail stations from where customers can buy the fuel and lube products. However this distribution approach ignores an important aspect of energy balance which can track the efficiencies and losses at every stage. It must be noted that the supply chain is not merely about transporting crude but also about the native energy is properly distributed with minimum loss. Even a pilferage or adulteration could be a loss in the overall supply chain as there is a loss of energy in such cases. In today's energy starved world, it is important to track energy balance throughout the supply chain and identify vulnerabilities. Previously it was not possible to track and monitor the energy getting explored all the way upto consumption points. This paper is an attempt to develop a framework for creating a mass and energy balance of Fuel Value chain from refinery all the way up to consumption point such as vehicle, furnaces and other consuming points using contemporary techniques such as Big Data Solution, Super Clusters, GIS and mobility application.*

Index Terms: Big Data, Downstream, Distribution, Fuel, Oil, Refinery,

1. Introduction:

It is well known that the conventional energy made up of fossil fuel has a finite supply. The known energy reserves are adequate to fulfil the energy demand of the world for about 59.2 years[2]. The day is not far when the entire mankind would be closely monitoring the consumption of hydrocarbon based energy source, at least till such time we do not have any credible alternatives or availability of unconventional source of energy.

The depletion of hydro-carbon based fossil fuels and increased cost of oil exploration and crude prices have already put significant strain on the overall economy of India. Almost 80% of India's oil demands are met through imports [1] which results in shrinking India's Foreign Exchange reserves which in effect impacts the exchange rate of Indian Rupee with US Dollar. We have seen that the cost of petrol, diesel and other products are determined based on market conditions and have gone up considerably over last few years.

We have recently seen that the government policy of having LPG Gas cylinders rationed with quota based supplies at subsidised rates, where government agencies refund the discounted amount for the fixed numbers of LPG cylinders per annum. Any additional LPG Cylinder over and above the yearly quota costs considerably more at market rates. Going by the same logic, it is inevitable that we will have a situation where in distribution of petrol and diesel will be controlled by the government and some kind of 'rationing" will be enforced as we have seen in case of LPG Cylinders. The consumption of energy in terms of usage of fossil fuel is increasing day by day.

While the crude production in India is likely to be relatively flat while the imports are likely to go up significantly by almost 22.3 % [3]. This is likely to impact India's foreign exchange reserves, exchange rate, inflation and overall economy at large. Obviously such drastic impact is not sustainable and is likely to invite controls which are hereto not being administered.

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It is also widely known that the currently available techniques do not track and measure the losses in the energy at various different points within supply chain; there is still no readily available framework to track the energy supply chain, from source to the consumption point (end point) yet. It is also a fact that unlike electrical energy, fuel distribution is measured based on litres, gallons etc. and not based on the unit of energy and the paper attempts a totally different paradigm for fuel energy distribution, monitoring and control.

The supply chain spans right from oil exploration all the way up to consumption passes through several different stages. This paper attempts to develop a "Big Data" architecture for tracking refinery products despatches and its consumption so that we are able to have a proper "Energy Balance" that can be tracked and controlled with a larger objective of bringing in regulatory compliances for elimination of wastes of any and all forms. The concept is also to track the entire supply chain including distribution points, track losses and compute useful consumption of energy content of refinery products so that we are able to develop a correlation between "Energy Content of products" in refineryvs. what gets converted into useful work.

Big data systems are known to handle data which has got characteristics of high volume, velocity and variety [5]. The Big data system use enterprise hadoop data structure for its database and is known to support enormous volumes (petabytes).

Some of the likely benefits of developing such a framework is the ability to enforce consumption compliance right up to the end use of the Oil is as below:

- Controlled distribution of FO, LSHS etc. for the production needs of industries and administration of consumption
- Ability to enforce a fixed quantity of fuel per vehicle, on the same lines as distribution of LPG cylinders
- Ability to administer Fixed quantity of fuel per vehicle at regulated prices and balance at an increased prices, similar to the mechanism adapted for LPG Gas Cylinders
- Efficiency linked allocation of fuel quota, less efficient the vehicle/Equipment/Process, more would be the price of fuel to discourage use of inefficient vehicles/equipment's/process

It is important to note that some countries have already resorted to measures such as minimum occupancy norms per vehicleat a particular time band or restrictive mobility (For e.g. odd/even numbered vehicles not allowed on particular days of the week).

2. Technology framework for Fuel Energy Moderation:

The supply chain of Fuel Oil begins at oil exploration either onshore of offshore and extends all the way up to consumption point where energy gets consumed. The intermediate stages through which the product moves including operations as below:

- Crude Exploration(onshore or offshore)
- Crude Transportation pipelines, barges, tankers
- Refinery operations
- Oil Terminal systems
- Depot operations
- Finished product transportation through pipelines, Integrated Railway Wagons and tankers to retail stations, customers, industrial and other consumers
- Retail station to individual vehicles/cars/Automobiles

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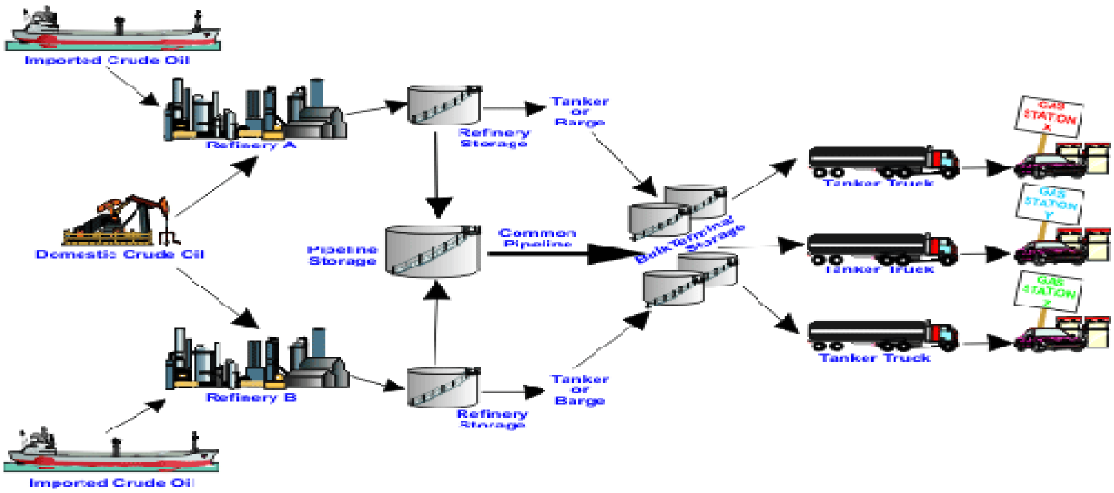
At a high level these phases are described in the below Figure1 below.



(Figure 1: Supply Chain of Oil and Gas products – Exploration to Retail)

In order to track the supply chain as well as to identify points of losses of energy, it if first necessary to identify the products produced in the Refineries. The following Table1 gives the products produced in refineries and usage of that product from commercial perspective. As can be seen from the table below, while there are many products getting produced in refineries, there are a few that contribute most from energy perspective. This does not mean that the products having low calorific value or low on energy content do not impact energy balance significantly, and in fact they do to a certain extent, what is more relevant from today's energy starved world is to come out with a proper track of how this vital energy is getting consumed or getting converted into useful work at the point of actual consumption.

Working out an accurate map of energy balance is not easy and would have situations where Energy is getting distributed (distribution of a tanker in to a retail station or multiple stations) or consolidated (Multiple tankers or supplies getting into one aircraft refuelling station). This in a situation of "many to many", "one to many", "many to one" etc. from the supply and turn creates consumption standpoint.

(Table 1) MAJOR END USE OF PETROLEUM PRODUCTS (Refinery output)			
Products	**Major End Use**	**Energy Value and Impact on balance**	**Considered for Energy balance of Fuel Value Chain**
LPG	Domestic fuel. Also for Industrial application where technobically essential. Now permitted as auto fuel.	**High**	**No**
NAPTHA / NGL	Feedstock/fuel for Fertilizer Units, feedstock for petro-chemical sector and fuel for Power Plants.	**Low**	**No**
MS (Petrol)	Fuel for passenger cars, taxies, two & three wheelers.	**High**	**Yes**
ATF	Fuel for aircrafts.	**High**	**Yes**
SKO (Kerosene)	Fuel for cooking & lighting.	**High**	**Yes**
HSD (Diesel)	Fuel for transport sector (Railways/ Road), Agriculture (tractors pump sets, threshers, etc.) and Captive power generation.	**High**	**Yes**
LDO	Fuel for agricultural pump sets, small industrial units, start up fuel for power generation.	**High**	**No**
FO/LSHS	Secondary fuel for Thermal Power Plants, Fuel/feedstock for fertilizer plants, industrial units.	**High**	**No**
BITUMEN	Surfacing of roads.	**Low**	**No**
LUBES	Lubrication for automotive and industrial applications.	**Medium**	**No**
Other Minor Products (Benzens, Toluene, MTO, LABFS, CBFS,Paraffin Wax etc.	Feedstock for value added products.	**Low**	**No**

2.1Energy Balance principles:

The energy balance basically can be computed by matching the supplies with consumption (useful work) plus the losses encountered at various stages. It is apparent that during every stage, there are losses occurring in the supply chain.The downstream product transportation is distributed to storage and further transported to depots and service station, either through pipeline, tankers, barges or IRD's. These losses are of various types such as leakages, process wastes, pilferage, evaporation etc. As per the known statistics the losses from source of Oil to retail distribution point at gas station is of the order of approx. 0.3 to 1% *[4]*.While the losses of this nature result in to environmental issues, they also result in to loss of energy in the overall supply chain.

In order to compute the energy supply chain, following equation is to be noted:

Crude Input in refinery = ∑ (Fuel Oil Products) + Byproducts such as NGL/Butane + Losses

This paper is an attempt to track the useful Fuel Oil product balance and tracking how much of the energy gets converted into useful work. In effect, this is an attempt to find out wastages within supply chain and creating a balanced energy system.

The Fuel Oil products relevant from the point of view of energy balance are:

- Petrol (MS)
- Diesel (HSD)
- Furnace Oil (FO/LSHS)
- LDO
- Kerosene (SKO)
- Aircraft Fuel/Jet Fuel (ATF)

The energy balance would be a simple summation of energy content from all the above products being distributed to the consumers. The energy balance could be described as below:

$$\text{Energy Content of product in Storage tanks} = \sum_{k=0}^{n} (Useful\ work + losses\ during\ transportation\ and\ loading + wastages)$$

While the computation and framework need to be developed for all the types of fuel oil stated above, this paper emphasizes energy balance of petrol (MS). The basis of the same and a big data solution for continuous analysis of energy balance is stated in following section:

2.1.1 Supply Chain Balance through useful work:

The framework proposes computing the consumptions at every retail point and create a network of all vehicles and track their consumption on continuous basis.

The energy and mass balance will be:

Refinery Storage (Millions of Gallons)= ∑ of {Volume dispensed to tankers + Transported through other channels such as pipelines + Leakages + Temperature and density correction}

Fuel in each tanker ={Fuel dispensed at each gas station + Leakages + Temperature and density correction}

The data analysis can further be done as below:

Fuel received at each gas station = {Fuel dispensed for each vehicle + Leakage + Temperature and density correction}

The framework proposed can track and help in analysing energy balance as below:

Consumption in each vehicle = Fuel filled up periodically over a period of time (Daily / weekly)

This also can be computed by

Total energy through fuel filled per vehicle= {Useful energy utilization for displacement (to be tracked through GIS) + inefficiencies of the engine + Temperature and density correction}

Similar consumption figures will be tracked for every consumer of energy (every vehicle).

Useful work needs to be computed based on the productive use due to burning of fuel oil. This is a factor of weight, speed, efficiency of the automobile engines. As we track the consumption of fuel oil by each vehicle which gets replenished from retail station as on when the tank level recedes.

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2.1.2 Losses:

There are multiple types of losses encountered during loading, unloading and transportation of fuel oil [9]. The losses are:

- Emission Losses (Loading losses, Ballasting losses, Refuelling losses)
  - Breathing, working and standing storage losses

These losses are subject to several factors and there are scientific ways of finding out how much would be the losses during loading etc. S One such formula to be noted is [10]:

$$L_L = 12.46 \frac{SPM}{T}\left(1 - \frac{eff}{100}\right)$$

where:

S = saturation factor
P = true vapour pressure of gasoline
M = molecular weight of gasoline vapours
T = temperature of gasoline
eff = overall reduction efficiency

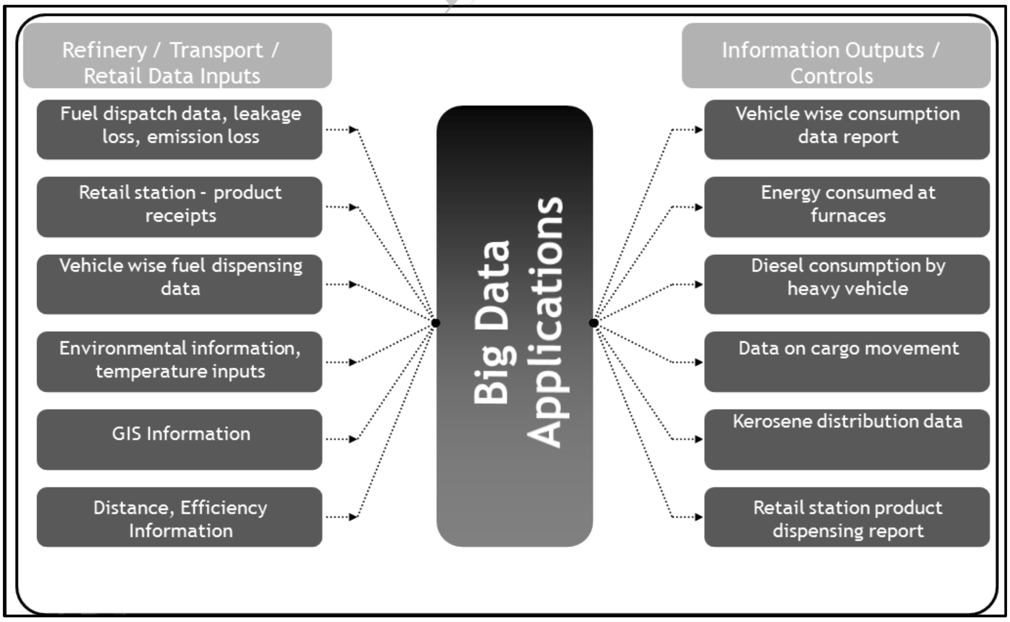
2.1.3 Wastage:

Wastages is on account of operational inefficiencies and largely difficult to measure. There are however assessed based on certain historical data and empirical values. The wastages will be on account of Pilferages, Seepages through the tanks and spillage etc.

Normally the gap between actual receivedquantities minus the shipped quantity is considered to be on account of wastages. Of course part of it is due to losses as described in 2.1.2 above.

3 Big Data Architecture:

The approach proposed is to capture various forms of data right from refinery output and shipments and track it to either retail station or the factories or units where the fuel will be consumed. The big data application will get information from every vehicle, truck and equipment through a use of RFID chip based vehicle tracking GIS system for petrol, diesel etc while for other fuel applications, data can be collected from the equipment's directly [6]. Once we have the availability of such information, it will be easy to generate intelligence of various types of reports such as vehicle wise consumption, wastage at retail stations, loss of energy at various points. This will as explained earlier will help in bringing out a sound regulatory and compliance framework for efficiently conserving the scarce energy in years to come. The big data system will have following information elements as detailed in Figure 2 below.



(Figure 2: Big Data System with Input/Output elements)

The broad approach will basically include the following:

- Data about crude production, calorific values along with density and temperature information is captured

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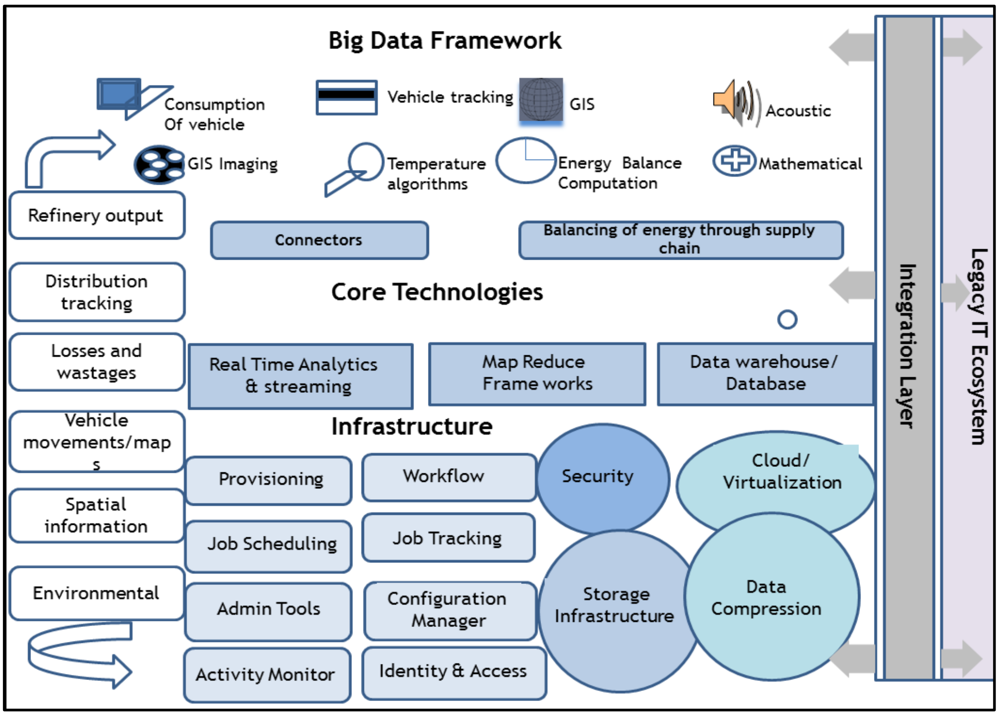
and balanced against the supplies to refineries wastages will be identified.

- The input to the refinery would then be tracked with respect to distillation process and yield derived from the process carried out. The energy of the fuel thus created will be balanced with crude supplies refinery has received
- The output/supplies from refinery will be tracked and each consumption point stored in a big data system. This will include transportation details such as tankers, pipelines as well as corrections due to temperature
- The retail gas stations will also be subjected to energy balance with information tracked for consumption per vehicle or consumption point [8]. This will become essential as without such tracking it will be difficult to track where the energy is getting consumed.
- Each vehicle level consumption and relative efficiencies will then be tracked. This system using GIS technology is already widely available
- This will also be done for all other consuming points such as:
    - Ships
    - Airlines
    - Furnaces/heating points
    - Any other industrial consumers of energy

Such system will be need of the hour as eventually we all need to control the consumption points of the fuel. The big data architecture will enable us to analyse the data in multiple ways and help in managing our energy needs significantly better. The systems involved in managing such complex architecture are:

- Back end Enterprise Resource Planning
- Process control computers and integration will PLC/DCS/SCADA
- Big Data Servers with Hadoop based data structure
- Business Rule engines
- MR Framework
- Data Warehouse and analytics
- Integration architecture
- Integration with environmental data such as temperature

Figure 3 below depicts the overall framework of using Big Data architecture. There are several large hardware vendors such as Oracle [11] who provide systems capable of providing such functionality.



(Figure 3: Big Data system capturing information from various sources)

The Big Data System gives the ability

- To handle the large volume of data
- Track productive use of energy at end point as we will be able to capture useful work
- Data analytics framework which will be able to give adequate information of where is the energy getting consumed and where it is getting wasted
- Ability to identify points of wastage
- Track inefficient equipment's resulting in wastages
- Help in creating a regulatory framework

4 Conclusion:

Energy is precious and will get scarce. The oil and gas industry will eventually have to track energy consumption right at the point where it is getting used. This paper has presented an architecture by which not only can such data elements be tracked but a near accurate energy and mass balance can be created for a retail oil and gas supply chain. The architecture is validated with the existing applications which leverage similar architecture.

The energy and mass balance will also help track all such points which make the supply chain inefficient and identify vulnerabilities from the point of view of losses. The system is capable of capturing data using unstructured sources such as temperature by locations etc.

5 Next Steps:

The research steps would now be elaborating the architecture and demonstrate how the overall framework would result in to gaining significant intelligence. Research will also include developing an energy balanced equations and identify points of wastage and losses. The integrated architecture of GIS, ERP, BI and Big Data system will be developed to demonstrate operationalization of this framework.

References:

1] *Ministry of Petroleum and Natural Gas, Report of the working group on Petroleum & Natural Gas sector for the IX Plan (2007 -2012)*

2] *BP Statistical Review of World Energy, June 2013*

3] *Indian Petroleum & Natural Gas Statistis -2012-13, Govt of India, Ministry of Petroleum and Natural Gas, Economic Division, New Delhi*

4] *Research Paper by Sartorius K, Eitzen C, Hart J on Examination of the Variables Influencing the Fuel Retail Industry, University of the Witwatersrand, Johannesburg, South Africa*

5] *Gartner Report on Big Data solution 2012*

6] *IBM Big data solutions, white paper no XII, 2013*

7] *Supply Chain For Liquids, Out of the box approaches to liquid logistics, Wally Klatch,*

8] *Sun Microsystem e-Gas station framework*

9] *Gasoline Distribution Industry (stage 1) – Background Information from promulgated standards, EPA – 453/R-94, 002b, US Environmental Protection agency, Research Triangle Park, NC – 1995*

10] *Gasoline Evaporative losses from retail gasoline outlets across Canada, 2009, Catalog No 16-001-M, NO 15 ISSN 1917-9693*

11] *In Memory Computing applications – Exalytics server architecture Oracle Corporation*

12] *Enterprise Hadoop: The Emerging Core of Big Data, James Kobielus, Connie Moore, Brian Hopkins and Shannon Coyne*

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