Fourth RGI Future Scenario Exchange Workshop
February 6, 2018, Brussels

Brief of studies and protocol

This document provides:

- Attendee list and agenda.
- A brief of the studies presented.
  - Elia - “Electricity scenarios for Belgium towards 2050”
  - Tom Brown - Frankfurt Institute for Advanced Studies (FIAS) “Modelling Paris: Scenarios for the electricity grid, heating and transport in Europe with 95% carbon dioxide emission reductions”.
- The main insights and comments.
- Conclusions and next steps.

1. Attendees

Name	Organisation
Thomas Rzepczyk	Amprion
Thomas Vanhauwaert	COGEN
Roland Joebstyl	EEB
Ciarán Rabbitt	EirGrid
Igor Lefebvre	Elia
Rafael Feito-Kiczak	Elia
Dante Powell	ENTSO-E
Jean-Baptise Paquel	ENTSO-E
Tom Brown	FIAS
Jérome Partos	FNE
Eva Schmid	Germanwatch
Jan Vande-Putte	Greenpeace
Matthew Wittenstein	IEA
Helena Schweter	Innogy
Jesús Mendiola	REE
Andrew Carryer	RGI
Antina Sander	RGI
Antonella Battaglini	RGI

Alice Collier	RSPB/Birdlife
Laetitia Passot	RTE
Vivien Molinengo	RTE
Marius Strecker	TenneT
Alberto Ponti	Terna
Wided Medjroubi	DLR-Institut
Thomas Köbinger	50Hertz

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2. Morning session: Elia - *"Electricity scenarios for Belgium towards 2050"*

2.1 Background and purpose of the study

The study presented builds upon the 2016 report on 'The need for adequacy and flexibility in the Belgian electricity system for 2017-2027'. The purpose was to provide a solid basis for the choices that Belgian authorities will make for the development of the electricity sector in the coming years.

2.2 Overview of scenarios[1]

Scenarios were calculated for 2030 and 2040, with an additional focus of ensuring security of supply in the short term.

"Electricity scenarios for Belgium towards 2050" Scenarios

1. **'Base Case' scenario (BC)** – scenario that is in line with the current policy for reaching the 2030 European climate targets, involving the electrification of sectors such as heating and transport
2. **'Decentral' scenario (DEC)** – base-case scenario plus, inter alia, additional renewable energy generation via decentralised sources, such as a large number of photovoltaic installations (up to 11.6 GW in 2030 and 18 GW in 2040) in combination with storage devices (from 3 GW in 2030 to 5 GW in 2040; including stationary and EV batteries and pumped storage) and in which prosumers (consumers that also produce) play a prominent role.
3. **Large Scale RES scenario (RES)** – base-case scenario plus, inter alia, additional renewable energy generation via large-scale projects which are mainly in onshore and offshore wind power (up to 4 GW of offshore wind in 2030 and 8 GW in 2040)

[1] For a summary of the scenarios and sensitivities framework, please see page 63 of the study.

Additional sensitivities considered (selected):

European Level:

- Grid + = Additional EU interconnectors assumed.
- Flex + = High flexibility across Europe assumed (demand-side management (DSM), Storage).

Merit order: (fuel and CO2 costs based on two different "IEA World Energy Outlook 2016 scenarios", shifts the merit order between coal and gas – both options evaluated for each scenario)

- C2G – Coal-before-gas merit order (based on IEA "New Policies" scenario)
- G2C – Gas-before-coal merit order (based on IEA "450" scenario)

A more detailed brief of the core assumptions is made in Annex 1 of this document.

2.3 Conclusions of the study

- The future Belgian electricity mix will mainly be composed by RES and thermal capacity, while further increasing cross-border exchanges.
- The European electricity mix will be mainly composed of RES, gas and nuclear in 2040. Decrease in coal and nuclear will be compensated by RES and gas.
- With the increase of renewable intermittent energy sources in the European electricity mix, the amount of cross border energy exchanges will increase (assuming same cross border capacity level).
- After the nuclear phase out, there will be a significant need for additional thermal capacity in the different scenarios for Belgium.
- At European level, keeping same adequacy level in all countries between scenarios leads to a decrease in need for thermal generation capacity in scenarios with more RES, flexibility and interconnections.
- Mature storage technologies and demand flexibility will contribute to the adequacy of the system but will not eliminate the need for thermal generation capacity as they cannot provide a solution for long periods without wind and sun.
- Under the current market design while keeping prices roughly convergent with neighbouring countries, the study shows that the wholesale market will not remunerate the full costs of the necessary investments. Additional measures to ensure new capacity investments will be necessary.
- Additional interconnections are a must and must be anticipated in due time.
- The wholesale market price is key. An increase of the market price due to a CO2 and fossil fuel price increase (at EU level) will imply that the costs of needed investments, both in renewable and thermal capacity, will be increasingly covered, with less recourse to support mechanisms.

2.4 Insights and comments (morning session)

2.4.1 Questions on the cohesiveness of the scenario storylines

It was considered that, while the "Decentral" Scenario is driven by the growth in prosumers and high sector electrification (largely technical considerations), the "Large Scale RES" scenario is said to be driven by the politically based considerations of "global climate policies and European Cooperation". It was questioned as to whether such an approach provides a cohesive and comparable set of scenarios. The Elia response was that this is how ENTSO-E separated its scenarios and that the scenarios taken for this study were based on this approach.

2.4.2 Biomass not considered relevant in Belgian context, with CCS (Carbon Capture Storage) not considered for largely economic reasons

It was proposed that biomass should be considered more favourably in the scenario storylines, as the technology has the potential to make up for some of the expected shortfall in thermal generation. Elia responded that the potential for Biomass within Belgium is very-low (due to geographic considerations), and that importing Biomass is not environmentally sustainable. The point was also made by other participants that Biomass generally is not environmentally positive, with some environmental organisations being explicitly opposed. Elia assumes around 1 GW of biomass in all the scenarios (Belgium having a peak load of 13-14 GW).

It was asked as to whether Carbon Capture Storage (CCS) technology was included, as a way to provide “lower carbon” thermal generation capacity. Elia decided, like ENTSO-E, that CCS technology is not at a stage to be considered economically viable and hence did not include it in the study.

2.4.3 Justifying the large assumed efficiency gains

It is assumed in the study that *total* energy consumed in Belgium (also including fossil fuel use for heating and transport etc.) decreases, but that more of this final total is electric. This means more electricity will have to be generated. Such a required rise in electricity demand is moderated by improved energy efficiency measures, including: behavioural changes, increased awareness, new technologies and improved building efficiency. It was questioned as to whether these assumptions are not overly optimistic and that, in reality, efficiency measures such as those listed will not be able to moderate demand to the extent that is assumed by the study.

It was stated by Elia that they only have the tools to make relatively accurate short-term predictions about demand and that tools for longer term demand forecasting need to be improved as a priority.

2.4.4 Peak loads

It was asked to what extent the peak loads vary between scenarios. The answer was that peak loads vary little in the 2030 scenarios (~14GW) and range between 14-16GW in the 2040 scenarios, with Decentral scenario showing the highest peak. Detailed figures can be found in the report.

2.4.5 The inclusion of climate change impacts on weather modelling

It was asked if climate change impacts were considered in the study, primarily in terms of the weather data modelling that was done. The answer was that potential climate change impacts were not included, as the model worked using 34 past climate years. It was also commented that the impact of climate change within the timeframe may not be significant and is highly unpredictable and difficult to account for in the models.

2.4.6 Immediate need for action to make up the thermal generation shortfall

Elia re-stressed the predicted shortfall in thermal generation capacity. The results show a shortfall in thermal capacity of approximately 3.6GW in *new* thermal generation in Base Case by 2030. Shortfalls are also experienced in the other two main scenarios. New market designs will likely be needed to encourage investments in thermal capacity (capacity mechanism) as the wholesale market prices will not properly remunerate investments. The tech that maybe be the most appropriate for filling this gap is CCGT gas fired plants.

3. Afternoon session: How to develop and model a Paris Agreement (PA) compliant scenario.

3.1 Presentation by Dante Powell, ENTSO-e

3.1.1 TYNDP process update

It was explained that the storylines for the TYNDP 2020 are currently being designed, and that the consultation will be ongoing throughout the year. For the 2020 version of the TYNDP, the scenario construction has been made independent of the modelling and turned into a standalone piece of work. This has been done to give the scenario design teams flexibility to consult a more diverse range of stakeholders. In terms of current scenarios for the 2018 TYNDP, the “Global Climate Action” scenario would be the nearest in ambition on CO2 reduction to a Paris Agreement compliant scenario.

3.1.2 Priority topics to be addressed regarding a Paris Agreement (PA)-compliant scenario

The below were presented by ENTSO-e as “open questions” which need to be addressed if we are to successfully design a PA-compliant scenario:

System operability – a PA-compliant scenario would have very high levels of RES. What does this mean for system services (reactive power support, frequency stability, reserves and response etc.)? What would this mean for the European market design?

RES share of demand – What share of RES would we need in the system to be PA-compliant? In the current “Global Climate Action” Scenario, 77% share of demand is covered by RES. Is this enough?

Electricity Demand – What would demand be in the future? There is currently a clear need to improve our demand forecasting tools. Understanding the efficiency rates and impacts of heat pumps, domestic EV's etc. And the potential role DSR could play in reducing peaks.

Carbon tax – It needs to be understood what the requirements of a carbon tax are. Would there be a set budget for Electricity and Gas? And if so, how is this carbon budget ceiling reached with regards to investment decisions? Would this be through some form of investment modelling?

Sector coupling – Assumptions on sector electrification and coupling are taken from the IEA's WEO. Are these sufficient? How do we better understand the behaviour and interactions of this technology with the system and the market?

Installed capacities and generation mix – What will we need in-terms of thermal capacity? Can gas play a bridging role? Etc.

3.1.3 Open question to the group

The presentation closed with the desire of ENTSO-e to receive more feedback and input on potential scenarios for the TYNDP 2020, and for the whole TYNDP process in general. Some of these open questions included:

- Are the time frames still appropriate (2025, 2030, 2040)?
- Should we widen the scope of possible futures?
- Should we have a "behind the targets" scenario?
- Should we start from a blank slate completely?
- Taking the electricity gas interlinked model to the next step?
- Open ENTSO-e's scenarios to more external references?

3.2 Presentation by Tom Brown, FIAS

Tom Brown from the Frankfurt Institute for Advanced Studies (FIAS) presented "Modelling Paris: Scenarios for the electricity grid, heating and transport in Europe with 95% carbon dioxide emission reductions". This presentation was based on a paper of which he was the lead author: "Synergies of sector coupling and transmission extension in a cost-optimised, highly renewable European energy system"

3.2.1 Study approach

The study used a simplified network with one node per country, calculating the cost optimal system for a 95% reduction in carbon dioxide emissions compared to 1990, **incorporating electricity, transport and heat demand**. The study used the first open, hourly, country-resolved, sector-coupled investment model of the European energy system to derive its results.

3.2.2 Defining a carbon budget

A carbon "budget" of 48 Gt of CO2 from 2015 until 2050 was defined for Europe (the EU28). This was calculated by assuming that a global 600 Gt CO2 global "peak" carbon budget exists, and if emissions are kept under this ceiling, it provides a 33% chance of limiting warming to 1.5C. It is assumed that the EU28 would receive 8% of this global 600Gt budget.

3.2.3 Determining the optimum grid for the electricity sector only

Initially, a model of the European HV grid with 256 clusters with both AC and DC interconnection was used to model the electricity sector only. Simulations were run on this model under a set of fixed boundary conditions:

- Reduce CO2 by 95% compared to 1990.
- Generation: Where potentials allow (no Natura 2000/Urban areas etc.), including onshore and offshore wind, solar, hydroelectricity, backup from natural gas.
- Storage: batteries for short term, electrolyse hydrogen gas for long term.

An n-1 factor was included, with a 70% grid capacity cap (no dynamic line rating assumed). Also, no DSM was assumed for these simulations, only stationary flexibility.

Scenario 1: No grid expansion beyond today – *Result:* Relies very heavily on storage to balance the variability with very high costs. Battery storage in the South is paired with hydrogen in the North for longer term seasonal variations.

Scenario 2: Grid Expansion allowed – *Result*: When grid expansion is allowed, a reduction in the need for battery storage is seen, with large increases in transmission capacity for northern Europe. This increase largely runs east-west to connect the growth in both onshore and offshore wind capacity in this region.

When grid expansion is allowed, in terms of costs, a big non-linear cost reduction is seen. This means that most cost reduction happens with the first 25% grid expansion compared to today's grid (such a 25% expansion corresponds to the TYNDP). Total costs are considered comparable to today's system (around €200 billion/a). Investment in batteries decrease significantly as the grid expanded; with a cost-optimal grid system dominated by wind.

3.2.4 Assumed electrification of sectors

Electricity, heating and land transport account for approximately 77% of CO2 emissions in 2015. In order to reach a 95% reduction in CO2 emissions these sectors also need to become largely decarbonised. The study therefore looked at ways to model a dynamic relationship between sectors, by harnessing the demand-side management potential from battery electric vehicles, power-to-gas units and long-term thermal energy storage to provide flexibility to the system

The study modelled the above types of demand and transport/heating flexibility in separate successive scenarios with a one node per country model (necessary to reduce the number of nodes due to increasing complexity of including heating and transport). By adding such flexibility in stages, it was seen as possible to understand how each flexibility option impacts and interacts with the system. In each of these flexibility scenarios, flexibility from sector coupling was weighed against grid expansion measures.

3.2.5 Conclusions

- Meeting Paris targets is much more urgent than widely recognised
- There are lots of cost-effective solutions thanks to falling price of renewables. Total costs are not that different form a business as usual scenario.

- Electrification of other energy sectors like heating and transport is important, since wind and solar will dominate low-carbon primary energy provision
- Solution for Europe: grid + wind in North, decentral solar + storage in South
- Grid helps to make CO2 reduction easier = cheaper - we're far from over-building grid
- Cross-sectoral approaches are important to reduce CO2 emissions and for flexibility
- Policy prerequisites:
    - A high, increasing and transparent price for CO2 pollution
    - Smaller bidding zones to manage grid congestion better
- The energy system is complex and contains some uncertainty (e.g. cost developments, scalability of power-to-gas, consumer behaviour), so openness is critical.

3.3 Insights and comments (afternoon session)

3.3.1 "Chicken and egg" problem regarding technology assumptions.

The point was made that certain technologies are not considered to be at an advanced enough stage to be considered in the TYNDP and other modelling exercises. And that, to be considered, the technology needs to "prove itself" on a scale which often seems arbitrary. This causes a "chicken and egg problem" in that, if you do not consider early stage technologies, it makes it more unlikely that a system for the future can be designed to properly accommodate these technology options, therefore making the inclusion of this technology into planning even more unlikely. Some participants believe that more "non-mature" technologies should be included.[2]

The response from ENTSO-e was that they are deliberately uncoupling the scenario development process from the modelling in order to provide more flexibility, so suggestions on what tech to include and how would be very interesting to hear. But there is a problem with data when dealing with such technology, ENTSO-e are trying to open up and are all ears to suggestions, but if they do not have (even vague) numbers (on costs etc.) for the technology, it is very hard to include.

3.3.2 The issue (or "second order issue") of Inertia

In relation to the "Modelling Paris" work, it was questioned as to whether such a system dominated by wind and solar would provide the inertia the system needs to maintain frequency and power system stability. This was considered by Tom Brown to be largely a "second order issue". Many technology options exist (such as synchronous condensers/frequency response from invertors) which can be used to provide the needed inertia. In a related point, the potential for an "inertia target" was raised.

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[2] For reference, the Danish Energy Database has good data on sector coupling tech https://ens.dk/en/our-services/projections-and-models/technology-data

3.3.3 Assumed deployment of heat pumps limited by efficiencies and costs

Points were raised relating to the assumed number of heat pumps in the "Modelling Paris" study. Air source heat pumps in particular use a lot of electricity in cold temperatures, if electricity prices are high, then take-up of this technology by consumers will be more limited. It was commented that this cost issue would be compounded by poor insulation of older buildings where relying on heat pumps alone would be prohibitively expensive. The TSOs present stressed the potential of hybrid heat pumps (i.e. a heat pump in combination with a fossil-fuelled boiler for cold spells). Tom noted that these types of hybrid system were included in the model.

It should also be noted that heat pumps were only one technology type for heating used in the model. Others included gas boilers, resistive heaters, solar thermal, short-term TES and district heating (Northern Europe).

3.3.4 Inclusion of more aggressive energy efficiency savings

Several NGOs present stressed that more aggressive efficiency savings should be considered in the modelling, i.e. houses insulated even beyond the economic optimum, to reduce the overall demand for energy and hence renewable generators and other infrastructure. Tom said this is possible to model, just that it requires good datasets describing building stocks in each European country, which are not currently available

3.3.5 Further opening up the TYNDP 2020 scenario process

It was restressed throughout the discussions that ENTSO-e is working hard to further open up the scenario development process to a wider group of stakeholders. Studies and work that can add value, especially in understanding how to build a Paris compliant scenario, would be appreciated.

3.3.6 The need for openness of process, models and input data

Energy modelling is uncertain, there are therefore significant benefits from open discussions and learning from one another. Openness is key as it increases transparency and credibility, reduces wasteful double-work and improves overall quality.

4. Next steps

- The RGI secretariat is trying to find resources which allow the NGO community to make a strong contribution with regards to developing a Paris Agreement-compliant scenario for the TYNDP.
- All present were encouraged to get in touch with the ENTSO-e team if they have new resources, studies, data that they wish to share.
- A "Fifth scenario exchange workshop" will likely be held in the summer (date TBC). If participants have any interesting studies that they would like to share at this workshop, get in touch with RGI.

Annex 1:
Elia study: Assumptions, methodology and results overview

4.1 Assumptions (selected)

It was assumed that there will be a reduction in total energy consumed thanks to energy efficiency measures, but that electricity, largely provided by RES, will grow as a percentage share of this reduced consumption. This shift is seen as necessary if European CO2 reduction targets are going to be met by 2050 (a required >93% decrease in the in CO2 from the electricity sector by 2050).

4.1.1 Domestic

Electricity consumption

Demand growth was based on: **economic growth, energy efficiency, thermo-sensitivity and electric vehicle/heat pump penetration.**

The highest increase in demand is seen in the "Decentral" scenario with an increase to 97.6TWh in 2040 (up from 85.6TWh today). Lowest growth is seen in the "Base Case", rising to 90.2TWh by 2040. In terms of peak load for 2040, given a higher spread in electrification assumptions (both in heat pumps and electric vehicles), a difference of 1GW on average between the scenarios is seen.

Demand response

The potential of load shedding (reducing demand due to prices) and shifting (demand that can be moved to another time in the day) were taken into account and were based on price signals taken from the market model. **Demand response that is contracted for ancillary service was not modelled.**

Load shedding volumes:

- 0.6GW current volume, rising to 0.8GW short term to 2020.
- 2030: 2GW Decentral, 1.1GW Base Case and Large-Scale RES.
- 2040: Unchanged from 2030, except for Large Scale RES which rises to 1.3GW.

Load shifting volumes:

Assumed that all additional electrification is eligible for demand shifting and is optimised to minimise costs of operation to the system. Largest rise in demand shifting volumes from the three core scenarios (given for a day in winter) was from the "Decentral" scenario at 6GWh/day in 2040. Significantly less forecast for the other two scenarios. For the '**FLEX+**' scenario, **it was assumed that 50% of the electric vehicles and heat pumps can be optimised**. This results in 31GWh/day for Belgium in 2040.

Renewables Grid Initiative

Renewable generation

Assumptions were informed by a number of Belgian studies, considering **technical, spatial, public acceptance and metrological constraints**.

A maximum potential of <62GW was assumed for Belgium, if all rooftops had solar, if all available (non-restricted) space is taken by wind generation, both offshore and onshore. Below are the assumptions for the main tech types for 2040 only:
Onshore wind: *2400MW capacity in 2020*

- Base Case: 4200MW (90MW/Year increase)
- Decentral: 5900MW (170MW/Year increase
- Large Scale RES: 8400MW (300MW//Year increase)

Offshore wind: *2300MW capacity in 2021*

Growth considered flat to 2025, looking at current project pipeline. Growth continues to remain flat in Base Case and Decentral scenarios to 2030. With the below capacities reached in 2040:

- Base Case: 4000MW
- Decentral: 5000MW
- Large scale RES: 8000MW

Solar: *3500MW capacity in 2017*

- Base Case: 6000MW (100MW/Year increase)
- Decentral: 18000MW (600MW/Year increase)
- Large scale RES: 10000MW (300MW/Year increase)

Storage

The study considered pumped-storage units, stand-alone (static) batteries and electric vehicles' (vehicle to grid). **No seasonal storage such as 'Power-to-X' were considered for the studied time horizons**. This being so, such technology was nonetheless considered as potentially important in the long term. For static and vehicle to grid, no/limited growth seen to 2030 in BC and RES scenarios respectively. Largest growth seen in DEC to 1.8GW (from a current base of 0MW). For 2040, 3.6GW assumed for DEC, with more limited growth for the other two core scenarios. **The FLEX+ scenario assumed 10.5GW in 2040 for battery capacity, again similar to demand response, a higher percentage of EVs are assumed to be active in optimising the system (50% as opposed to 10% for DEC).** For assumed behavioural characteristics of batteries (both static and vehicle to grid) see page 43 of the study.

Thermal Generation

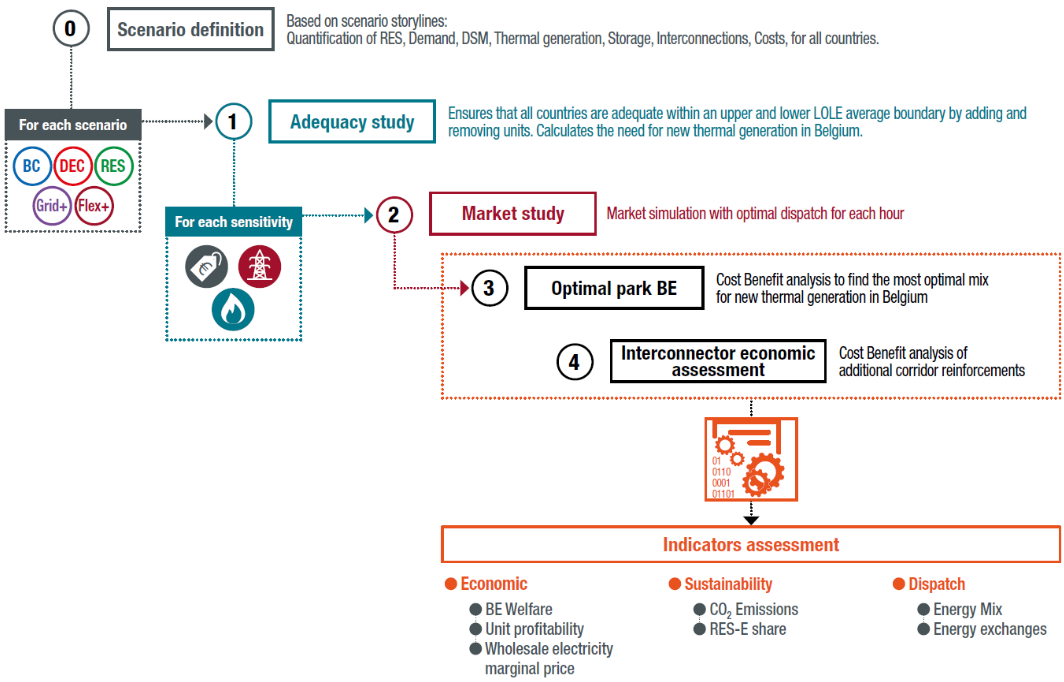
Nuclear: **Nuclear is phased out from 5.9GW to zero by 2025** in all scenarios. An additional sensitivity of a 10 year 2GW extension of some nuclear capacity was looked at.
Gas: Gas phased our incrementally from 3.8GW to 2.3GW in 2030, to 0GW in 2040. Based on 25year lifetime assumption.

4.1.2 Europe

Twenty-two countries were modelled in detail (named 'EU22') **clustered in eight regions**. **The data was sourced from the TYNDP2018 scenarios, national studies, Wind Europe data, and the e-Highways study**.[3]

The possible commercial exchanges between countries are modelled with 'Net Transfer Capacities' (NTC) rather than flow based. These values correspond to fixed maximum commercial exchange capacities for cross-border exchanges between two countries, with these values representing a best forecast. **The European GRID+ sensitivity was an additional scenario based on the "Large Scale RES" and provides for additional cross border capacity.**

4.2 Methodology overview



Source: Elia: "*Electricity scenarios for Belgium towards 2050*" Page 65

[3] For full European assumptions see Pg. 47-53.