The year is fast drawing to a close and here we are at the last edition of WattsUp for 2019.

Numerous key events have taken place in SB and MESI as a whole in the last quarter. On 22 August 2019, Jimah East Power (JEP) Unit 1 successfully achieved its Commercial Operation Date (COD). The 1,000MW ultra-supercritical coal power plant has boosted the Peninsular Malaysia’s generation capacity to 25,032MW. Meanwhile, JEP Unit 2 is on track to achieve its COD in December 2019. Strategically located close to the central area, both plants are crucial in reinforcing the security of Peninsular Malaysia’s power supply.

NEDA achieved another important milestone on 19 September 2019 as it welcomed the third participant, Perusahaan Sadur Timah Malaysia (PERSTIMA) into the market as a Price Taker. SB hopes that more players will be keen to participate in NEDA following the enhancement initiatives announced in the recent NEDA Enhancement Workshop, based on the outcome of the NEDA Viability Study. The past two months have seen SB in active engagement with prospective players and stakeholders to brief and clarify on the NEDA mechanism moving forward.

In line with the recently announced MESI 2.0 reform initiatives, SB is committed to continuously support MESTECC and ST through the transformation journey towards a more efficient, competitive and green power sector.

Finally, I would like to take this opportunity to wish all of our Indian colleagues a Happy Deepavali. May this festival of light pave the way for more great achievements in the MESI.

Charanjit Singh Gill
Chief Executive Officer
Single Buyer
PERSTIMA is a tinplate manufacturer in Pasir Gudang, Johor.

With a 22kV connection to the distribution network, PERSTIMA’s co-generation plant is registered to produce a maximum of 3.6MW of Export Capacity under NEDA.

In conjunction with the completion of PERSTIMA’s registration process, SB was requested to conduct a refresher training on the Market Participant Interface (MPI) and One Stop Settlement Centre (OSSC) at their premise in Pasir Gudang on 18 September 2019. The training ended with a hand-over ceremony of the Firm Participation Notice, as well as the MPI and OSSC token by SB to PERSTIMA.

SB would like to thank PERSTIMA for their support and we look forward to their active participation in NEDA.
12 July 2019, Bangsar | A meeting was held to explore the possibility of GMEA’s planned co-generation plant to sell its excess capacity to NEDA as a Price Taker in the next few years’ horizon.

29 July 2019, Kemaman | This was the second meeting after the first engagement session conducted in January 2018. The new management of OOSB has revived the company’s initial interest to participate in NEDA as a Price Taker. As such, a briefing session on NEDA was conducted for the new management.

9 August 2019, Bangsar | Solar Pack is a Spanish company that is specialised in solar PV development projects in Malaysia and Vietnam. The company is participating in the LSS3 Bidding Programme and is keen to participate in NEDA under the Large Scale Solar category should it win the LSS3 bid.

16 August 2019, Bangsar | BSL Eco Energy is one of Malaysia’s solar PV solution providers. The company is looking at the prospect of installing roof top solar PV for its factory and participate in NEDA under the Price Taker category.

13 September 2019, Bangsar | A meeting was held with Eastern Steel, which is considering to participate in NEDA in view of the commissioning of its co-generation plant in October 2019.

23 September 2019, Bangsar | This was the second meeting following the first meeting held in May 2019. The consortium is exploring the possibility to participate in NEDA as a Price Taker.

24 September 2019, Bangsar | A meeting was held to discuss the potential opportunities specifically for solar and storage solutions to participate in NEDA.

30 September 2019, Bangsar | A discussion between YB Rajiv (a Board member of SEDA), SB, ST and MESTECC was held on the prospect of solar plants without PPA and with capacity less than 30 MW to participate in NEDA. Under the current arrangement, this type of plants can readily participate in NEDA under the Price Taker category.
The total utilisation of KWIE for the period (July 2017—December 2019) to cushion the ICPT implementation is RM 2.7 billion.

**Breakdown of Total Utilisation by Period (RM billion)**

<table>
<thead>
<tr>
<th>Period</th>
<th>Utilisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jul-Dec 2017</td>
<td>1.3</td>
</tr>
<tr>
<td>Jan-Jun 2018</td>
<td>0.9</td>
</tr>
<tr>
<td>Jul-Dec 2018</td>
<td>0.1</td>
</tr>
<tr>
<td>Jan-Jun 2019</td>
<td>0.3</td>
</tr>
<tr>
<td>Jul-Dec 2019</td>
<td>0.1</td>
</tr>
</tbody>
</table>

**GOVERNANCE**

1. Kumpulan Wang Industri Elektrik (KWIE) is a fund set up by the Government under the Electricity Supply Act 1990.
2. KWIE is administered by ST.

**INDUSTRY REGULATORY FRAMEWORK**

In this issue, we look into KWIE, which is one of the elements in the ICPT exercise.

**PURPOSE**

1. Accumulate savings from the electricity supply industry
2. Manage the impact of electricity tariff to end users e.g. utilisation of the fund for Imbalance Cost Pass Through (ICPT) implementation

**SINGLE BUYER RING-FENCING**

This Guideline will be featured in several upcoming issues. Let’s start with an overview of the document.

**Definition**

- A guideline issued by ST in exercise of the power conferred by Section 50C of the Electricity Supply Act 1990 [Act 447].
- Malaysia adopts a Single Buyer Market model in managing its electricity supply industry. An entity called Single Buyer is entrusted to manage the procurement of electricity and related services in Peninsular Malaysia.

**When was it registered?**

18 April 2018

**Purpose**

Governs the operation of the Single Buyer Market which sets out:

- the roles, functions of the Single Buyer (and other Single Buyer Market Participants) and the detailed procedures and conducts in performing each function.
- the ring-fencing requirements to ensure that the Single Buyer performs its functions and duties in a fair and non-discriminatory manner in managing the contracts or agreements for the purchase of electricity on behalf of the off-taker.

**General Contents**

- Annex 1 — Single Buyer Market Rules (Applicability of Annex 1– All participants in the Single Buyer Market in Peninsular Malaysia only)
Thermal Engineering Software used to **design & simulate** Combined Cycle Gas Turbines (CCGT), Co-Generation plants, conventional steam plants, renewable energy plants and other thermal systems.

Capable of producing power plant heat balance design, simulation and preliminary engineering and financial outlook for the plant.

Worldwide usage currently includes over 2,150 companies at over 1,250 sites in 75 countries.

**Programs / Functions**

- **GT PRO / GT MASTER**: Design program for CCGT and Co-Generation plants.
- **STEAM PRO / STEAM MASTER**: Automates the process of designing a conventional steam power plant.
- **PEACE**: Plant engineering and construction estimator.
- **THERMOFLEX**: Modular program with a graphical interface that allows user to assemble a model from icons.

**Applications in Single Buyer**

Currently **THERMOFLOW** is being used by Capacity Planning Unit, System Planning and Technical Advisory & Industry Development.

**THERMOFLOW** is used to design & extract information such as investment cost, heat rates and operational data of a power plant with the latest technology. These inputs are crucial for long term generation planning especially in determining new capacity requirement in the system.
Inertia is defined as resistance to change. In a grid system, the rotating machines' mass produces inertia for the electricity grid. When there is change of power, the frequency changes, but inertia slows this change. The differences between consumption and production appear smaller and the rate of frequency change becomes slower when the inertia is high. Revolution in the power sector is driving a rapid change towards a Renewable Energy (RE) future. The fast developing exploitation of RE resources have raised concerns on decrease of grid inertia due to the fact that they do not have rotating mass. When inertia decreases, sudden changes in frequency caused by a change in electricity consumption or production are faster and enormous. Energy storage system has the capability to reduce the effect of decreasing grid inertia when combined together with solar. To make it more fail-safe, dual fuel engine is integrated into the combination, leading to greater efficiencies while addressing intermittencies. How Do They Operate?

### Day
- Excess energy to grid
- Gas/diesel engine ramping up during battery discharge

### Night
- Ramp up
- To grid
- Excess energy to battery

The fast developing exploitation of RE resources have raised concerns on decrease of grid inertia due to the fact that they do not have rotating mass. When inertia decreases, sudden changes in frequency caused by a change in electricity consumption or production are faster and enormous. Energy storage system has the capability to reduce the effect of decreasing grid inertia when combined together with solar. To make it more fail-safe, dual fuel engine is integrated into the combination, leading to greater efficiencies while addressing intermittencies.
Ramp rate control
From the utility in the wholesale market to the residential end-customer, everyone wants a stable supply of energy. Energy storage with ramp rate control is the way to achieve stability with growing solar penetration in the grid, while protecting solar inverters from excessive wear and tear.

Energy time shifting
Daily peak energy consumption is affected by demand growth, energy efficiency, temperature and other factors. Energy storage helps bridge the gap between daily production and consumption. While gas/diesel engine optimises performance to provide a fast response when called upon.

Operational flexibility
Fast starts to full load leads to wider starting and stopping (gas/diesel engine acts like a back-up to battery) with no impact on maintenance.

Fuel flexibility
The operation of the dual fuel engine using gaseous or liquid fuels including biofuels improves fuel security by continuous choice of the most feasible fuel.

Energy efficiency
High plant efficiency over a wide load range due to flexibility of operation.
9-10 July 2019 & 16-17 July 2019  SB recently organised a workshop on Risk Awareness with the objective to provide participants with the general understanding on risk management. To ensure the effectiveness of the workshop, the workshop was conducted in two sessions. Representatives from Risk Management Department were invited as the speaker and facilitators for the workshop.

17 July 2019  A visit to Maju Intan Biomass Power Plant by a group of SB staff from various units has allowed them to gain valuable insights into the generation of electricity from Empty Fruit Bunch (EFB), a waste effluent palm oil. Located in the vicinity of over 20 palm oil mill processors in Teluk Intan, the biomass power plant is capable of generating 12.5MW of electricity under a 16-year RE PPA arrangement. The plant, which is not only reducing methane and carbon output is also an integrated waste management plant that could turn palm oil EFB into usable products.

18 – 19 July 2019  Representatives from TNB Group Finance, led by En. Neezuan Ibrahim were invited by SB to conduct a knowledge sharing session to understand the financial modelling of power plant projects. Participants were briefed on the basic Excel functionalities used in reviewing the financial models and the key parameters used in interpreting the financial models.

27 July 2019  Several SB staff participated in the TNB Energy Night Run 2019 in conjunction with TNB 70th Anniversary. The event, which drew a crowd of 3,500 participants, was organised to raise awareness towards energy conservation, environmental consciousness and ultimately the cause of saving the planet.
Technical Visit to Sg Perak Hydroelectric Power Stations

**Perak**

**5-8 August 2019** SB conducted a technical visit to the generating facilities under the Sg Perak Hydroelectric scheme. The visit’s objective is to understand the operational and design challenges of the power stations such as sedimentation, hydrology condition and outages. These challenges will be addressed and reflected in the new Service Level Agreement (SLA), which will cater for the extension of the Sg Perak Hydroelectric scheme as approved by ST recently.

Ensuring a Safe, Reliable and Economic Operation of a Power Grid System

**Bangsar**

**20 - 21 August 2019** SB organised a two-day training entitled Ensuring a Safe, Reliable and Economic Operation of a Power Grid System. The course provided understanding on power system operations including power system stability and security, as well as economic dispatch. Total Power Solution Sdn. Bhd. was invited to conduct the training as its trainers have decades of experience operating Peninsular Malaysia grid system.

Coal Handling Process at Jimah East Power (JEP)

**Lukut**

**23 August 2019** A technical visit to JEP, a 2x1,000MW coal power plant was organised to gain better understanding on the coal handling process. The participants had the opportunity to observe coal unloading from the ship to jetty conveyors and subsequently the transfer of coal to the coal yard via the conveying belt. JEP Unit 1 has achieved its commercial operation on 22 August 2019, while Unit 2 is currently in the commissioning stage and is scheduled to achieve its commercial operation by December 2019.

PPA Knowledge Sharing Session with Jimah East Power (JEP)

**Sepang**

**12 September 2019** SB was invited by JEP for a knowledge sharing session on the Power Purchase Agreement (PPA). After the sharing session, participants were given the opportunity to test their understanding on the PPA by answering online interactive quiz and solving case studies. The session has strengthened the relationship between JEP, TNB REMACO and SB.
Three topics were presented and discussed during the seminar:

**Session 1 - Compliance Audit 2020 by Enterprise Management Unit, SB**


**Session 2 - Integrity at Workplace by Integrity Department, TNB**

Apart from integrity at workplace, the speaker also talked about integrity when dealing with external people. One of the interesting topics discussed was on gift policy, where the speaker enlightened us on how to differentiate an appreciation gift from an act of bribe.

**Session 3 - Sexual Harassment at Workplace by Bahagian Pengurusan Sumber Manusia, Kementerian Pelancongan, Seni dan Budaya Malaysia**

With years of experience in this sensitive subject, the presenter shared on the different ways that sexual harassment can occur at the workplace and useful tips to avoid from being a victim.

On 23 July 2019, SB conducted a seminar entitled “SB Ethics and Compliance”. The one-day seminar is an annual requirement for all SB staff, with the objective to create awareness on the various codes and regulations governing SB’s operations. It is also a platform to update the staff on matters pertaining to ethics and compliance.

The event kicked off with opening remarks by the CEO of SB, En. Charanjit Singh Gill, followed by a recap session on the “SB Ethics and Compliance Seminar 2018”.

To test staff understanding on the topics presented, a unit assessment was conducted at the end of the seminar. The event concluded with closing remarks by the COO of SB, En. Abdul Malik Mohd Jaafar. §
On 12 September 2019, SB and ST co-organised a workshop on NEDA Enhancement in Putrajaya. The half-day workshop was attended by existing gas generators, current NEDA participants, potential NEDA participants and stakeholders including MESTECC, ST, Ministry of Economic Affairs, Sustainable Energy Development Authority and GSO. The workshop was conducted with the aims:

- To present the outcome of NEDA Viability Study that was concluded in March 2019
- To present the detail enhancement of NEDA for the short term period (2020-2024) as proposed by the Study

The workshop began with opening remarks by Pn. Azimah Abdul Aziz, the Deputy Director of Electricity Industry and Market Development unit at ST, followed by two presentation sessions by SB:

- Session 1: NEDA Viability Study
- Session 2: NEDA Enhancement in the Short Term

Valuable feedbacks on NEDA were gathered from the Q&A session and the survey forms, which have been noted by SB and ST to further enhance and strengthen NEDA moving forward.

The workshop ended with closing remarks by En. Abdul Malik Mohd Jaafar, the COO of SB who also shared the hope that more generators will be keen to participate in NEDA following the enhancements introduced.

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NEDA ENHANCEMENT WORKSHOP

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## Short Term, Medium Term and Long Term Generation Planning

### Comparing the Three Types of SB’s Generation Planning Models

<table>
<thead>
<tr>
<th>Objective</th>
<th>Short Term</th>
<th>Medium Term</th>
<th>Long Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>To determine the optimum economic commitment schedule that reliably serves demand</td>
<td>To forecast energy mix and fuel volume for the medium term, and determine the system cost</td>
<td>To determine system adequacy while adhering to reliability criteria</td>
<td>To address energy policy objectives including energy trilemma</td>
</tr>
<tr>
<td>Study Horizon</td>
<td>Current day - 3 months</td>
<td>&gt; 3 months - 5 years</td>
<td>1-20 years</td>
</tr>
</tbody>
</table>

### Key Input Data

- **Load forecast**
- **Generator availability**
- **Generator heat rate**
- **Commercial rates**

### Simulation Phases

- **ST**: To optimise generator dispatch for each hour or half hour (generating level, MW)
- **MT**: To pre-compute unit commitment decisions for generating units available in the system
- **LT**: To determine capacity additions & reserve margin level
- **PASA**: To determine reliability criteria (LOLE)
- **ST**: To determine generation mix, fuel requirement, emission projection and system cost

### Simulation Time

- **3 minutes (Day ahead)**
- **30 minutes (3-month ahead)**
- **1.0 - 1.5 hours (1 year)**
- **1.5 - 2.0 hours (20 years)**

### Deliverables

- **Day ahead unit commitment as required by Malaysian Grid Code (MGC)**
- **Day-ahead power sector gas nomination for Gas Framework Agreement (GFA)**
- **Weekly generation outlook for planning and operational purposes as required by MGC**
- **3-month ahead coal dispatch forecast for coal procurement as required by Guidelines for Single Buyer Market**
- **Generation and fuel volume forecast for IBR and ICPT**
- **Year-ahead power sector gas forecast for Gas Framework Agreement (GFA)**
- **1-5 year Supply Outlook as required by Guidelines for Single Buyer Market**
- **5 years Generator Outage Plan from GSO**
- **5 years Generator Outage Plan from GSO**
- **UOR based on PPA/SLA**
- **Single-point of average heat rate at maximum capacity**
- **VOR, FOR and CRF are based on PPA/SLA rates. Capacity cost is not modelled**
- **VOR, FOR and CRF are based on latest signed PPA**
- **VOR, FOR and CRF are based on PPA/SLA rates. Capacity cost is not modelled**
- **For new additions, VOR, FOR and CRF are based on latest signed PPA**
- **Long term generating capacity plan for JPPPET**
- **10-year Supply Outlook Report as required by Guidelines for Single Buyer Market**
FAILURE TO DISPATCH INSTRUCTION (FDI) WORKSHOP 2.0

Following the success of the first workshop held in August 2018, a second workshop was hosted on 1 August 2019. The platform provides an opportunity for parties to discuss operational matters with respect to Despatch Instruction (DI) as well as hands-on experience on the subject matter.

The workshop was attended by 45 participants from Generation Division, GSO and SB. The morning session began with a recap of the FDI module presented in 2018. During the afternoon session, participants interacted in groups to investigate and determine non-compliance of DI based on evidence and documentations of past FDI events. In parallel, critical feedback was gathered in order to enhance the efficiency of the FDI identification process.

WATT SAY YOU?

Deepavali, a festival that marks the triumph of light over darkness and good over evil, is often associated with bright colours and tantalising aromas. Let’s hear from our Indian colleagues on their favourite dishes and delicacies served during the festivity.

On the eve of Deepavali, my mum usually prepares a variety of cuisines and one of my favourite dishes is aloo paneer, served with puri. This traditional dish is very popular amongst Indians and serves as the highlight during Deepavali. Gulab jamun is another mouth-watering dessert that is a winner during the festive season. (Previnsha)

Many Indians are vegetarian on Deepavali, including my family. I like my mum’s vegetables kurma. It is delicious and I like to eat it with idli, a kind of rice cake. Among the many traditional sweet delicacies, my favourite is nei urundai. The ghee’s aroma and moong dal’s flavor blends very well and you can taste it in every bite... it will just melt in your mouth. (Kavitha)

When I think of Deepavali, the first thing that comes to my mind is obviously murukku. Murukku is a savoury and crunchy snack, which is typically made from rice flour and seasoned with salt as well as some spices. It’s a must-have in the Indians’ houses for Deepavali, as it is too delicious to resist! After all, what’s Deepavali without murukku?! (Thurgashini)
WattsUp: Thank you for giving us an opportunity to get to know you better. Can you share with us a brief background about yourself and how you started joining TNB?

Hakim: I was brought up in Kuala Lumpur and did my Bachelor of Electrical Engineering in Universiti Malaya. I got married in 2015 and now have 2 daughters. Upon graduation, I started my career with Texas Instruments for a year. I was then employed by FELDA for about 2 years before I joined TNB in the newly formed New Business & Major Project Division (now Energy Ventures or EV) in January 2013. Throughout my 5 years in EV, I was seconded to an Australian consultancy firm (Snowy Mountain Engineering Corporation) for 2.5 years under the Ulu Jelai Hydroelectric project. I spent another 2 years working at the Ulu Jelai site and was responsible to commission the project. Upon the project completion, I was assigned to the Tekai Hydroelectric project before joining SB in 2018.

WattsUp: How did you subsequently join SB and what is your role here?

Hakim: I applied for the opening in SB because it was getting a little quiet at work as the Tekai project at that time was in the tendering phase; and I was actually missing the ‘working around the clock’ experience. I joined SB officially in January 2018, under the Generation unit in Technical Advisory & Industry Development (TAID) section.

I see TAID as the consultancy arm of SB, particularly in providing technical expertise and advice not just internally, but also to the stakeholders. We also carry out studies, simulations and assessments to assist in providing the best possible solutions to others.

WattsUp: What is your first impression on the SB-ians?

Hakim: The people here are smart. I actually had a culture shock when I first joined SB because I came from a very technical background. Back when I was handling projects, I saw things in a practical way and needed to ensure that projects are completed smoothly. On the other hand in SB, I learn to be more forward-looking, for instance predicting what will happen in the industry in the next 5-10 years.

WattsUp: What do you love most about working in SB?

Hakim: The opportunity to learn new things. From my previous working experience, I was only exposed to hydro plants and the opportunity to do something different was limited. In SB, I get to look at the industry as a whole. I also have the opportunity to learn new technologies and obtain first hand information on new updates and policies among others, in the industry.

WattsUp: Recently you have presented a paper on Pumped Storage Hydro Plant in Bali. Can you tell us more about it?

Hakim: When I was working for the Ulu Jelai project, pumped storage was of less importance as there were no solar plants in Malaysia. This time around, due to growing solar penetration into the grid, it seems like it is the right time for pumped storage to come in. Battery storage is also an option to mitigate solar intermittency. These technologies are worth exploring especially as solar is growing in Malaysia and the government is aspiring to achieve 20% RE capacity by 2025. I submitted the abstract in December 2018. Upon receiving the acceptance letter, I submitted the paper in February 2019 and subsequently presented it in March 2019.

WattsUp: Lastly, can you share with us 2 random facts or about yourself?

Hakim: (1) I did not get to be with my wife on the birth of my second child because she gave birth on the last day before I came back from Bali. My wife was initially due to deliver my second child before I head off to Bali for the paper presentation mentioned earlier but I guess my baby was not ready to meet the world yet. (2) People are often bemused when they know how old I am!
Understanding the concept of Dollar Cost Averaging (DCA)

DCA is a well-known concept in investing. It's a proven disciplined method while taking emotion out of the equation.

DCA is the art of investing fixed amount of money at a regular interval (usually monthly) regardless of the price over a long period of time.

Thus, investors will buy more units/shares if the price is low and buy less units/shares when the price is high for the same amount of money, lowering their average cost over time.

This is a story of Tom and Jerry...

Tom invests $5,000 in January when the price is $10 and no additional investment is made. His holding from January to May is 500 units.

When the price in May drops to $8.5/unit, his total units value now is just $4,250 (500 x $8.5). His return is $750 or -15%.

Jerry invests $1,000 in January when the price is $10 and keeps on adding $1,000 every month. His total holding from January to May is 619 units.

Although the price in May is lower than the initial price of $10 in January, his total units value now is $5,260 (619 x $8.5). He has achieved profit of $260 or 5.2%.

Market price will always move and be volatile. In order to combat the short term volatility, DCA is always a good practice. However, make sure your fund or stock has good fundamentals and performance among their peers.

MARKET WATCH

EVOLUTION OF COAL POWER PLANT EFFICIENCY

Legend:
- Global Historical
- Global Future Development
- Malaysia’s average

2015 — China developed a double-reheat ultra-supercritical power plant with efficiency of 47.62%, highest globally

1957 — Philo Power Plant, Ohio was the first commercial steam-electric generating unit with super critical technology, approaching 40% thermal efficiency

1882 — Thomas Edison built the first coal-fired steam generator power station in New York with 1.6% efficiency

1988 — The first coal power plant (sub critical) was introduced in Kapar, Malaysia

2019 — The average efficiency of coal power plants in Peninsular Malaysia is 36%, encompassing sub critical, super critical and ultra-supercritical plants of 11,000MW total capacity

2030 — International Energy Agency (IEA) predicts coal technology will continue to develop and still contribute to the world’s generation mix

- Umar ibn Al-Khattab -

CONTACT US

We welcome any comments or content that you would like us to include in the upcoming editions of WattsUp.

Please email us at sbet@singlebuyer.com.my

DISCLAIMER

Disclaimer: The contents of this newsletter are of a general nature and is intended for informational purposes only. You are advised to seek specific advice on any matter that may be affected by such information. The views of third parties set out in this newsletter are not necessarily the views of SB.
Since the 1900s, boiler technology has evolved from Sub Critical to Super Critical to Advanced Ultra Super Critical (A-USC), while increasing the efficiency of plant, lowering fuel cost and reducing CO$_2$ emission.

**Subcritical Plant**
- Works below critical pressure and temperature of water.
- A typical example of this system is the drum-type steam generator.
- The term supercritical refers to main steam operating conditions being above the critical pressure of water.
- No distinction between steam and water.

**Super / Ultra Super Critical Plant**
- The critical PRESSURE and TEMPERATURE of water:
  - 221.1 Bar
  - 374°C

**Phase Diagram of Water**

**Benefits of USC Technology**
- Less fuel consumption
- Less CO$_2$ emission
- High plant efficiency
- Less per MW infrastructure investment

**Development of Super Critical Technology**

- **38%**
  - Efficiency
  - Steam Temperature < 550°C
  - < 221 Bar
  - SUB CRITICAL

- **45%**
  - Efficiency
  - Steam Temperature 600-700°C
  - ~ 275 Bar
  - ULTRA SUPER CRITICAL

- **42%**
  - Efficiency
  - Steam Temperature 500-600°C
  - ~ 240 Bar
  - SUPER CRITICAL

- **50%**
  - Efficiency
  - Steam Temperature > 700°C
  - ~ 330 Bar
  - ADVANCED ULTRA SUPER CRITICAL

**Challenges**
- Advanced and stronger high-temperature materials required for key process components, such as membrane wall tubes, high-pressure steam piping.
- This type of boiler has a drumless steam generator and has a limitation in term of MW response to support the grid during disturbance.