Integration of Renewable Energy into Grid System ï The Sabah Green Grid

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***Abstract*—In Malaysia, renewable energy made its official debut in 2001 through the 8th Malaysia Plan whereby renewable energy target was embedded in the national energy mix. Since then, the government has rolled out several policies and act to promote renewable generation but the take up rate was very slow. The introduction of Feed in Tariff (FiT) in 2011 in Peninsula Malaysia, managed to heighten the interest in commercial renewable energy generation, predominantly from solar producers. The scope of FiT was then expanded to include Sabah and WP Labuan beginning 2014. Sabah, being the largest crude palm oil producing state in Malaysia, hosts a huge potential for biomass integration to the grid via this scheme. This paper looks generally into the renewable acts and policies in Malaysia and their impact on the development of renewables in the country. The paper then discusses the renewables potential and their challenges in integrating renewables to the grid by focusing on biomass in Sabah as a case study. Finally, the paper explores the way forward through establishment of the Sabah Green Grid as a means to promote grid integration of renewable generation.**

Keywords— green grid, grid planning, renewables; transmission planning; malaysia

I. INTRODUCTION

Traditionally, countries worldwide relied heavily on fossil fuels such as coal, oil and natural gas to produce electricity. However, recent decades have borne witness to the rise of renewables in the energy landscape globally. Concerns over the depleting fossil fuels, reliance on imported fuel and climate change are among the main drivers propelling the development of renewable energy and its integration to the grid. Similarly, the push factor for Malaysia is fuel diversification and reduction of carbon footprint. In line with this aspiration, Malaysia has made a conditional voluntary commitment in the 2009 United Nations Climate Change Conference in Copenhagen to reduce its GDP emission intensity levels by 40 percent by 2020 relative to the 2005 levels [1].

However, Malaysiaô effort to introduce renewables started much earlier when renewable energy was included in the national energy mix under the 8th Malaysia Plan in 2001. In this plan, Malaysia had set a target of 5 percent of total generation capacity to come from renewables by 2005 [2]. However, to date, there is less than one percent renewables in the generation mix whereas natural gas and coal continue to dominate with 55 percent and 40 percent of the total generation mix respectively [3].

Nevertheless, the failure to meet the initial penetration level for renewable energy in the national generation mix is not due to the lack of initiatives from the government. Various acts and policies were formulated by the Government and adopted to promote greener generation mix but the response in terms of project development is very sluggish [4]. Studies have been carried out to identify the factors impeding the growth of renewable energy in the country and improvements were made via the regulations and policies as discussed later in this paper.

II. OBJECTIVE

This paper aims to identify the remaining barrier to renewables penetration in the generation mix, particularly biomass in Sabah and propose an enabler such as the Sabah Green Grid.

III. SCOPE AND LIMITATION

The scope of this paper is limited to facilitating integration of renewable energy at transmission level. The paper also covers the conceptual design of the grid and addresses the adequacy aspect of the grid only.

IV. MALAYSIAô RENEWABLE ACTS AND POLICIES

Malaysia is blessed with abundance of natural resources for renewable energy generation. Biomass, biogas, municipal waste, solar and mini hydro are the five renewable energy resources, which have been identified to have potential to be harnessed commercially for heat and electricity generation [4]. Malaysiaô commitment to promote these resources as renewable energy was reflected in the acts and policies beginning with the Five Fuel Policy in 2001.

A. *Five-Fuel Policy (2001)*

In the Five Fuel Policy, renewable energy was recognized as the fifth fuel alongside oil, gas, coal and hydro [5]. A penetration level of 5 percent of the total generation was targeted to come from renewable energy by 2005, which is about 500MW nationwide. Under this policy, the Small Renewable Energy Program (SREP) was launched in May 2001 whereby renewable power producers of 10MW or less is eligible to sell electricity to the utility. Despite approval being given to 48 projects, amounting to 267.3MW of grid connected capacity, only 12MW of renewable generation was successfully connected to the grid by the end of 2006 [5]. Consequently, the target was reduced to 350MW in the 9th Malaysia Plan whereby 245MW was expected to be contributed by biomass and the remaining 105MW from mini hydro [6]. Location wise, 300MW of the renewables were targeted to be connected to the power grid in Peninsula Malaysia and the other 50MW in Sabah [7].

B. *Malaysia National Renewable Energy Policy and Action Plan (NREPAP) (2010)*

The Government recognized the need to encourage a more systematic growth of renewable energy industry following the failure to meet the previously set targets [8]. Therefore, on 2nd April 2010, the cabinet approved the National Renewable Energy Policy and Action Plan (NREPAP) [7].

NREPAP is the Governmentôs attempt at providing a holistic roadmap for renewable energy growth in the country. The objectives of the policy are to increase percentage share of renewable energy in the national power generation mix by facilitating renewable energy industry growth. In order to achieve this, the Government must first ensure that renewable energy generation costs are reasonable. The policy also aims to conserve the environment for future generation and to increase awareness on the role and importance of renewable energy [9].

Under NREPAP, the contribution from renewables in the fuel mix is expected to reach 6 percent or 975MW by 2015, led by biomass, 330MW and mini hydro, 290MW. The renewable penetration is anticipated to grow to 13 percent by 2030 [10]. NREPAP is a significant milestone in the development of renewable regulatory framework in Malaysia as it identifies the root cause and blockers for poor response in terms of renewable project development as well as the way forward.

C. *Renewable Energy Act and Sustainable Energy Development Authority Act (2011)*

By the end of 2010, there were only 68.45 MW of renewable generation connected to grid which translates to about 20 percent of the 9th Malaysia Plan target [8]. The lukewarm response was attributed to the lack of regulatory framework and poor governance as outlined in the NREPAP. Subsequent to this finding, the Renewable Energy Act 2011 and the Sustainable Energy Development Authority (SEDA) Act 2011 were enacted. The enactment of these acts was the turning point for renewable energy as the former focuses on renewable energy development. Meanwhile the latter provides for the establishment of SEDA, the statutory body mandated to oversee the implementation and management of renewable energy that includes the Feed in Tariff mechanism [11].

V. FEED IN TARIFF (FIT)

FiT system was officially introduced on 1st December 2011 starting with Peninsula Malaysia [12]. It is meant to stimulate interest in renewable generation by providing a premium tariff, FiT rates, up to a specified period to renewable energy producers [8]. The FiT rates are available for biogas, biomass, biomass, mini hydro, and solar photovoltaics (PV) [13]. The rates differ depending on the type of renewable resource and the installed capacity. On top of that, incentive in a form of bonus FiT rates also applies upon meeting specified criteria [11].

A renewable energy fund (RE Fund) was set up to pay for the agreed FiT rates. This RE fund is financed by all consumers with exception of domestic customers who use less than 300kWh per month. Initially, a 1 percent surcharge of the monthly electricity bills was applied to be contributed to the RE fund. However, beginning 1st January 2014, the contribution was increased to 1.6 percent and FiT was expanded to include Sabah and WP Labuan [12]. Each Feed-in Approval Holders (FiAH) are guaranteed a payment from the RE Fund for a period of 21 years for solar PV and small hydropower. Meanwhile, for biogas and biomass, the commitment is only for 16 years [11]. Fig. 1 shows the outcome of FiT implementation as at 31st Jan 2014 [14]. Meanwhile, Fig. 2 shows the approved quota for various renewable energy technologies for 2014-2017 [12].

	RE generation (MWh)	Installed Capacity (MW)	FiTCD Capacity (MW)	CO2 Reduction (tonnes)
Biogas	147,494	29.53	11.73	140,290
Biomass	835,155	166.49	50.40	575,460
Mini hydro	821,188	130.99	15.70	605,218
Solar PV	252,429	209.06	85.40	188,564
TOTAL	2,056,266	536.07	163.19	1,509,534

Fig. 1 - FiT outcome in Malaysia as at 31 January 2014

Source/Technology	2014	2015	2016	2017
Biogas	10	15	15	15
Biomass	15	18	20	35
Small Hydro			50	100
Solar PV for industry	10	15	15	15
Solar PVfor non industry	35	54	53	24
Solar PV for community	5	7	7	7
Geothermal			30	

Fig. 2 - Schedule of available RE Quota (MW) based on Commercial Operations Year (2014-2017)

VI. SABAH GRID

Malaysia constitutes of Peninsula Malaysia and East Malaysia. Sabah is one of the two states that form East Malaysia. Fig. 3 shows the location of Sabah in Malaysia. The main electricity utility in Sabah is Sabah Electricity Sdn. Bhd. (SESB). Up to August 2013, Sabah has recorded a peak demand of 867 MW [15] and the electricity demand is expected to grow steadily for the next 3 years at an average of 7.6 percent per annum. The peak demand is expected to reach 1,300MW in 2020 [16].

Fig. 3 - Map of Malaysia [source: FOTW Flags of The World]

A. Generation in Sabah

As of FY2013, the installed generation capacity stands at 1.194 GW with a reserve margin of about 38 percent [17]. However, only 42 percent of generation is contributed by SESB plants. Meanwhile, the remaining 58 percent is generated by Independent Power Producers (IPPs) [18]. Presently, the generators in Sabah are predominantly fueled by natural gas, diesel and MFO as shown in Fig. 4. The remaining is contributed by biomass and hydro [17].

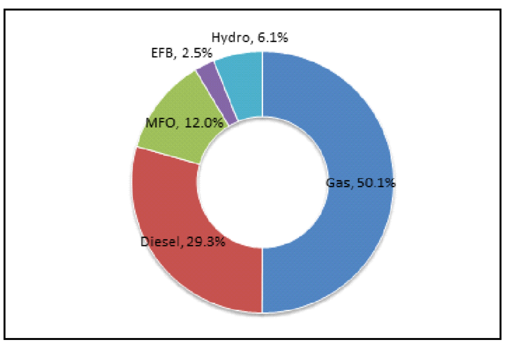

Fig. 4 - Sabah Capacity Mix by Fuel Type Year 2013

B. Transmission in Sabah

The Sabah Grid is made up of 275kV, 132kV and 66kV transmission lines which act as the backbones in supplying electricity in all major towns in Sabah and Federal Territory of Labuan [19]. The transmission grid in Sabah can be divided into West Coast Grid (WCG) and East Coast Grid (ECG).The WCG and ECG are connected via a 275kV link from Kolopis to Segaliud. Most of the generators and load are on the west coast. Fig. 5 shows the location of generators and transmission lines in Sabah.

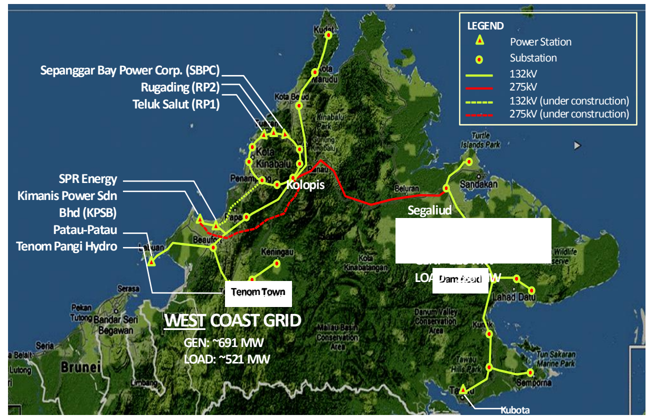

Fig. 5 - Location of generators and power plants in Sabah

VII. RENEWABLES IN SABAH

Presently, there is about 30MW of renewable generation connected to the Sabah Grid, all of which are from biomass [17]. They are all connected to the ECG through the 132kV network. However, this is only a small fraction of the renewable potential in Sabah, particularly biomass. The installed capacity from biomass is expected to grow following introduction of FiT in Sabah.

A. Biomass Potentials in Sabah

Malaysia is the second largest crude palm oil (CPO) producer in the world after Indonesia [20]. As of December 2013, there is a total of 5,229,739 hectares of oil palm planted in Malaysia and 28 percent is in Sabah [21], making it the largest CPO producer state in Malaysia. The oil palms are processed by more than 400 palm oil mills nationwide. The by-products from these mills includes solid wastes from the empty fruit bunches, (EFB), mesocarp fibres, palm kernel shells and palm oil mill effluent [22], which can be used to produce biomass and biogas generation respectively.

In Sabah, there are 124 identified palm oil mills and an estimated of 500MW potential of biomass generation. Majority of the palm oil mills are located in the east coast of Sabah as shown in Fig. 6 [22].

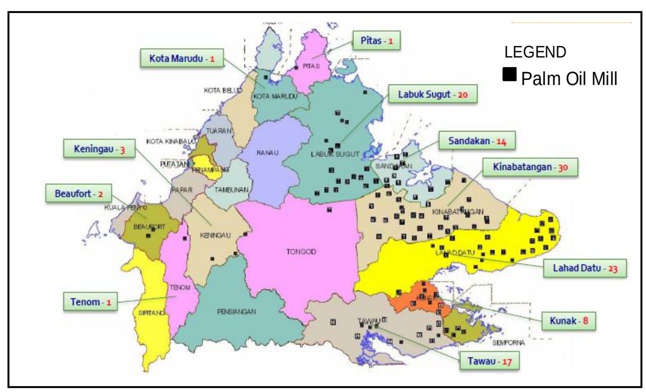

Fig. 6 - Location of palm oil mills by state/district Year 2012

B. Challenges for Grid Integration in Sabah

Despite the large biomass potential in Sabah, the rate of realisation for grid connected renewable generation for electricity in the state is very sluggish. The low penetration level is primarily caused by economic, financial and technological constraints [23].

Previously, there were no real incentives in terms of financial gain for the developers to be connected to the grid as the utility is incapable to offer the ñright priceò for renewable generation. On top of that, in the absence of firm return in the long term for renewable generation, the developers had difficulties in financing the renewable generation project especially if they also have to bear the cost of interconnection to the grid.

In order to be connected to the grid, the renewable energy producers need to construct transmission lines to the nearest substation or existing transmission grid. For biomass producers, it can be expensive to be grid connected as they are usually located at remote areas, which is at a distance to the nearest grid facility [24]. Nevertheless, the biomass producers have the option to build the plants close to the existing grid infrastructure but they then have to pay for substantial transportation cost between the palm oil mill and the plant.

Attractive pricing offered under FiT addresses the concerns on return of investment and commitment from utility via attractive rates and long term contracts respectively but not the issue of grid integration cost.

VIII. SABAH GREEN GRID (SGG)

SGG is a group of transmission network specially developed to pick up renewable generation particularly biomass in Sabah by means of providing collector substations (CSS). The CSS are located strategically such that the distance from the renewable energy producers generally and the palm oil mills specifically are reduced. These collector substations are meant to be connected to the grid network at transmission level via 275kV or 132kV lines.

Each CSS will at least have step down transformers to distribution levels and the connection from the biomass producers will be at the 33kV level or lower distribution voltage such as 11kV if existing 11kV reticulation is available within the supply zone.

Presently, the responsibility to construct infrastructure and transmission lines to the existing grid falls on the renewable energy producer. Typically the renewable energy generated does not exceed 30MW and therefore can be connected to the grid via 33kV network. Unfortunately, the 33kV network supply area is limited to about 30km radius before the voltage starts to drop significantly and in most cases, the location of the renewable plant is more than this. As a result, the developers will have to resort to higher voltage transmission lines to connect to the grid. In the case of Sabah, they will have to go the next voltage level, which is 132kV. This option unfortunately is about six times more expensive than 33kV lines and will definitely require a right-of-way or land acquisition to construct the towers.

With the SGG in place, the cost of integrating renewable energy to the grid could be shared between utility and the developer. By funding the SGG, the Government also benefit in reducing carbon emission, in line with Malaysiaôs goal to reduce its carbon footprint by 40 percent by 2020 [1]. As for the utility, having the SGG increases Sabahôs supply security through fuel diversification and strengthening of network by having parallel networks. Indirectly, the SGG can entice more investors to come to the state as the supply is more reliable.

As for the developers, the cost to connect to the grid should be more palatable as the distance between the renewable generation site and the grid is reduced and can be done at a lower voltage level. Fig. 7 illustrates the concept of collector substations in the SGG. The number of renewable generator within the supply area can be increased by increasing the number of collector substations. Therefore it is the upmost importance to place the collector substations strategically for optimum connectivity.

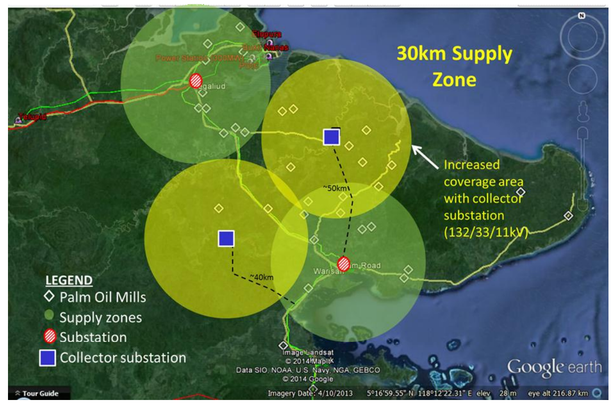

Fig. 7 - 30km supply zone concept in Sabah

IX. APPROACH AND METHODOLOGY

Location of the collector substations is vital in realizing the SGG. They have to be strategically located and optimized such that it is fair to all the biomass producers in terms of distance to the CSS. The CSS in SGG are chosen based on two main criteria which are the realisable potential of the palm oil mills and the technical transfer capability of the distribution network which is 30km. In order to ensure that connection cost is kept to a minimum, the CSS are chosen such that every interested biomass producer is within the 30km supply zone of the CSS.

A methodology was developed to decide on the locations of the CSS. It starts by tabulating the locations of potential palm oil mills and existing substations. Next, the 30km supply zones for the existing substations are identified. Palm oil mills that are not within any existing 30km supply zones are then clustered and a centre point is calculated to estimate the location of the new collector substation. The actual locations of new CSS are subjected to land availability. The methodology is summarised in Fig. 8.

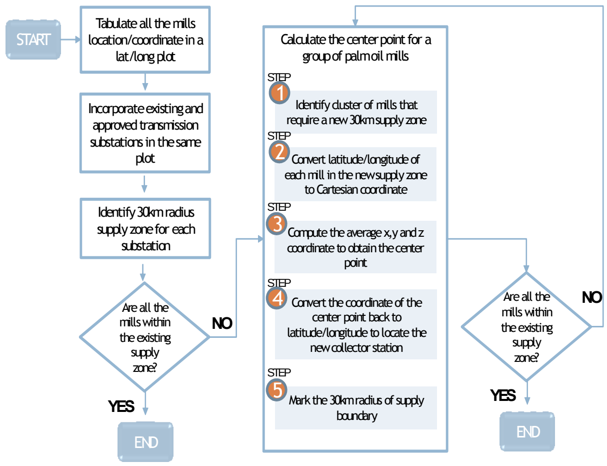

Fig. 8 - Methodology to identify CSS Location

Next, the nearest existing transmission lines and substations to the proposed CSS are identified. The SGG is then designed to connect these CSS to the rest of the grid. However, for the initial stage, this case study only addresses the adequacy of the proposed connectivity scheme for the CSS. A more detailed study is required once the schemes have been finalized.

X. Results

Preliminary study indicates about 97 percent supply coverage is achievable through eight existing/approved substations and five new CSS. The anticipated supply coverage area is illustrated by Fig. 9. These CSS will be connected to the existing grid network via 132kV and 275kV lines, spanning 363km (shown in Fig. 10).

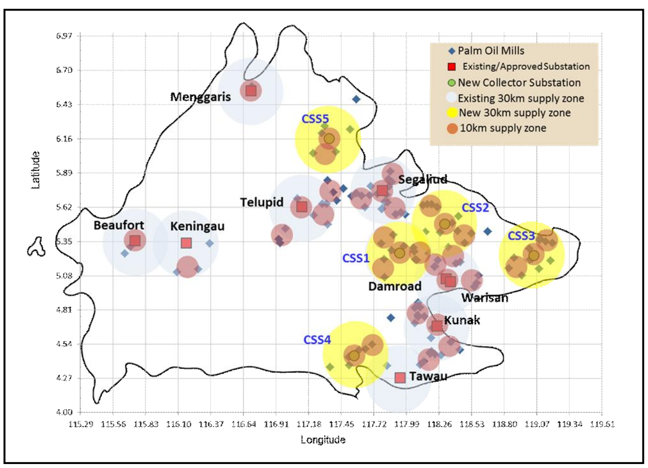

Fig. 9 - Supply coverage area for existing substations and new CSS

Based on this proposed scheme, SGG is realisable with an estimated total cost of about RM863 million. The bulk of the cost is contributed by the overhead lines which is about RM710 million. This amount includes the cost of land acquisition for the lines. The remaining cost comes from retrofitting of existing substation and construction of new CSS, which cost approximately RM142 million and RM11 million respectively.

However, the investment does not have to be made in one go. Instead, it should be done in stages to achieve the envisioned target network for the SGG. The staging and project prioritisation may be carried out based on the size of potential electricity generation at each collector substation. Fig. 11 shows the expected biomass potential for each new CSS.

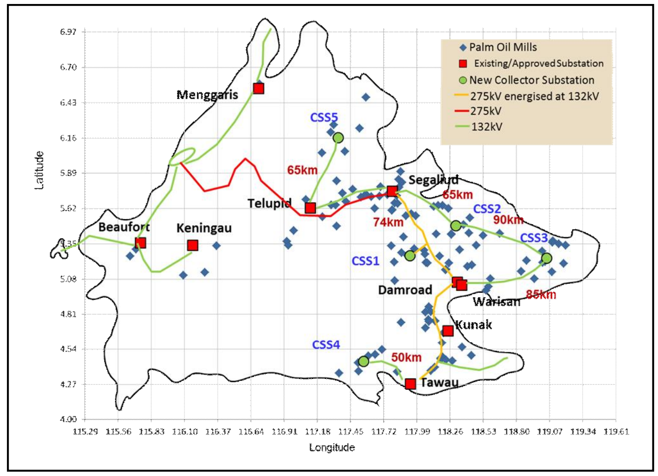

Fig. 10 - Indicative connections from CSS to existing transmission network

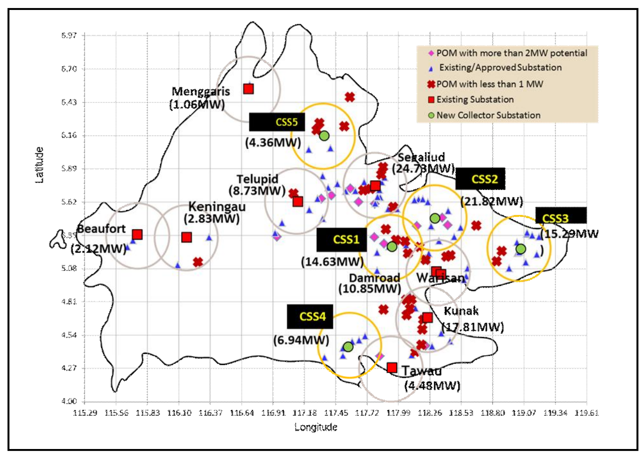

Fig. 11 - Expected biomass potential for each CSS

XI. Discussion

SGG is an extension of the existing transmission network to accommodate the collector substations that is required to pick up the renewable generations in Sabah particularly from biomass. These collector substations are strategically located such that the cost of grid integration is minimised for the developers and is not shouldered solely by the utility. It should be realized in stages with priority given to areas with high interest and potential for grid integration.

SGG does not only provide the solution to integrate renewable energy to the grid but also provides means for the Government to achieve its goal to reduce carbon footprint by 40 percent by 2020. On top of that, the SGG also increases fuel security to Sabah through fuel diversification.

A. Way Forward for SGG

In order to reap optimum benefit from SGG, more inputs are required to prioritise and stage the development of SGG. Although there are many biomass potential, not all of the palm oil producers necessarily interested to generate electricity commercially. For a start, a survey to gauge the level of seriousness to be grid connected should be undertaken to obtain the list of interested producers. The next step is to find out the year of integration to the grid and the capacity of each biomass plant. This information is vital in determining the sizing of grid facility and the urgency for the facility to be constructed. Depending on the requirements, existing distribution facility within the vicinity of the palm oil mills may also be an option for grid integration.

XII. CONCLUSION

Malaysia generally and Sabah specifically has a huge potential for renewable generation. With FiT already in place, the focus now is to remove the barrier in the form of grid connection cost that is holding the renewable producers back. The collector substation concept such as SGG may be the enabler and the missing puzzle in promoting renewable generation in Malaysia. It facilitates the integration of renewable energy into the grid by overcoming the integration cost barrier. In Sabah, biomass producers may be the first to benefit from the SGG but the grid also facilitates integration of future renewables. The SGG should be established in stages as it brings many benefits to the development of renewable energy in Sabah specifically and Malaysia generally. However, the source of funding to establish the SGG is to be identified and may come from Government fund.

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