Designing Photovoltaic Feed in Tariff Policy Based on Market Dynamics: The Japanese Market as an Example

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Abstract

Feed in tariff policy has been successful in diffusing photovoltaic energy around the world. This success however usually comes on the cost of photovoltaic market. While the share of renewable energy might increase to reach national targets, market shakeout and series of bankruptcies might take place resulting in a boom bust cycles. Such market instability happens due to the frequency and magnitude of policy makers' interventions to the feed in tariff policy. Through the understanding of dynamics of photovoltaic industry, this paper discusses the development of resilient and responsive feed in tariff policy using system dynamics.

Keywords: Photovoltaic; Profitability Analysis; Feed in Tariff Policy; Japan

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1. Introduction

The feed in tariff policy has been acknowledged for its success since its introduction with the German experience in the beginning of the last decade. Unlike other policies, the feed in tariff provided a regulatory framework, financial incentives and guarantees to attract investors to invest in renewable energy. The result has been a rapid growth in wind and solar photovoltaic energy diffusion. The feed in tariff experience with variation has been implemented in more than 100 countries and states around the world (Couture et al. 2010).

The feed in tariff policy as a result is a very influential factor for the growth of photovoltaic industry and its acceleration. As it provides long-term contracts, usually between 10 to 25 years of fixed tariffs, careful estimation of feed in tariff price is essential in order to reduce the national renewable energy program budgets or budget over runs. The photovoltaic government bill to support such policies might over run in the magnitude of billions if not trillions of dollars (Nemet 2009). Although its known that the feed in tariff price and consequently feed in tariff budget is primarily dependent on the cost of photovoltaic (PV) electricity, the complexity of the photovoltaic market however makes it difficult to estimate the cost. Such complexity in cost estimation will eventually make feed in tariff price optimization very challenging.

Previous feed in tariff experiences in Spain, Germany and Italy, have shown that the market might behave differently from what is supposed to and tend to exploit the feed in tariff policy in ways which are not aligned with the feed in tariff policy conditions[1] (for the case in Spain please see (del Río González 2008; de la Hoz et al. 2010) and for case in Germany please see (Frondel, Ritter, and Schmidt 2008; Wand and Leuthold 2011; Jacobs 2012a) . For example, when actual PV costs decreases more rapidly than expected, it results in unreasonably high profit margins for PV electricity generators and so this urges the policy makers to introduce reactive policy interventions (Figure 1). Reactive measures, which come as frequent and unplanned decreases feed in tariff price, or halting feeling in tariff system temporarily or permanently, drastically impact investors trust as the stability of markets (Figure 2 and Table 1). Although policy makers currently overcome this challenge with continuous monitoring for the PV materials prices, and apply strict measures to the volume of installed PV, the feed in tariff policy design remains inefficient due to complexity and uncertainties of the variables incorporated within its formula.

The PV market in Japan has been very dynamic due to the frequent changes in the supporting policy for PV energy (see Figure 3). The feed in tariff policy was discussed after great earthquake in Fukushima 2011 and was implemented starting from April 2012. The Japanese feed in tariff experience shows similar trend to the boom-bust cycles that took place in some countries in Europe. The scenarios which summaries this discussion are illustrated in Figure 4 and Figure 5.

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[1] For example, the volume of installed PV capacity might exceed the announced target capacities, or the local PV prices might be actually be lower than expected or increased artificially.

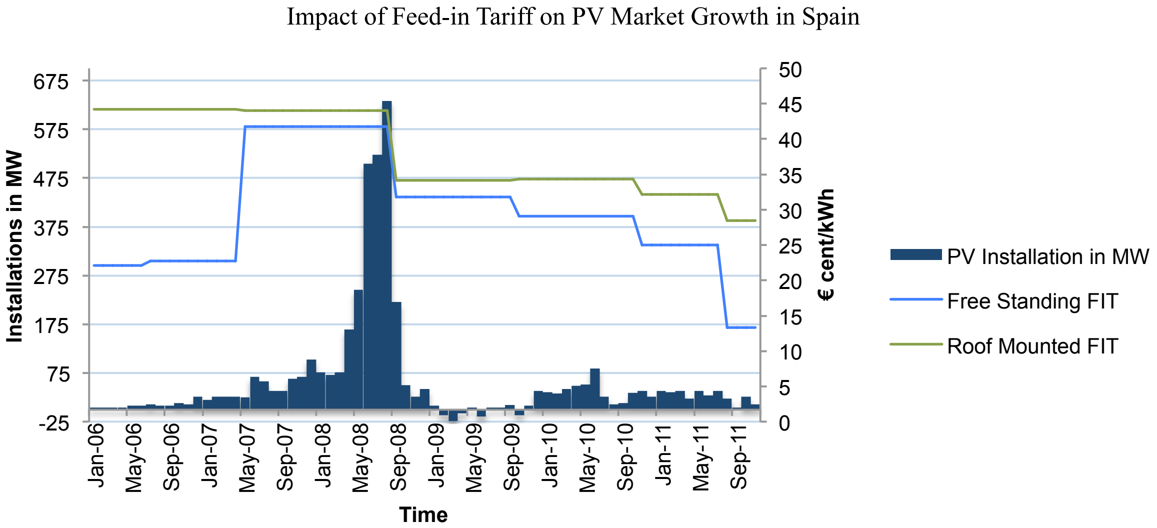

Figure 1: Imapact of FIT on PV market growth in Spain

Source: (Jacobs 2012b; Río and Mir-Artigues 2012)

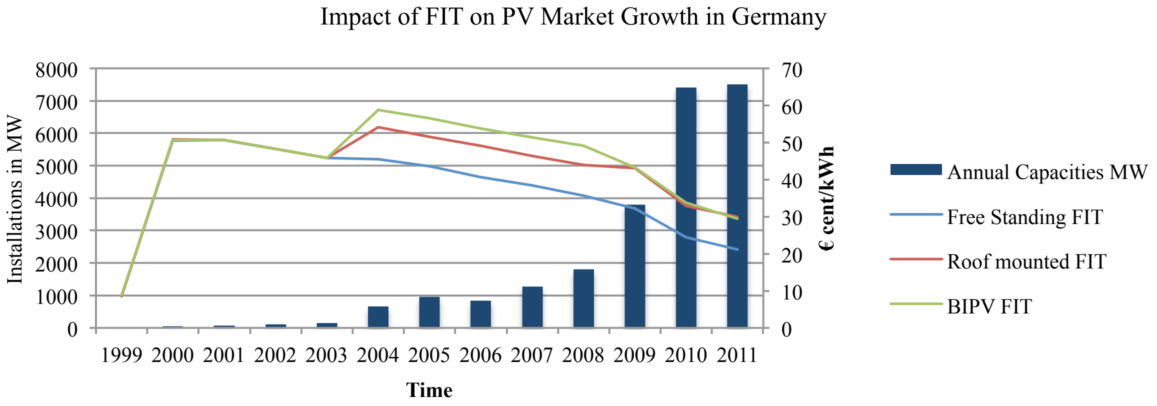

Figure 2: Impact of FIT on PV market growth in Germany

Source: (Jacobs 2012b)

N	Company	Bankruptcy date	Location
1	Solon	December, 2011	Berlin, Germany
2	Odersun	April, 2012	der Oder, Germany
3	Solar Millennium	December, 2011	Erlangen, Germany
4	Sun Concept	February, 2012	Germany
5	Ralos New Energies	February, 2012	Germany
6	Solarhybrid	March, 2012	Franfurt, Germany
7	Sheuten Solar	March, 2012	Freiburg, Germany
8	Q-Cell	April, 2012	Germany
9	Solvello	May, 2012	Germany

Table 1: Example of bankrupted PV companies in Germany

Source: Author compilation

In our view, the feed in tariff policy should be assessed in the way it can be responsive to internal or external changes. We argue that the understanding of the structure and dynamics of photovoltaic market is crucial to design efficient and optimized feed in tariff policy. System dynamics methodology will be used in our model to analyze the structure of photovoltaic market. The advantage of system dynamics over the econometric and statistical techniques is that system dynamics can capture the structure of the system and by doing so it can more efficiency predicts its behavior (Lyneis 2000). Moreover, econometric models are limited in capturing the feedbacks, and time complexity (Sterman 2000) between the interdependent factors.

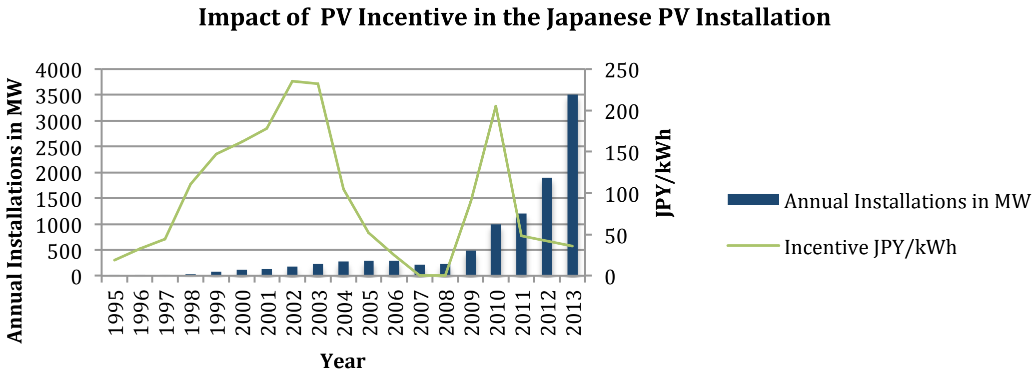

Figure 3: Impact of PV incentives on PV market growth in Japan

Source: (Corporation 2012; Renewable Energy World 2014)

Note: (1) The government subsidy was stopped by fiscal year of 2005 and resumed back again in 2007. (2) Feed in Tariff policy was implemented in April 2012 and revised in April 2013.

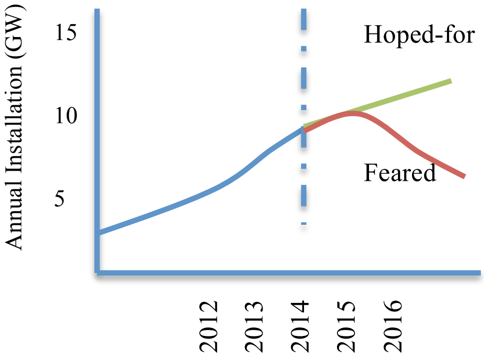

Figure 4: Japan PV Market Annual Installation Growth Scenarios

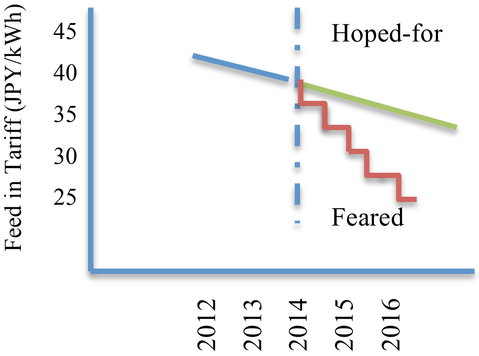

Figure 5: Feed in Tariff Future Scenarios

There are very few system dynamics models that have attempted to analyze feed in tariff policy, for example (Hsu 2012; Santiago Movilla 2012; S Movilla, Miguel, and Blázquez 2013). Although these models analyzed the photovoltaic market dynamics in specific countries, these models were not designed for the purpose of designing efficient and responsive feed in tariff policy.

2. Feedback Loop Analysis

The dynamics of PV market can be represented in eight feedback loops (Figure 6) and summarized in table 2. The first loop, R1, illustrates the growth cycle in PV market. The high feed in tariff leads to high business profitability, and this in turn attracts local and foreign investors to support developers to file applications for installing PV projects. The applications have to go through an approval process from the Ministry of Economy, Trade and Industry (METI) and the relevant electric utility. The approval cycle usually takes between 3 to 6 months for projects of more than 2 mega watt (MW), and around one month or one month and half for smaller projects. Approved projects then are installed to generate electricity. And based on the feed in tariff price a certain profit can be generated.

As investors file up applications to install more PV projects, it means that the demand for PV materials increases. The increase demand in turn sends indicatives to manufacturers to increase their manufacturing capacity to fulfill orders on time. Therefore, the cost of developing PV project decreases based on an experience curve effect (Nemet 2006) shown in R2 loop. Inversely, if the manufacturing capacity cannot fulfill the demand, the cost of PV project increases temporarily until manufacturing capacity adjusts.

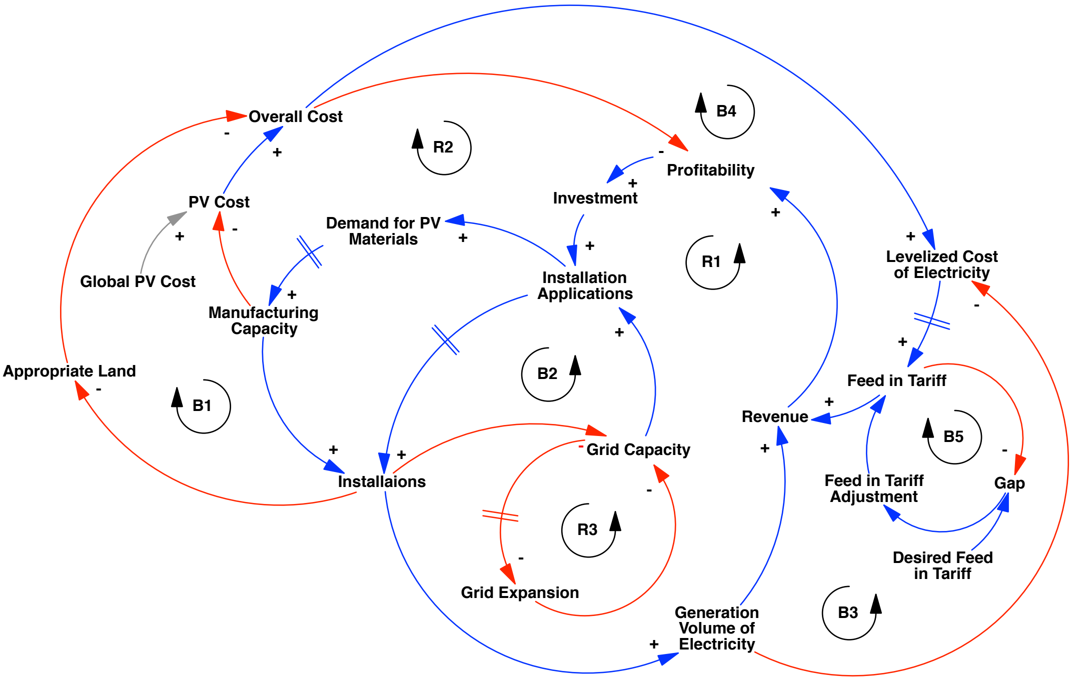

Figure 6: Causal Loop Diagram

Loop	Name	Description
R1	Market growth	The more photovoltaic business is profitable, the more installation will take place, and more electricity volume will be generated.
R2	Experience Curve	As experience curve suggests, manufacturing capacity drives cost down and so profitability and market attractiveness increase.
R3	Grid Capacity Growth	Grid capacity expands to meet the demand
B1	Land Utilization	With more PV installations, appropriate land for PV plants decreases and so the overall costs of PV increases.
B2	Grid Utilization	With more installations, grid capacity declines
B3	Generation Volume	More installations results in more electricity generation volume, which drives the levelized cost of electricity down. Consequently the feed in tariff is decreased accordingly.
B4 [2]	Overall Cost Effect	As the over all costs increases and the levelized cost of electricity increases and so the feed in tariff should be increased accordingly.
B5	Feed in Tariff Adjustment	The feed in tariff should be adjusted to reach the desired feed in tariff level, which occurs when the levelized cost of electricity of photovoltaic matches the equitant cost of Fusil fuels.

Table 2: Causal Loops Summary

The growth of PV installations is constrained by several factors. The first constraint is the grid capacity, which is illustrated in B2. The grid capacity as a constraint is actually comes in two forms: the transmission capacity and the grid geographical reach. The transmission capacity constraint happens when the transmission capacity between utilities is limited. For example, many areas in Hokkaido prefecture were found to be attractive locations for PV power plants considering the land cost and land other land characteristics. Toru Suzuki, the chairman of the nonprofit Hokkaido Green Fund said, "No growth target for renewable energy would be feasible without Hokkaido" emphasizing the competiveness of Hokkaido areas and in the same time scarcity of appropriate land in Japan for renewable energy projects. Between April 2012 and March 2013 more around 1.53 GW of capacity was approved by METI and filed for grid connection from Hokkaido Electric Utility. However, since the volume of electricity is much more than what Hokkaido prefecture demands, such volume should be transmitted through the transmission lines to the neighboring prefectures. However, the transmission line capacity was found to be limited and hence 70% of those filed

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[2] Note that B4 can also be a reinforcement loop if the outer loop is considered.

applications have been rejected by the utility in Hokkaido. (BNEF 2013; Asahi Shinbun 2013)

The other grid constraint is related to the geographical grid coverage. As solar developers target affordable and appropriate land far from the major cities, the distance from the grid becomes further and so the substantial grid connection cost makes such projects unfeasible. Moreover, since building connection takes time, that will eventually delay these projects. (Sasa 2013)

The second constraint is the appropriate land. Appropriate land for solar project requires certain requirements, like its rent or cost, nature of its soil, inclination towards south, flatness, having minimum shade from the surroundings and proximity to the grid. The more appropriate the land is, the less cost it will require. The rent or purchase of land in Japan is well known to be highly expensive. However, as B1 suggests, with more PV projects, the less appropriate land will be available, and so the overall cost of PV projects will be expected to increase even more making PV projects less profitable. (Sasa 2013)

Loop B3, B4, B5 are related to the factors that influences feed in tariff pricing. Based on loops B3 and B4 the Levelized Cost Of Electricity (or LCOE) is calculated. The LCOE is an important measure that is used to estimate cost of the electricity generated form photovoltaic energy. And based on this cost, the PV electricity generators are compensated. With more PV installation, the overall cost of PV decreases while the investment and volume of the generated PV electricity increase. This in turn encourages to policy makers to step down the feed in tariff accordingly. B5 explains what is called feed tariff degression. Feed in tariff is supposed to keep dropping until the LCOE of PV reaches the LCOE of fossil fuels.

3. The Market Structure

The stock flow model describes the structure of PV market dynamics in Japan through the aging chain illustrated in Figure 7. The lifecycle of PV power plant starts applications submitted to METI and ends up with a functioning PV power plant. When the market is profitable and attractive enough, investors or PV project developers submit applications to METI for approval. The process for filing a solar project usually starts with a consultation with the relevant utility. A permit follows this from the ministry of trade, economy and industry, and finally a request for grid connection. The average time to obtain varies between 3 to 6 months depending on the project details. Applications that do not satisfy the standards are normally rejected.

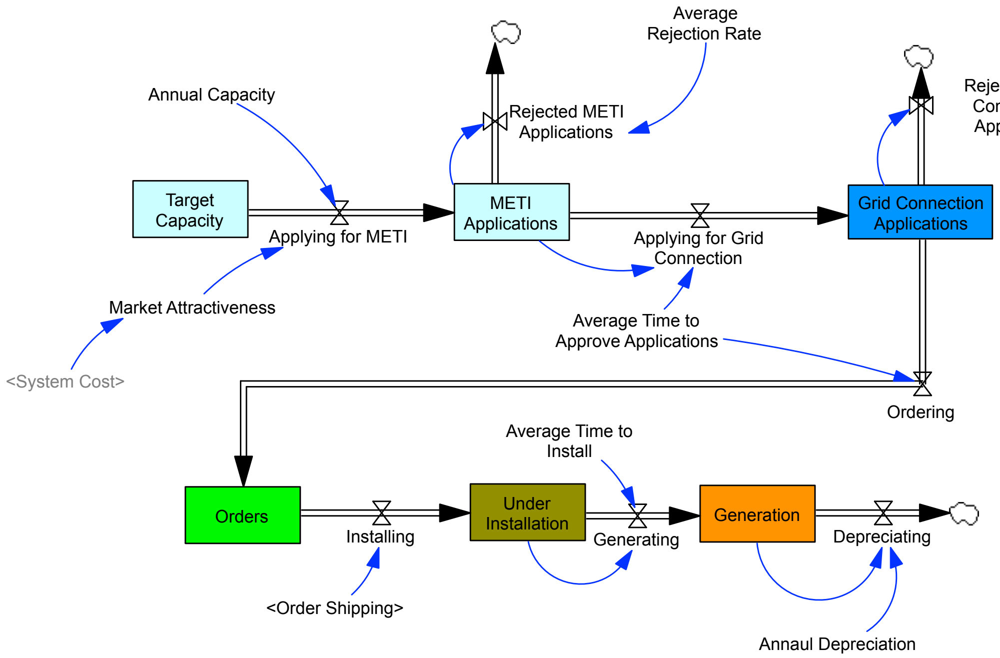

Figure 7: Basic Stock Flow Model

Approved applications by METI are then submitted to the relevant utility. Depending on the grid available capacity projects are accepted or rejected. With every application approved to be connected to the grid, the grid capacity decreases. And as the grid capacity becomes not sufficient for the demand, grid expansion is scheduled (see Figure 8).

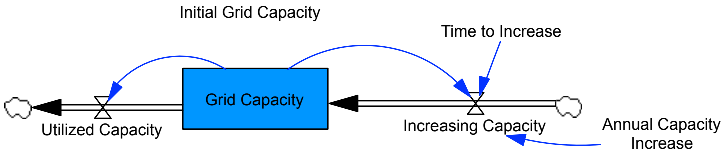

Figure 8: Grid Capacity Stock

Once applications are approved for connections, project developers then order the power plant materials from the manufacturers. Due to the abundance of panels stocks of several local and foreign companies, the procurement of panels is not a real issue for PV projects. However, the procurement of power conditioner is quite challenging as the order might take up to 6 months till its delivery[3]. The power conditioner is actually a key component of solar system projects without which the entire plant cannot be connected to the grid to the generated electricity, and so the plant cannot generate any revenue until then. Once the power

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[3] The power conditioner is an electric equipment required to invert the DC current produced from the panels to the AC current used in the grid).

conditioner is availed and the power plant is connected, the facility operation has to be tested for one month before live production for safety, protection, and standards compliance.

However, as orders increase the manufacturing capacity has to increase to cope with the demand (Figure 9). Once the materials are delivered, the installation work starts. The average time to install PV mega solar plant is usually between 1.7 to 2.7 years (Izadi 2013).

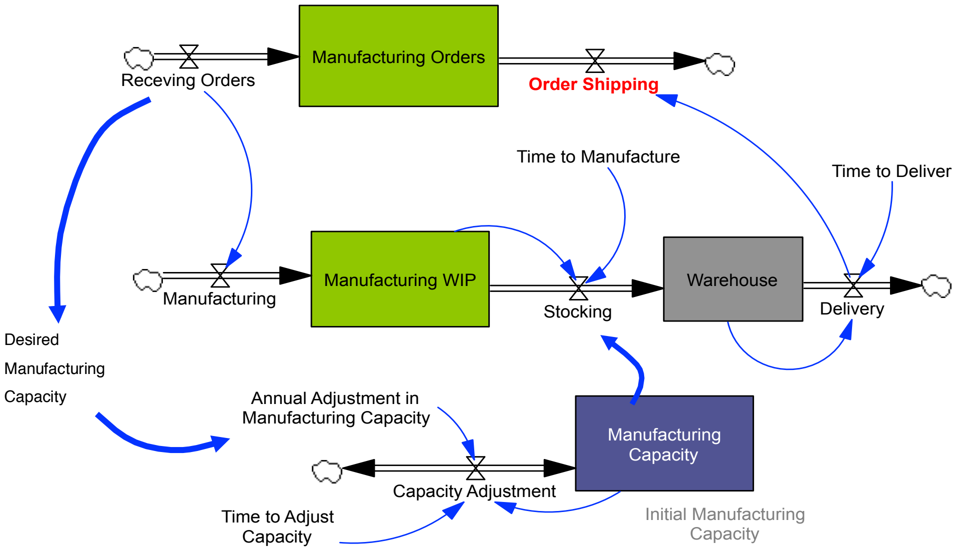

Figure 9: Manufacturing Capacity Dynamics

The manufacturing capacity stock is significant as it shows the speed of which PV industry can fulfill the market demands, and in the same time it helps to estimate the PV cost using the experience curve (Nemet 2006). The experience curve is then can be used to calculate the feed in tariff, which in turn finally feeds back to update market attractiveness and profitability. The complete stock flow model is shown in Figure 10.

4. Analysis

The model provides a simple approach to understanding the market dynamics for photovoltaic market in a holistic way. The stock and flow model can capture the flows and material delays within the system, and hence make it is easy to experiment PV market growth rate and size relative to time. Similarly, designing mechanism that dynamically set feed in tariff at equilibrium is likely to be more efficient making the policy more resilient to external or internal changes.

The model can help in managing the time complexity between the interdependent factors within the described system and help policy makers to make decision in over coming the market growth constraints in right time. For example, while the transmission line is under expansion in some areas of congestion, un-favored areas could be promoted to evenly distribute PV installations by subsidizing grid connection cost. Another example to deal with growth constraint is the related to project resources. The cost of project resources (whether it is project materials like panels or resources like land) can be bounded with an upper limit to avoid price spikes due to temporary period of high demand. Resources with cost that outbound the range can be subsidized to ensure a minimum level of profitability.

In addition, the model captures the supply and demand within the market. Whereas the manufacturing capacity and stocking capacity can show market supply, METI applications stock and material orders are indicatives about the market demand. Therefore, the model can estimate PV pricing in case of over stock or under stock situations. More importantly, the model can simulate the effect of feed in tariff on the industry and its plan for expansion. Therefore, as the model illustrates the full picture of the market, policy makers can be more careful about taking reactive measures that can negatively impact the market in general.

5. Future Research

The existing model uses simple structures for capacity growth for the sake of simplicity. However, these structures can be replaced with more sophisticated ones well known in the system dynamics literatures for supply chain management and cost management. Such enhancements in the model can lead to more efficient and responsive results. In addition, the model was based on the Japanese PV feed in tariff policy, however; further comparative research will be required to generalize the model to other renewable energy supporting policies or other renewable energy markets other than photovoltaic.

6. Conclusion

The model aims to provide a feed in tariff mechanism that is efficient and responsive developed based on market dynamics, which helps the policy to be in equilibrium. Identifying major feedback loops were essential to understand market growth constraints and bottlenecks. The model developed helps to provide a holistic understanding of the market where feed in tariff policy can be experimented to develop a resilient, efficient and responsive feed in tariff policy.

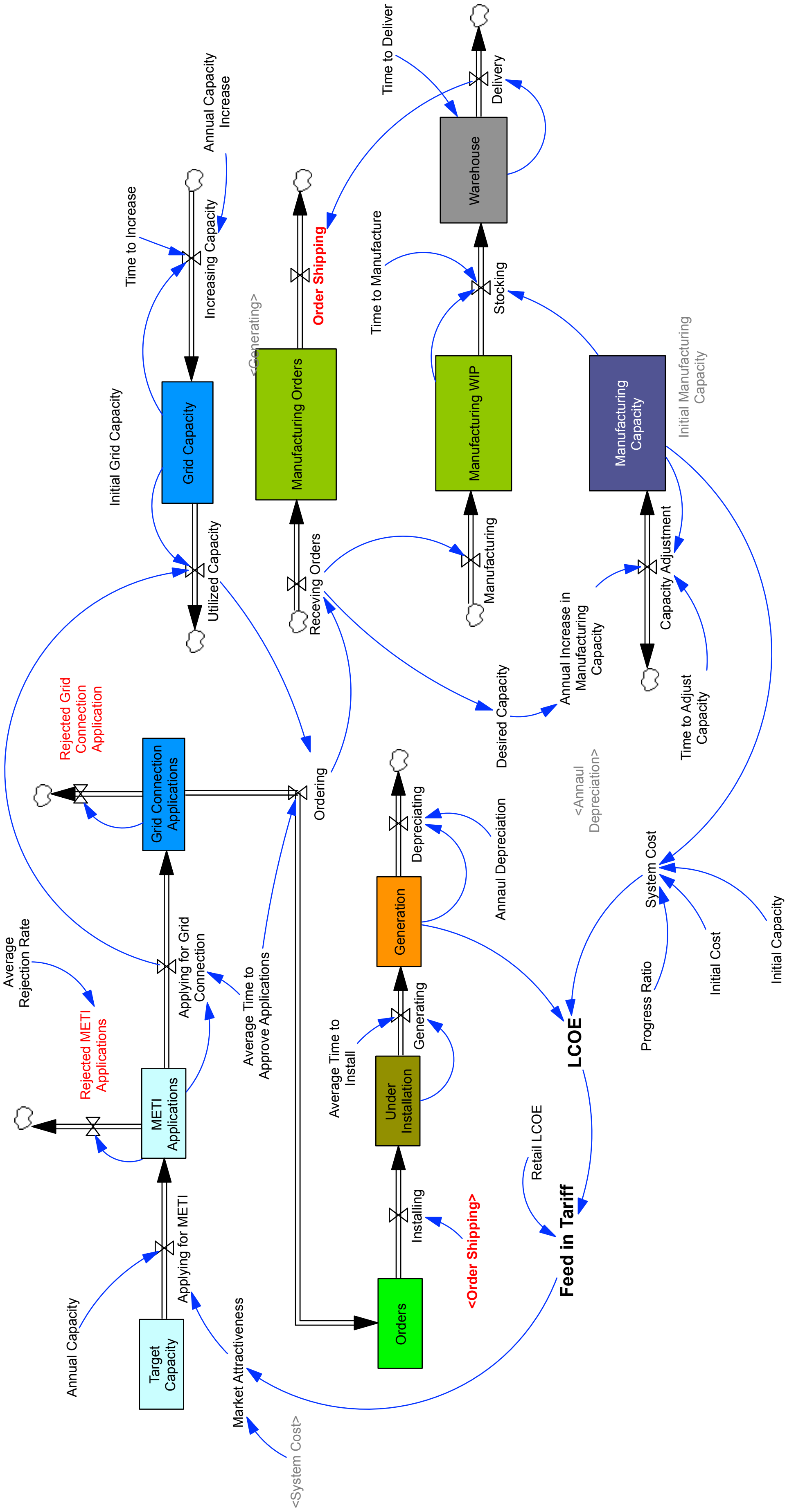

Figure 10: Photovoltaic Market Dynamics

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