A simulation methodology on grid displaced photovoltaic (PV) prospective for existing terrace house supply in Malaysian peninsular.

Abdul-Razak, AHN; Ahmad, N.A; Ahmad, S.S.; Haron, S. N; A.K Ermeey.
Universiti Teknologi MARA, Malaysia

haqqi250@perak.uitm.edu.my

Abstract. Accounting for the government’s intention towards sustainable energy development and the deployment of Malaysia’s first smart grid system, inclusive participation of residential units will transform their role from consumers to prosumers, enabling them to become “positive nodes” of the smart grid system. This paper evaluates the simulation output of a grid displaced electricity demand of a significant terrace-based housing cohort in Malaysia. Utilising Integrated Environmental Solution Virtual Environment (IESVE) as the simulation tool, solar panel retrofitted to the existing terrace houses in urban centres across peninsular Malaysia is investigated in order to identify its potential to displace current grid electricity demand, consequently shaving peak demand and reduced household’s electricity bill.

1. Introduction
Worldwide residential energy demand shares a substantial amount of the overall national demand, where Malaysian residential energy demand equated to 19% that fell within the range of 15% to 50% of global energy consumption [1]. According to the Malaysian final energy demand data, a steady increase across various sectors were recorded (21,883 ktoe in 1995 to 51,806 ktoe in 2015) [2]. This trend is expected to continue, driven by national economic and population growth, reflected by 3% to 5% annual GDP growth [3]. UN Habitat predicts that Malaysia’s urban population will reach 78% in 2030 and lifestyle shift will have a consequential impact on energy demand. Given the rising demand yet limited supply, Malaysia has set its own sustainable energy development through diversification of the energy trend mix, via Five Fuel Diversification strategy [4]. Despite this, the majority of Malaysian energy source are still fossil fuel based, which is widely known to be the main cause of environmental issue causing global warming and is exposed to volatile global energy prices [5]. Nevertheless, effort by the Malaysian government together with its leading utility company, Tenaga Nasional Berhad (TNB) are showing inclination towards renewable energy (RE) sources. Current Energy, Green Technology, Science and Climate Change Ministry aims to increase renewable energy from 2% to 20% by 2025. Malaysian residential sector final energy consumption is divided into five aggregated categories; appliances, cooking, space cooling, lighting and water heating [6]. Meanwhile, typical terrace household energy use is segregated into cooking (45%), cooling (29%), others (11%), lighting (8%) and laundry/cleaning (7%) [7]. Under the cooling category, 17% is used up for air conditioning, 10% for ceiling fan and 2% for other types of cooling devices. Increasing use of electricity to substitute Liquid Petroleum Gas (LPG) has been recorded as modern society value electricity as indispensable form of energy.
Compelled by the above issues, factors of future energy security and changes to government policy, TNB has initiated the smart grid system transformation plan [8]. Alongside the aim to achieve Sustainable Development Goals (SDG) 2030 similar to other developed countries, the transformation plan is expected to reduce carbon emission and facilitate renewable and sustainable energy production. Furthermore, smart grid implementation empowers and encourages consumers to actively participate in reducing electricity use from the grid [9]. Adopting demand side management, critical information and data linked to pricing mechanism and total energy use are relayed to the consumers thus helping them to make sustainable decision [10]. Plus, the smart grid system enables consumers to become prosumers as they can visibly identify and control their daily energy consumption aside from the ability to generate electricity on-site [11]. The activation of houses as positive energy generation nodes in the smart grid may have a significant impact on the Malaysian electricity sector, thus future terraced houses must be designed and constructed according to the requirement of the smart grid, taking full advantage of its potentials.

Considering energy related issues in this sector, many studies were engaged aiming to reduce energy demand [12], increase energy efficiency [13], and optimize residential design to adopt passive design strategies [14,15]. Nevertheless, concerns of shifting lifestyle status quo have impeded such efforts [16]. As air-conditioning (AC) system becomes affordable and energy efficient, modern society have become accustomed to this new indoor climate, leading to higher electricity use [17]. In 2016, Berkeley National Lab reported that global AC installation will reach 700 million by 2030 and 1.6 billion by 2050. Accordingly, several local studies on the terrace house dwellers revealed more than half of the survey respondents owns AC unit, with at least two units installed in each households [7,18]. These indicators show AC will remain significant and more may be installed in the future. Thus, local electricity generation to offset grid demand and transform houses as positive node is imperative.

2. Terrace house electricity household consumption and the way forward
Malaysian residential electricity end use can be categorised by refrigeration (21.1%), cooking equipment (14.7%), air-conditioning (11.9%), washing machines (10.5%), illumination (5.1%) and others (36.7%) [19]. A typical monthly terrace house electricity consumption were 455kWh [7]. Under TNB’s revised domestic tariff (Tariff A) [20], consumers pay RM 0.218/kWh for the first 200kWh (1kWh-200kWh), RM 0.334/kWh for the next 100 kWh (201kWh-300kWh), followed by a substantially higher rate of RM 0.516/kWh (301kWh-600kWh), RM 0.546 (601-900kWh) and RM 0.571 for the subsequent kWh used. Therefore, a consumption of 300kWh will cost RM 77.00, but typical consumption of 455 kWh will be substantially higher; i.e. RM 156.98. Such tariff system is expected to encourage sustainable and sensible use of electricity but as many researches have pointed out, current lifestyle shift disrupts this concept.

Abundance of studies have seen solar photovoltaic (PV) as a significant device to support increasing electricity demand, but this study will show that retrofitting PV on existing terrace house population will have a significant impact on grid demand. Following the falling and competitive solar PV price with increased efficiency (system cost for installing PV system in Malaysia fell around RM 7.5/watt [21]), it’s integration into the current and future terrace housing stock will be significant, transforming homes into positive nodes of the future smart grid. Furthermore, there is an inversely proportionate relationship between on-site energy generation, occupancy rate and commercial peak demand [2,18,22].

3. Simulation setup
The simulation for identifying amount of grid-displaced electricity is carried out via Integrated Environmental Solutions Virtual Environment (IESVE) simulation tool. IESVE is known and widely accepted as a reliable simulation tool to carry out dynamic energy analysis. Two variables investigated in this simulation process are orientation and tilt angle. The prototype for the model house for this simulation were developed based on findings of an earlier study [18]. Four models were created and
orientated along (i) Northwest-Southeast axis, (ii) North-South axis, (iii) Northeast-Southwest axis and (iv) East-West axis (See Figure 1). The population of terrace houses based on its orientation were discussed elaborately in another study [18].

Figure 1. Simulation setup of the study model.

Despite the variety of PV array currently available, thin film is selected for this simulation as it yields higher energy conversion efficiency [21,23]. Despite 24.7% efficiency have been reported using heterojunction with intrinsic thin-layer (HIT) [24], this simulation study will use solar panel model CSUN250-60P (1.64m x 0.99m x 0.04m) with 15.4% efficiency manufactured by ChinaSunEnergy (CSUN) as it is readily available. The solar arrays were placed on the roof of the study model as shown in Figure 1, with varying tilting angle. The tilt angle was set at 0°, 15° and 23°, following findings for the best tilt angle to effectively capture solar energy [25]. The simulation analysis was carried out using SunCast and Apache modules in IESVE software.

4. Simulation findings and analysis

Findings from this simulation is read together with the orientation setup as shown in Figure 1.

| Orientation | Panel Tilt: 23° | Panel Tilt: 15° | Panel Tilt: 0° |
|-------------|----------------|----------------|---------------|
|             | (i)            | (ii)           | (i)           |
| Jan 01-31   | -1.8817        | -1.8425        | -1.8783       |
| Feb 01-28   | -1.782         | -1.7662        | -1.7766       |
| Mar 01-31   | -2.0501        | -1.9983        | -2.0414       |
| Apr 01-30   | -1.9168        | -1.8818        | -1.9194       |
| May 01-31   | -1.8516        | -1.8294        | -1.8596       |
| Jun 01-30   | -1.8094        | -1.7882        | -1.809        |
| Aug 01-31   | -1.9299        | -1.8917        | -1.9336       |
| Sep 01-30   | -1.8856        | -1.8526        | -1.8751       |
| Oct 01-31   | -1.8696        | -1.8494        | -1.8707       |
| Nov 01-30   | -1.754         | -1.733         | -1.7515       |
| Dec 01-31   | 1.7265         | -1.7194        | -1.74         |
| Total       | 22.3317        | 21.9992        | 22.3284       |
| Median      | -1.8696        | -1.8425        | -1.8707       |

Table 1. Grid displaced electricity (MWh) by varied tilt angle and orientations.

Referring to Table 1, the simulation findings denoted that PV arrays installed along the North-South axis (ii) with a tilt angle of 23° yields the highest converted electricity, equating to 22.756 MWh/year and a median of 1.8997 MWh/month. The lowest yielded electricity conversion occurs in months of November and December as cloud cast affect solar radiation intensity received by the solar panels. This phenomenon occurs on all tilting angles and orientations. The simulation also show that...
panel installed along West-East (iv) with tilting angle of 0° is the least to capture solar energy, yielding only 17.2 MWh/year with a median of 1.5461 MWh/month.

5. Discussion and conclusion
The simulation finding above indicate the potential surplus energy generated on site, if considering the monthly typical terrace house consumption of 455kWh as mentioned earlier. Accounting for the data in Table 1, average electricity generated by houses along North-South axis is 1895 kWh/month. So, each housing unit will be able to store or sell back to the grid around 1440kWh of energy surplus and transform consumers into prosumers making these houses as positive nodes of the smart grid. A study in [18] revealed that existing terrace house supply orientation can be categorized into North-South (30.12%), NorthEast-SouthWest (20.77%), East-West (24.27%) and Northwest-Southeast (22.52%). Utilising NAPIC record indicating existing terrace house supply of 2,236,640 units, potential units built along North-South axis alone may be able to generate 970 GWh of electricity. However, the Feed in Tariff (FiT) substitute, Net Energy Metering (NEM) only allow for 12kWp (72 kWp max for three-phased system) of grid-linked electricity generation. Therefore, excess electricity could only be locally stored and consumed. As future Electric Vehicle (EV) becomes more attractive and relevant, excess energy can be used to charge the EVs, offsetting the need to rely on non-sustainable resources. In addition, surplus energy can be diverted to commercial use hence potentially shave peak demand via feed-in supply.

The discussion above points out the potential of terraforming these terrace houses into a positive node of the future smart grid, but more study is required from various angle, including the electrical engineering and architectural design aspect which have not been given priority in any previous research.

6. Reference
[1] Saidur R, Masjuki H H and Jamaluddin M Y 2007 An application of energy and exergy analysis in residential sector of Malaysia Energy Policy 35 1050–63
[2] Suruhanjaya Tenaga (Energy Commission) 2017 Energy Statistics Handbook 2017
[3] ERCD E R and R C D 2010 Key Indicator for Asia and the Pacific 2017 vol II
[4] Wong J, Seng Y, Taylor P and Morris S 2011 Optimal utilisation of small-scale embedded generators in a developing country e A case study in Malaysia Renew. Energy 36 2562–72
[5] Sovacool B K 2013 Assessing energy security performance in the Asia Pacific, 1990–2010 Renew. Sustain. Energy Rev. 17 228–47
[6] Suruhanjaya Tenaga (Energy Commission) 2017 National Energy Balance 2016
[7] Kubota T, Jeong S, Toe D H C and Ossen D R 2011 Energy Consumption and Air-conditioning usage in residential buildings of Malaysia J. Int. Dev. Coop. 17 61–9
[8] TNBR 2014 Tnbr insight TNBR Insight 4
[9] Stephenson J, Ford R, Nair N K, Watson N, Wood A and Miller A 2018 Smart grid research in New Zealand – A review from the GREEN Grid research programme Renew. Sustain. Energy Rev. 82 1636–45
[10] Kakran S and Chanana S 2018 Smart operations of smart grids integrated with distributed generation: A review Renew. Sustain. Energy Rev. 81 524–35
[11] Haider H T, See O H and Elmenreich W 2016 A review of residential demand response of smart grid Renew. Sustain. Energy Rev. 59 166–78
[12] Mirrahimi S, Mohamed M F, Haw L C, Ibrahim N L N, Yusoff W F M and Aflaki A 2016 The effect of building envelope on the thermal comfort and energy saving for high-rise buildings in hot-humid climate Renew. Sustain. Energy Rev. 53 1508–19
[13] Jamaludin A A, Inangda N, Ariffin A R M and Hussein H 2011 Energy Performance: A Comparison of Four Different Multi-residential Building Designs and Forms in the Equatorial Region IEEE First Conf. Clean Energy Technol. CET 253–8
[14] Rahmah W, Zaki M, Nawawi A H and Ahmad S S 2011 Indoor Environmental Conditions in
Passive Architecture Terraced House 1–3

[15] Ibiyeye A I, Mohd F Z J and Zalina S 2015 Natural ventilation provisions in terraced-house designs in hot-humid climates: Case of Putrajaya, Malaysia Pertanika J. Soc. Sci. Humanit. 23 885–904

[16] de Dear R 2011 Revisiting an old hypothesis of human thermal perception: alliesthesia Build. Res. Inf. 39 108–17

[17] Attia S, Evrard A and Gratia E 2012 Development of benchmark models for the Egyptian residential buildings sector Appl. Energy 94 270–84

[18] Abdul-Razak A H N, Leardini P M and Nair N-K C 2015 Adapting Malaysian housing for smart grid deployment based on the first nationwide energy consumption survey of terrace houses Living and Learning: Research for a better built environment ed R H Crawford and A Stephan (Faculty of Architecture, Building and Planning, The University of Melbourne, Melbourne, Australia.) pp 311–21

[19] Chong C, Ni W, Ma L, Liu P and Li Z 2015 The use of energy in Malaysia: Tracing energy flows from primary source to end use Energies 8 2828–66

[20] TNB 2016 Pricing &b Tariff TNB

[21] Ghazali A, Salleh E I, Haw L C, Mat S and Sopian K 2017 Performance and financial evaluation of various photovoltaic vertical facades on high-rise building in Malaysia Energy Build. 134 306–18

[22] Abdul-Razak A H N 2017 Malaysian residential housing for the smart grid: identifying optimization attributes for design and energy performance improvements How to face the scientific communication today. International challenge and digital technology impact on research outputs dissemination p 109

[23] Halabi L M and Mekhilef S 2018 Performance Analysis of Multi-Photovoltaic ( PV ) - Grid Tied Plant in Malaysia Performance Analysis of Multi-Photovoltaic ( PV ) -Grid Tied Plant in Malaysia IOP Conf. Series: Earth and Environmental Science

[24] Taguchi M, Yano A, Tohoda S, Matsuyama K, Nakamura Y, Nishiwaki T, Fujita K and Maruyama E 2014 24.7% Record efficiency HIT solar cell on thin silicon wafer IEEE J. Photovoltaics 4 96–9

[25] Khatib T, Mohamed A, Mahmoud M and Sopian K 2015 Optimization of the Tilt Angle of Solar Panels for Malaysia Optimization of the Tilt Angle of Solar Panels for Malaysia

Acknowledgement
This study has been made possible with funding from Performance Based Research Fund (PBRF) The University of Auckland, Universiti Teknologi MARA and Ministry of Higher Education of Malaysia