Smart Grid Integrated Vehicles

Innovation to enhance energy security, environmental sustainability, and community resilience

Knowledge Partnership Week, 20 May 2015, Manila

Toru Kubo

Principal Climate Change Specialist
Southeast Asia Department
Asian Development Bank

Years in the making

Grid Integrated Vehicle (GIV) concept and technical potential

Kempton, W. and S. Letendre. 1997. "Electric Vehicles as a New Source of Power for Electric Utilities", *Transportation Research* 2(3): 157-175.

Kempton, W. and T. Kubo. 2000. "Electric-drive Vehicles for Peak Power in Japan", *Energy Policy* 28(1): 9-18.

Singh, M., et al. 2010. "Analysis of Vehicle to Grid Concept in Indian Scenario." *International Power Electronics and Motion Control Conference*: 149-156.

Shouxiang, W., et al. 2012. "Modeling and impact analysis of large scale V2G electric vehicles on the power grid." *IEEE Innovative Smart Grid Technologies - Asia*: 6 pp.

Renewable energy expansion through GIV

Kempton, W. and J. Tomić. 2005. "Vehicle to Grid Power Implementation: from stabilizing the grid to supporting large-scale renewable energy". *Journal of Power Sources* 144(1): 280-294.

Ekman, C. K. 2011. "On the synergy between large electric vehicle fleet and high wind penetration - An analysis of the Danish case." *Renewable Energy* 36(2): 546-553.

Background: Mobility and Energy Security

- Transport sector growing rapidly in Asia; **mobility remains largely dependent on oil**.
- **Two-thirds of incremental global oil demand by 2035 expected to come from developing Asia** (IEA).
- Declining supply from conventional sources; new supply more expensive (e.g. deep ocean, shale). Prices depressed for a few years but average forecast to 2030 is above $100 per barrel.
- Oil prices affect the cost of transport and food. **The poor spend a significant portion of their income on food and fuel and are the most affected**.
- Alternative liquid fuels emerging but few viable substitutes at the scale required.

Background: Climate and Environment

- **Climate change** concerns driving countries to consider low-carbon development paths.
- Over 20% of global carbon dioxide emissions from transport. Transport sector slow to diversify energy sources.
- Many Asian cities suffering from severe air pollution levels and associated health effects.
- Globally adopted approach is to **Avoid-Shift-Improve (A-S-I)**:
    - **Avoid** the need for travel through better urban planning;
    - **Shift** the mode of transport to more efficient and lower carbon options (e.g. train, bus, bicycle);
    - **Improve** the efficiency of current modes (e.g. fuel-efficient engines).

Background: Disaster and Resilience

- Communities in developing countries have limited capacity to cope with disasters.
- Climate change impacts expected to further exacerbate disaster vulnerability, particularly in the Asia-Pacific and Africa.
- Need to invest in enhanced resilience; build redundancy

BUT

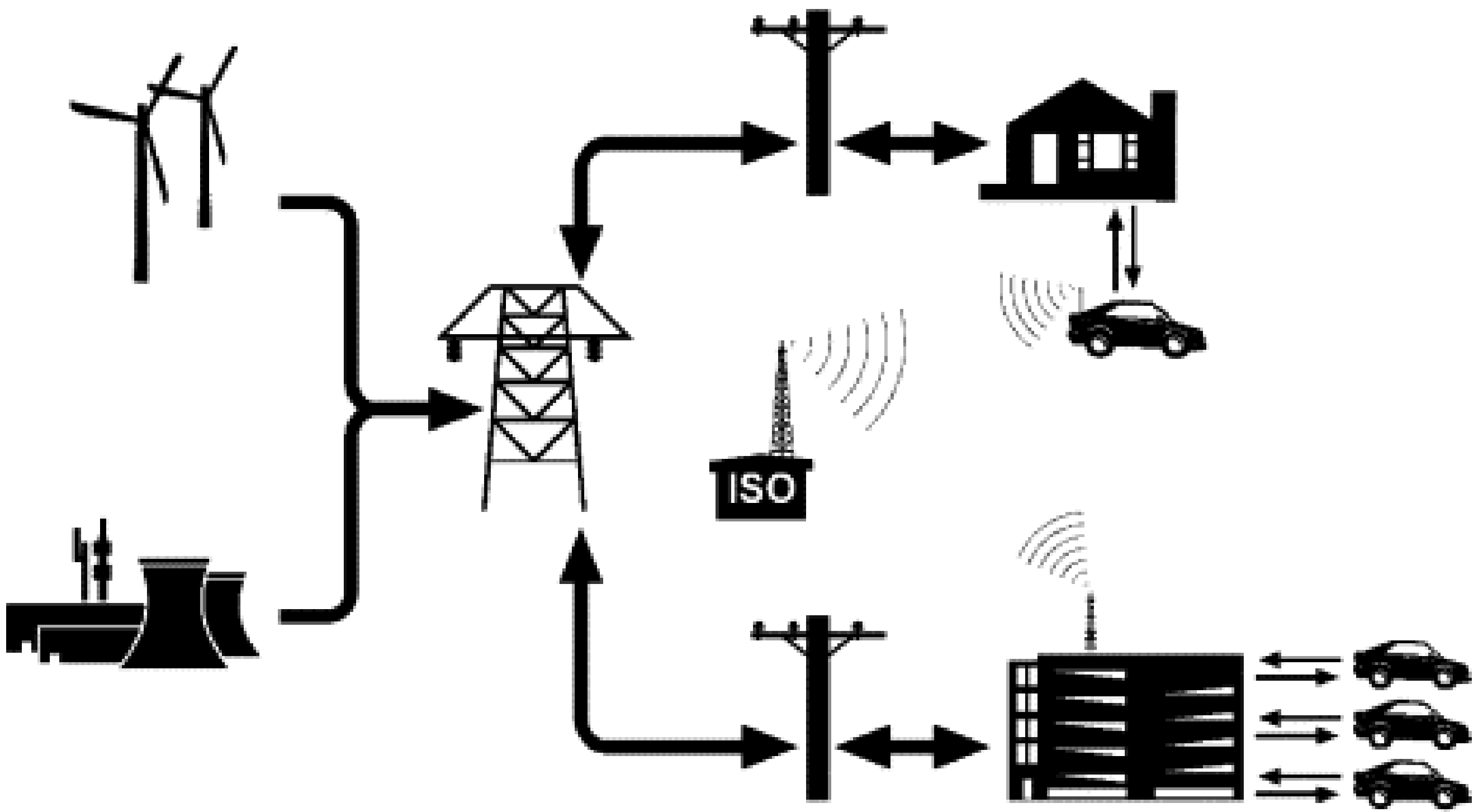
- How do we cover incremental costs?

Look at options that serve multiple core purposes, thereby spread costs and tap into different budgets/funding sources.

Smart Grid Integrated Vehicles

- **Grid Integrated Vehicles (GIVs)** are Electric-drive vehicles (EDVs) that can communicate with the power grid operator and contribute to system optimization. Also called **Vehicle-to-Grid (V2G)** services.
- Different charging patterns
  - No intervention: vehicles will charge randomly with the risk of increasing peak system load.
  - No-brainer intervention: vehicles will charge at night when system load is low; and hopefully when tariff is low with time-of-use rates.
  - **Smart** management: vehicles will charge overnight, and also when there's abundant renewable energy (e.g. windy or sunny times)
- Integrated as part of a **Smart Grid** system, the stored energy can be tapped during power disruptions and for providing peak load capacity, contributing to higher share of intermittent renewable sources.
- GIVs can also contribute to high-value ancillary services (e.g. frequency and voltage regulation) where such markets exist.

Schematic of GIV/V2G

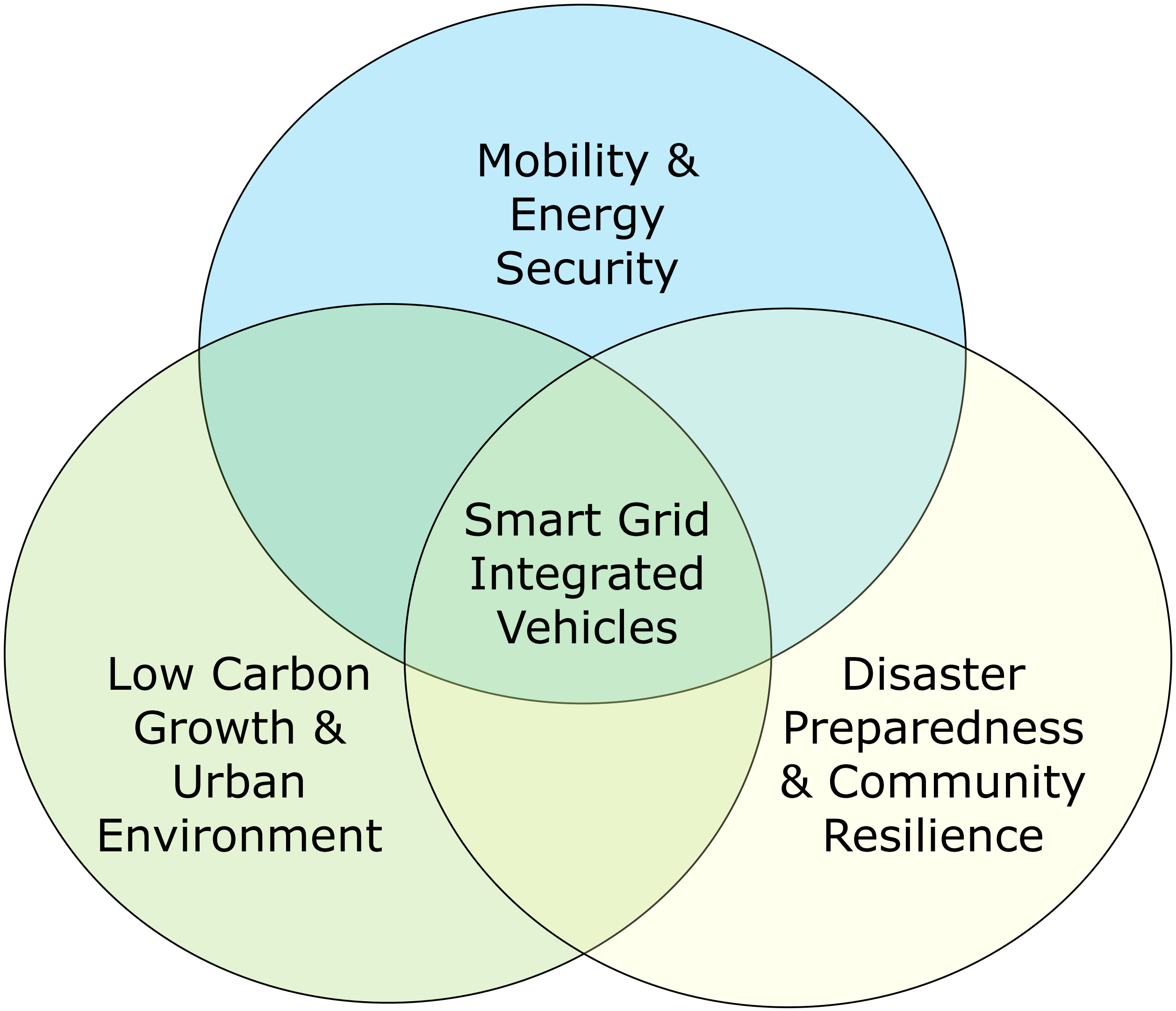


Source: Kempton and Tomic 2005

Smart Grid Integrated Vehicles (continued)

- An intermediate option, "Vehicle-to-Buildings/Home (V2B or V2H)" discharges power back to the connected buildings or homes – this can be done with equipment available today.
- Even in the U.S. where cars are used heavily, they are **in active use only 4% of the year**. Secondary value can be extracted while they are parked the vast majority of the time.
- Vehicle owners can easily control the amount and frequency of discharge allowed through an on-board controller, computer, and/or a smartphone app.
- GIVs are mobile **"storage on wheels" that can deliver energy where needed**. They can be very useful during initial **disaster response**.
  - A single Nissan Leaf (24kWh battery) can power a typical grid-connected Japanese home for 2 days and Indian home for 10 days.
- Capital costs paid by vehicle owners for propulsion; system operators only pay for usage costs.

Smart Grid Integrated Vehicles (continued)



The New York Times

Business Day

Energy & Environment

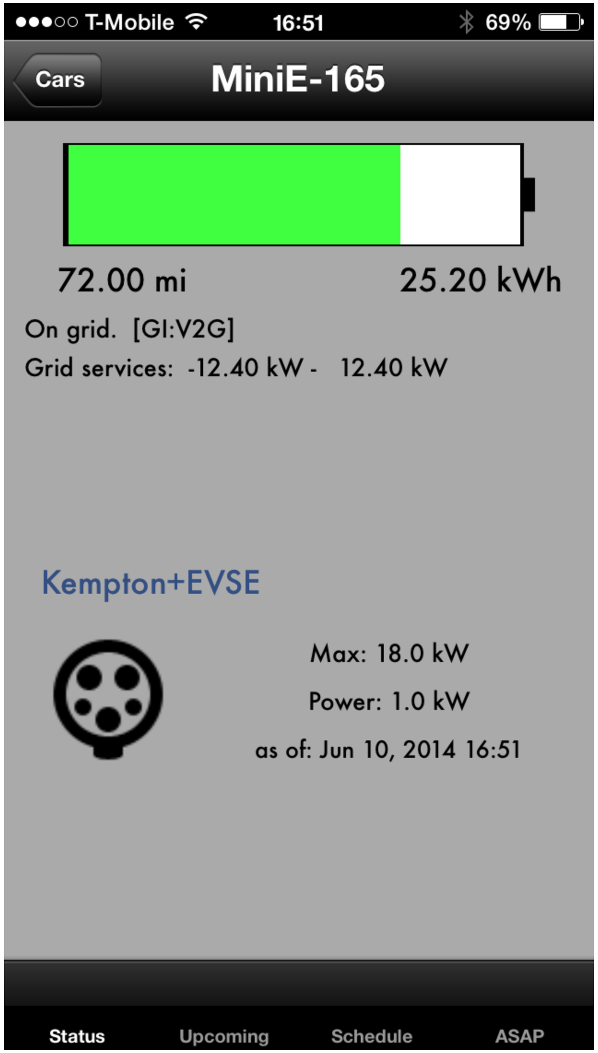
WORLD | U.S. | N.Y. / REGION | BUSINESS | TECHNOLOGY | SCIENCE | HEALTH | SPORTS | OPINION

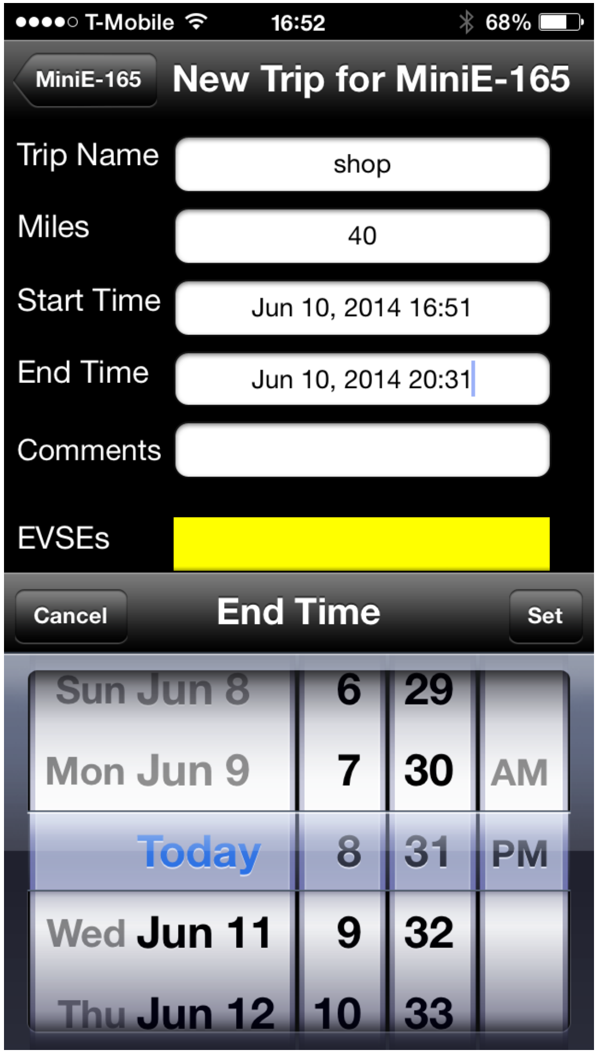
Search | Global | DealBook | Markets | Economy | Energy | Media | P

In Two-Way Charging, Electric Cars Begin to Earn Money From the Grid


MINI
165


User control app





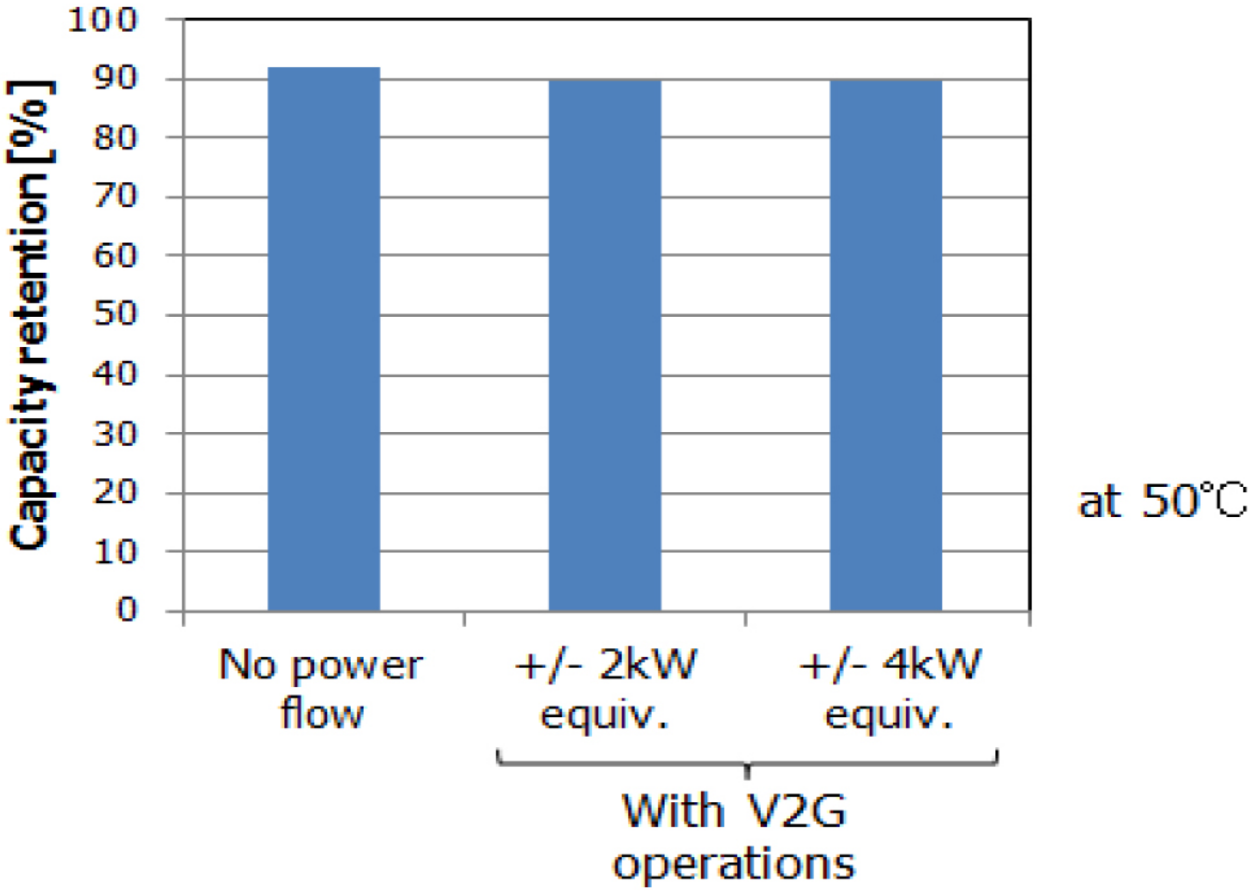
Source: Kempton 2014

Business case

Delaware, U.S. pilot project

- Electric Mini (Mini-E) vehicles at 12 kW, 1 phase bidirectional connection, provides frequency regulation services.
- Each vehicle earns approximately **$5/day or $150/month per car** if always parked.
- In use, if car is unplugged 6 hours/day, and if aggregator charges 1/2 for service, driver would still receive $56/month.
- Light load on battery for frequency regulation: ± ~5% charge. Negligible impact on battery capacity retention rate.

Battery capacity retention rate



Source: Shinzaki et al. 2015

Business case across system operators

Country/Transmission system operator	Established rate for 1MW-hour[a]	Potential Monthly Revenue[b] (existing connection[c])	Potential Monthly Revenue[b] (high capacity connection[d])
US Northeast, PJM	$30	$194	$842
Germany, RTE	€16	$140	$502
Denmark East, NORDEL	€26	$227	$815
Denmark West, UTCE	€49	$429	$1536

Source: Adapted from Kempton 2014

Notes: a) 2013 TSO market price

b) based on 18 hour daily availability, converted at 1.35 USD/EUR

c) 12kW in US and EU

d) 52kW in US, 43kW in EU

Nuvve Demos in Hong Kong

Source: Kempton 2014

Illustration of potential GIV capacity in S.E. Asia

	Number of light duty vehicles[a, b] (thousand)	Number of EDVs if share reached 5% (thousand)	Total EDV fleet power capacity[c,d] (GW)	Total installed generation capacity[a] (GW)	Proportion of EDV fleet to total capacity (%)
Indonesia	19,977	999	10.0	21.4	46.7%
Malaysia	9,865	493	4.9	13.0	37.9%
Philippines	2,771	139	1.4	12.0	11.5%
Singapore	732	37	0.4	5.5	6.7%
Thailand	9,199	460	4.6	19.0	24.2%
Vietnam	672	34	0.3	5.0	6.7%
Subtotal	**43,215**	**2,161**	**22.0**	**75.9**	**28.5%**

Sources: CAI-Asia 2014; US DOE/EIA 2014

Notes: a) 2010 data

b) Does not include 2 and 3 wheelers

c) Hypothetical case under 5% market share

d) Using average 10kW connection between vehicle and grid

Challenges

- Standards: need to develop and align necessary standards across two large industries (power and transport).
- Rate structure: user services to the grid need to be paid fair value.
- Vehicles: need increase in number of vehicle models with GIV/V2G capability in production volume.
- Battery wear: negligible for ancillary services (frequency and voltage regulation) but need to examine carefully for deeper depth of discharge.
- Smart grid: to integrate EDVs and extract full value from distributed and mobile energy storage opportunities.

Groups and companies involved

Research

- University of Delaware (US)
- Danish Technical University

Transmission and distribution system operators

- PJM (US)
- Energinet.dk (Denmark)
- China Light and Power (Hong Kong, China)

Auto companies and suppliers

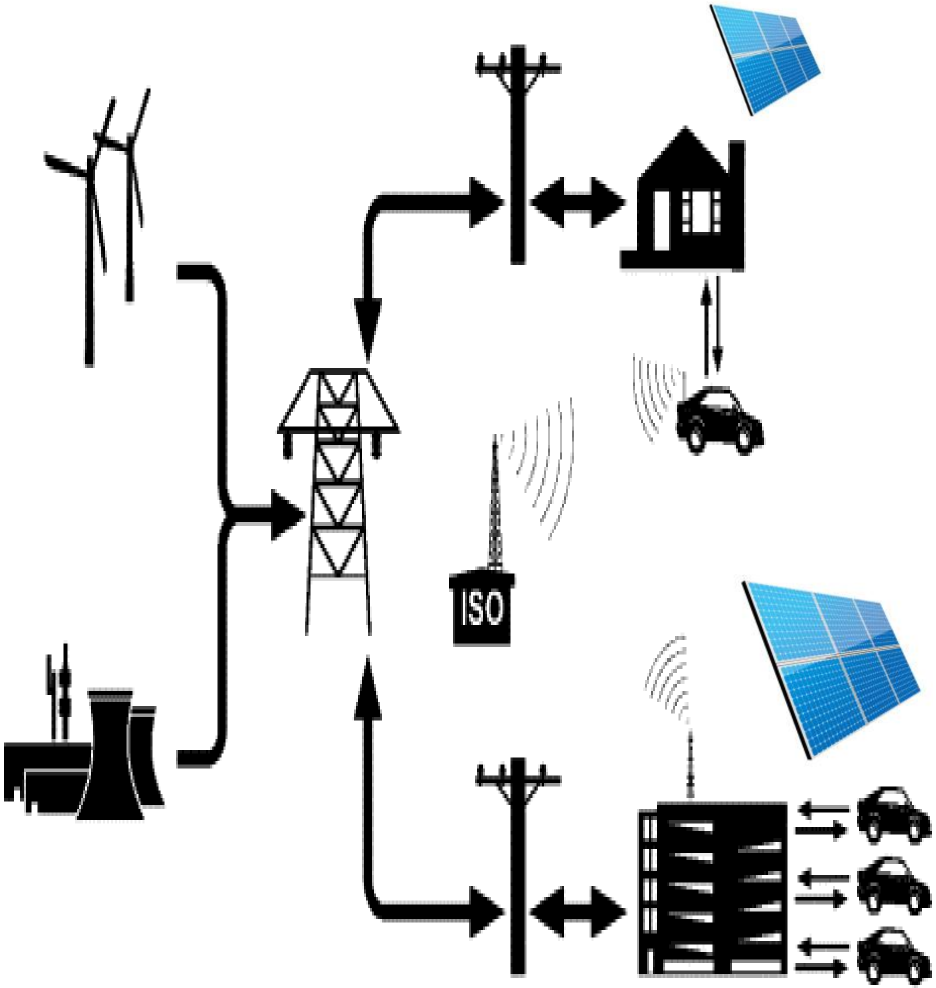
- Honda, BMW, Nissan, Toyota
- AC Propulsion

GIV/V2G service companies

- eV2G/NRG (US)
- Nuvve (Europe and Asia)

Note: this is not an exhaustive list; e.g. almost all major automakers have EDV models and are involved in partnerships to develop common GIV standards

Food for thought:
Partnerships to promote SGIV in the Asia-Pacific

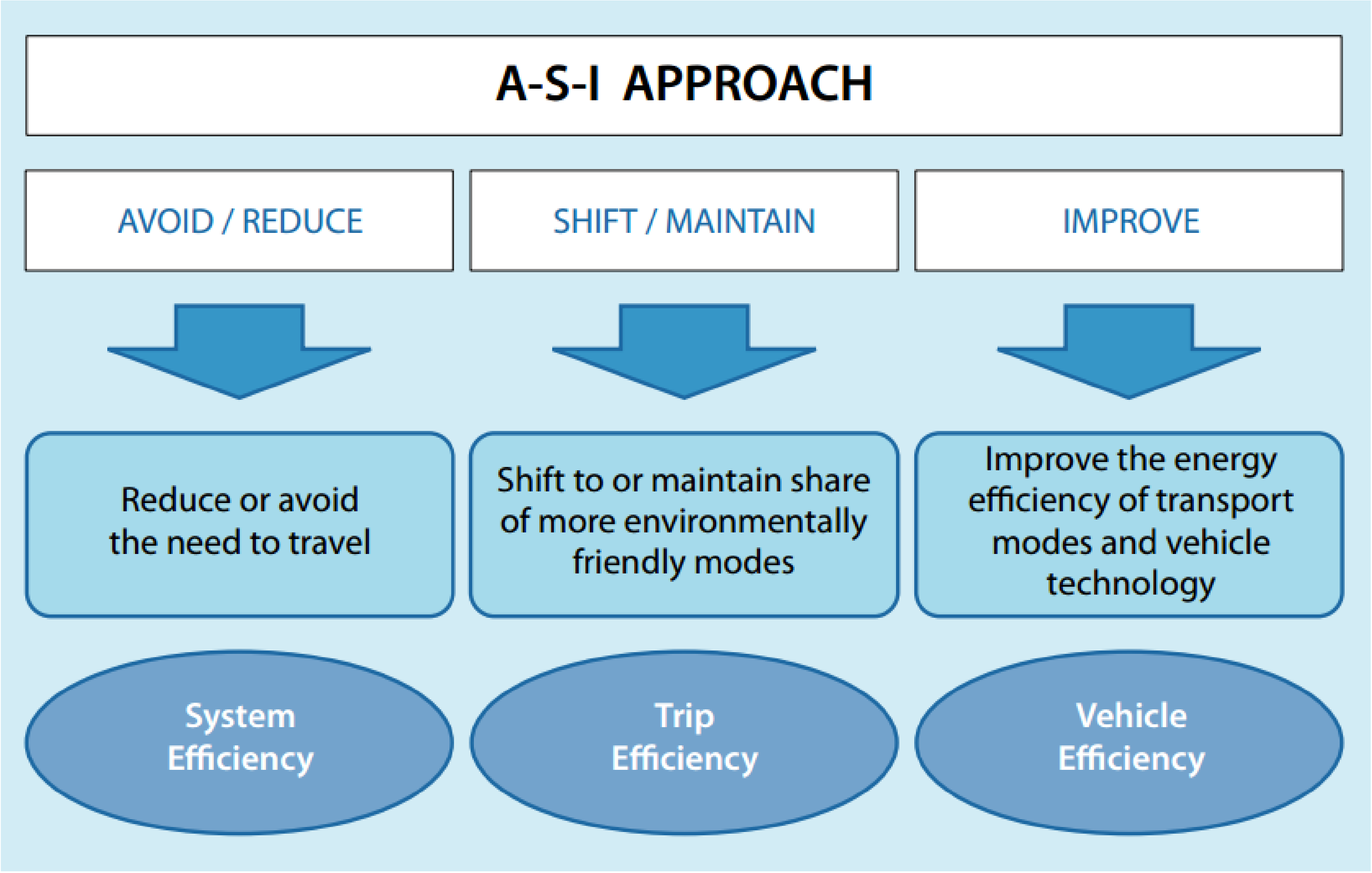


THANK YOU!

tkubo@adb.org

Additional Slides for Discussion

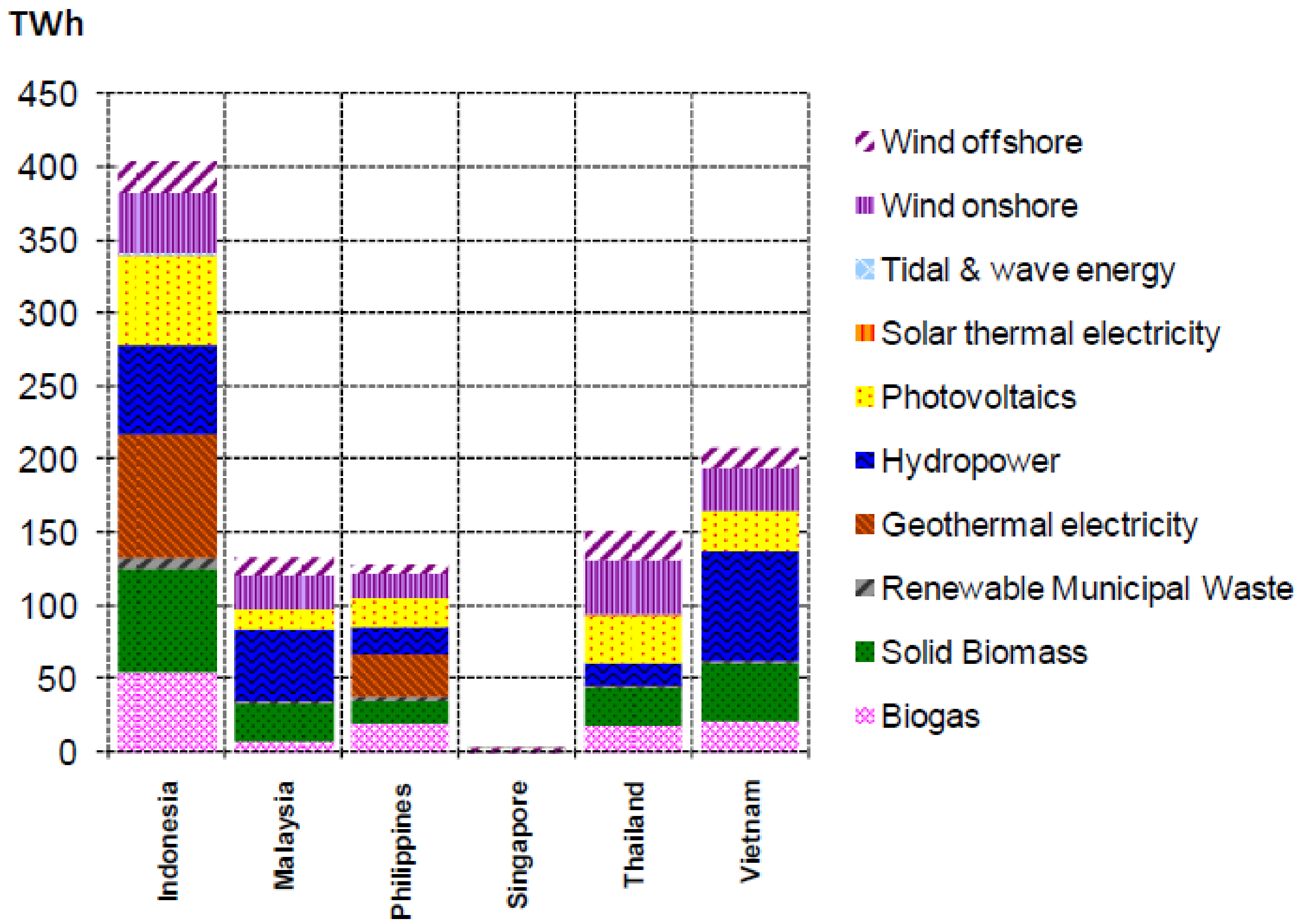
Sustainable transport solutions



Source: GIZ 2011

RE potential in selected ASEAN countries

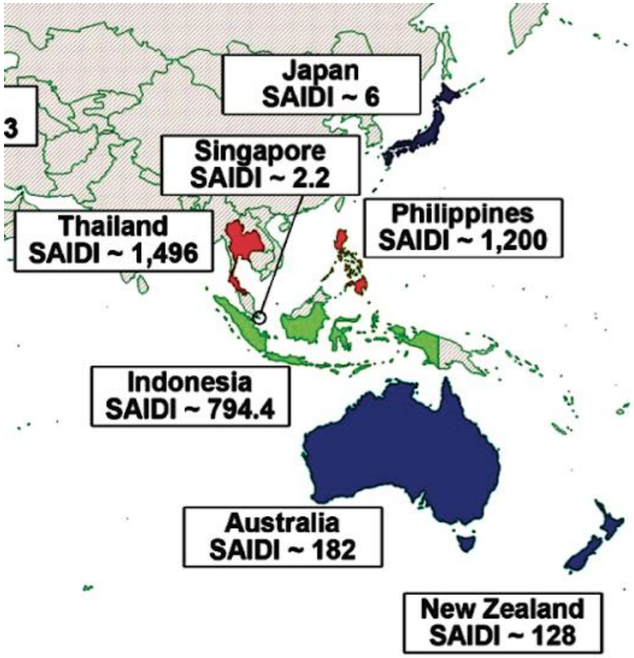
(Realizable potential by technology to 2030)



Source: IEA 2010

Backup generators in developing countries

- Many industrial facilities and commercial/residential buildings in developing countries have backup generators.
  - South Asia study (Nexant, 2003): 92%, 76%, 64% of the industrial installations had standby generation capacity in Sri Lanka, Nepal, and Bangladesh, respectively.
  - Sub-Saharan Africa study (Foster & Steinbuks, 2009): generation equipment by firms accounts for about 6%percent of total installed generation capacity and more than 20% in 6 countries.
- Cost of own generation is very high.
  - \$0.66-1.08 per kWh in Sri Lanka.
  - \$0.30-0.70 per kWh in Sub-Saharan Africa.



SAIDI = *System Average Interruption Duration Index.* Total number of minutes per year of outage experienced by an average customer; explicitly excludes major events (hurricanes, earthquakes)