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Fleet Electrification through FleetGrid

ABB Digital Transformation Group

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Summary:
For many city bus operators, the move to electric buses is an obvious choice: decreasing pollution and lowering total cost of ownership (TCO) are all good reasons to act without delay.

But the situation of delivery fleets is much more complex. They face difficult issues and financial challenges while converting their vehicles from Internal Combustion Engine (ICE) to Electric Vehicles (EV). In addition to some operational risks, the TCO is expected to be higher for electric vehicles for the near future.

Despite these challenges, the transition to EVs is inexorably moving forward. The main drivers of this change are regulations, incentives and desire to be a "good corporate citizen", and, ultimately, expectations of lower TCO, especially with significant fluctuations in the price of traditional fuels. Adoption of alternative fuel vehicles, including electric trucks, has been on the rise.

Fleet operators, who have begun the transition to EVs, need to take advantage of new energy management, energy storage and generation capabilities in order to decrease TCO. They must use new planning tools to properly assess the impact of their rollout on the infrastructure and to enable optimization of capital expenditure (CAPEX), operating expenditure (OPEX), and in some cases, Green House Gas emission (GHG). The difference between careful planning and lack of it can have significant cost impact. The cost of energy for two identical facilities in the same location with 50 identical EV trucks and with identical energy consumption can vary from $0.6 M to $ 2M. Locaton can further affect this and increase the difference from $0.3 to $2 M.

It is still extremely difficult, if not impossible, to truly optimize GHG emission due to lack of data. To enable optimization of GHG emission, utilities will need to provide much better information and tools to estimate GHG emission based on the location, month, time-of-day, weather, and demand.

Regulations and incentives
There are many examples of regulations and incentives driving the transition to electric vehicles.

The European Union (EU)'s target is to reduce GHG emissions by 40 percent by 2030, and as much as 90 percent by 2050. This is also accompanied by individual clean city initiatives, driving the policies ranging from specific targets for reduction of GHG emissions to a complete ban of diesel or petrol cars in city centers (Oxford City Center Petrol Ban).

The first ban of diesel cars in Germany was imposed in Hamburg, in May 2018. This was followed by additional bans in Cologne and Bonn in November. Since then, there have been many other regulations banning or limiting the use of diesel cars, which will be enforced starting later in 2019 in Mainz, Stuttgart, Frankfurt, Berlin, and other areas.

There are other examples of the regulatory pressures and incentives driving the transition. In Shanghai, the cost of a license plate for an ICE car can reach $14,000 and more through the auction system, while the separate allocation of license plates for electric vehicles makes it relatively easy to obtain them for free. New York City's OneNYC plan requires the City to reduce transportation-related GHG emissions by half in 2025, and by 80 percent in the decade after that.

These restrictions are accompanied by various incentives and funding initiatives. For example the California air resource board has approved significant funding for low carbon transportation, with the most recent initiative (January 2018) allocating $1.7 billion.[1]

(1) https://ww2.arb.ca.gov/our-work/programs/california-climate-investments/cci-funded-programs

In addition ING and the European Investment Bank are contributing €300 M to support projects with a "green innovation element" in Europe's maritime sector, which includes port transport.(2) Green Bonds issued by Bank of America (BofA), European Investment Bank, and others, reached USD $180 billion by the end of 2016 and were expected to add $150 billion in 2017.(3)

Transition is real
One of the most visible and large-scale early deployment examples was that of electric garbage trucks in preparation for the Beijing Olympics in 2008. At that time, Beijing deployed 3,000 garbage trucks converted to battery powered electric drive trains.

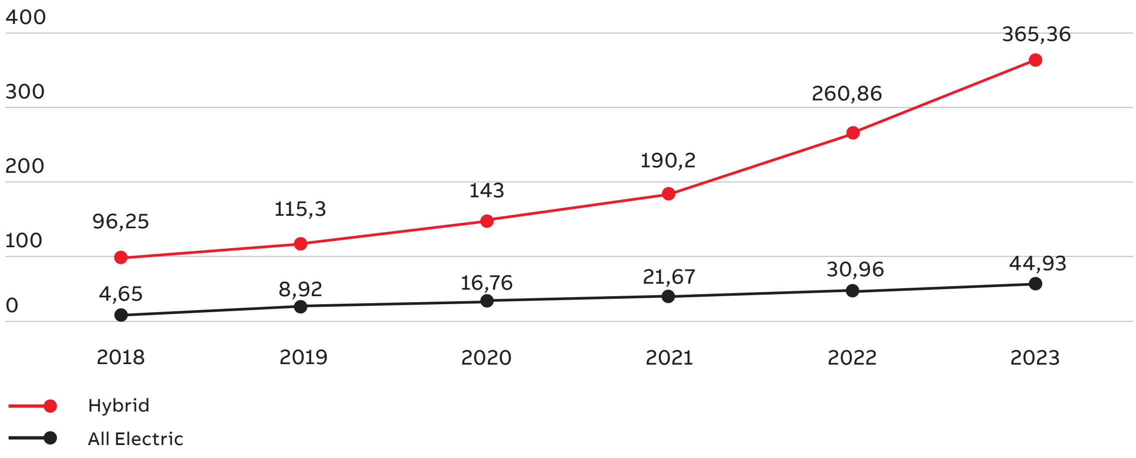
In Europe, Emoss began converting its diesel trucks to electric in 2012 for its customers. In London, UPS has converted nearly one third of its delivery vehicles from diesel to electric and has been running extensive trials. Encouraged by the outcome, UPS, together with Arrival, is rolling out a fleet of modular electric delivery vehicles with a range of over 150 miles. The plan is to deploy 35 trucks in London and Paris in 2019.

Walmart announced that all of its trucks will be powered by alternative fuels by 2028. The company ordered 15 Tesla Semi electric trucks for U.S. and 40 for Canada. In addition to Walmart, UPS placed an order for 125 Tesla Semis, Pepsi for 100. Additional orders were placed by J.B. Hunt Transport, FedEx, Deutsche Post (DHL), and Anheuser-Busch. UPS has also ordered eCanter electric trucks from Daimler.

For operators of city bus fleets, the decision is usually easy. If they have sufficient energy supply available, TCO of electric buses is typically lower than ICE. If energy supply is insufficient, in most cases, careful planning of a microgrid will allow them to lower their TCO by moving to electric vehicles.

For fleet operators of delivery trucks, the decision process is much more complicated. The first question they ask is about range versus charging infrastructure. For some, that issue is easy to solve – the distance that their trucks travel is lower than the current typical ranges which allow them to completely rely on their own depot-based charging. This is typically true for local delivery, utilities, and local public transportation fleets (see Chart 02). Others have to wait because of insufficient infrastructure. This infrastructure is being rolled out at different rates and geographical density in different parts of the world calling for different strategies in EV rollout.

EV Trucks Annual Shipments (in Thousands)



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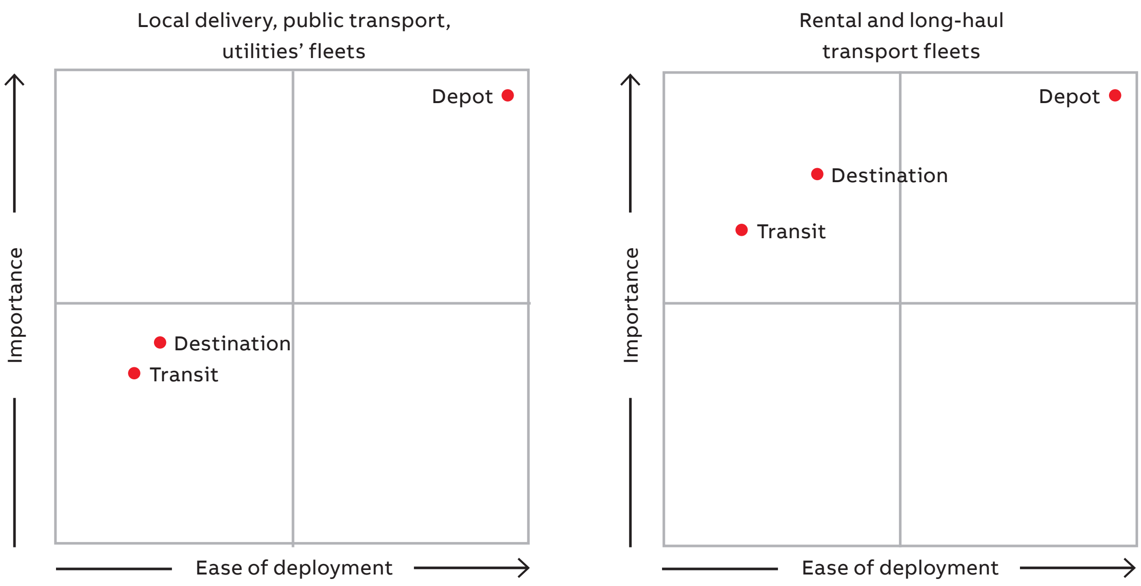
Source: Global Electric Trucks Market, TechNAVIO 2019

(2) https://www.eib.org/en/infocentre/press/releases/all/2018/2018-036-ing-and-eib-provide-eur-300m-to-finance-green-shipping.htm

(3) https://www.weforum.org/agenda/2017/07/what-are-green-bonds-explainer/



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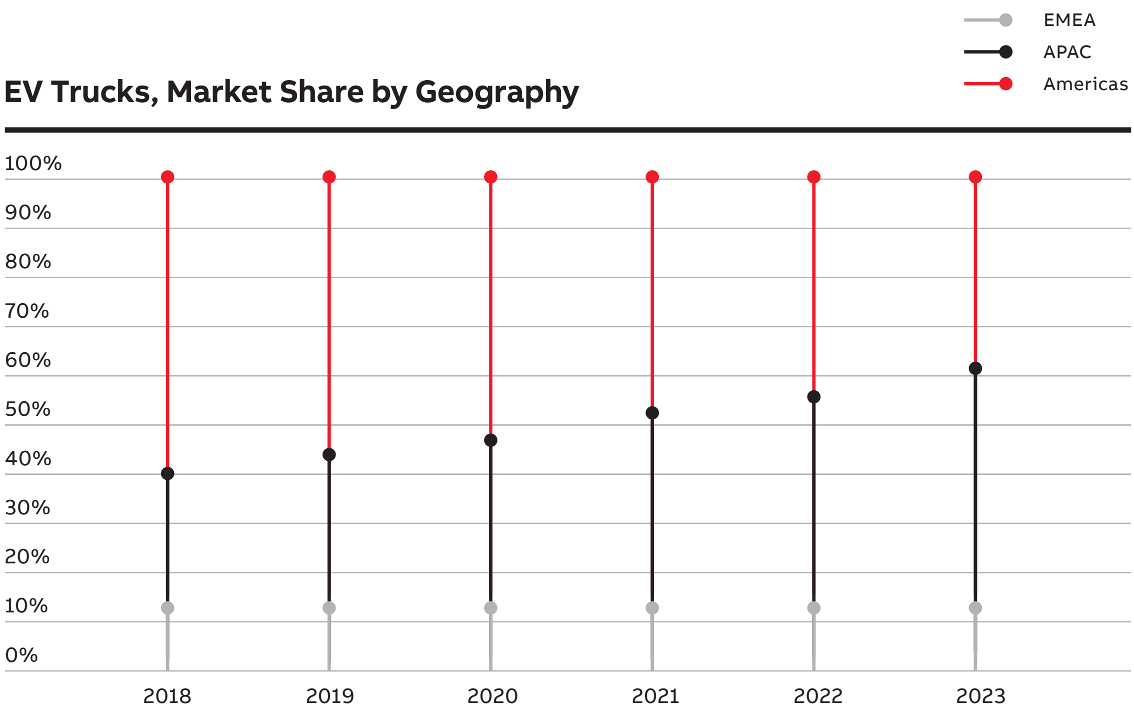
Importance of availability or EV chargers at the locations vs ease of deployment of charging infrastructure based on the fleet type.
Source:
ABB Analysis, 2018

UPS, in particular, has announced significant commitments to electrification of its fleet. In addition to the trials in London and Paris, the group announced a partnership with Thor Trucks (class 6 trucks) and a binding agreement to buy 950 vans and trucks from US-based Workhorse.

Daimler Trucks North America delivered the first eM2 truck to Penske Truck Leasing in December 2018. Penske initially ordered 10 eM2 medium-duty and 10 eCascadia heavy-duty semi-trucks. The eM2 is designed for local distribution and last-mile logistics and has a range of up to 230 miles, while eCascadia has a range of 250 miles and has a gross combined weight of 80,000 lbs.

Considering the current TCO of eTrucks, this process is only going to accelerate with eTrucks' TCOs becoming closer to ICE Trucks' TCO and as a result of a better understanding of the operational implications. However, as these parities are expected to be realized at different times in different geographies, and as regulatory forces will continue to operate differently in different jurisdictions, so will the rates and intensities of trials and deployments. Fleet operators need to consider these differences when planning their trials and consecutive rollouts.

Deployment considerations
Those that can rely on their own charging infrastructure at their own facilities are still facing many issues. While some issues are outside their



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Source: Global Electric Trucks Market, TechNAVIO 2019

control (energy availability from utilities and tariffs), many others can be managed by fleet operators directly (type of charging infrastructure, software to control local non-EV load, power generation, energy storage, and EV charging timing and rate.)

Deployment of charging infrastructure can be cumbersome and quite expensive. Assuming that there is a sufficient energy supply, an average cost of infrastructure needed per charging station typically varies between $10,000 and $18,000, but in some cases can exceed $25,000. In case of adding local storage, photovoltaic (PV) and other local energy generating capabilities, additional costs can quickly climb to $1 million and can be much higher per location. Costs of some elements of the infrastructure are spread across all charging stations. Consequently, while the initial rollout might be quite expensive, subsequent additions may have much lower costs per charging station, assuming sufficient planning during the initial infrastructure design and buildout.

Unfamiliar operational differences such as maintenance and time for charging, create additional complexities and costs. While most experts expect that costs of maintenance will be lower for electric vehicles than for ICE vehicles, the exact difference is still not clear despite many trials. In addition, commercial deployment, especially into highly time sensitive operations such as logistics requires retraining of service personnel, setup of new processes and new maintenance activities. This might require even deeper changes of loading, scheduling, and distribution of planning processes due to limited ranges, potential change in load capacity, and “refueling” time.

In some locations, there is insufficient supply of energy from the grid. In that case, an operator might have one of these two choices:

- Pay the utility company for upgrades. This can amount to multimillion-dollar investments and long deployment times. However, in many cases this can be avoided, and the second option below might be applicable.
- Add local energy storage and possibly power generation capabilities. While this is expensive, it can also further increase flexibility in how/when vehicles are charged, increase resilience of the infrastructure, and reduce long term costs of energy, by using various optimization techniques and enable the fleet operator to potentially provide value added auxiliary services to the grid.

Operating efficiency and cost optimization can be accomplished only through the use of sophisticated optimization tools relying on multiple

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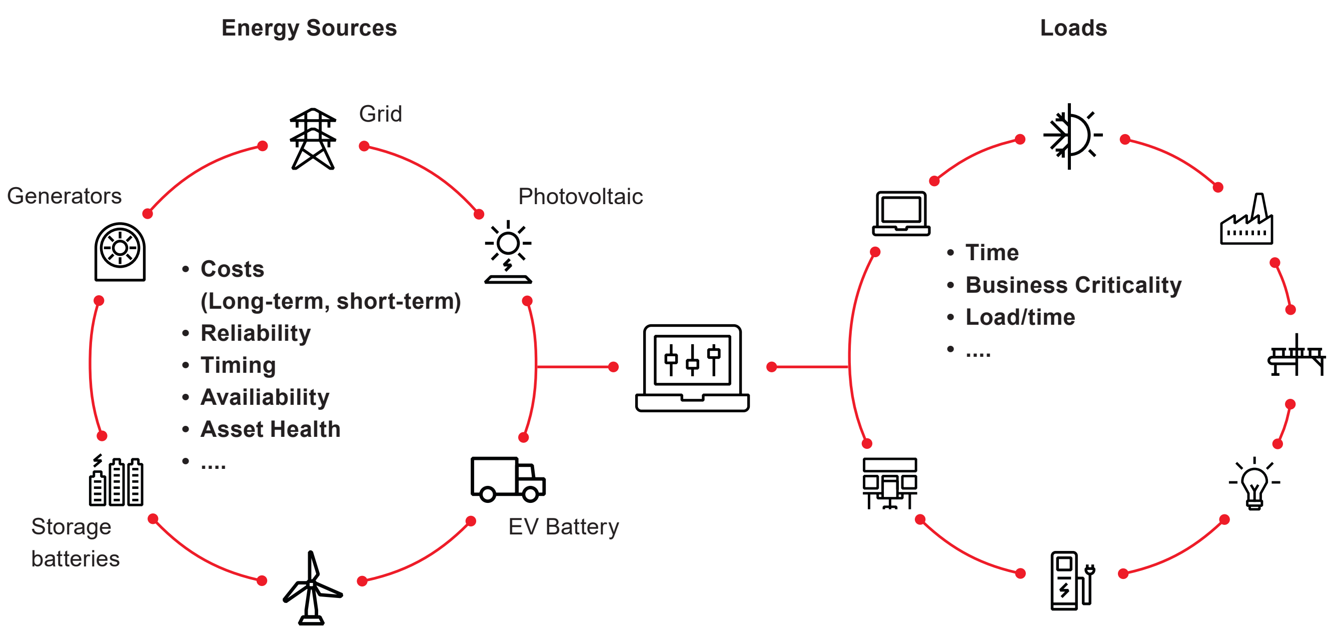

intelligent agents (route and load planning; energy optimization for charging; load control for charging infrastructure and facilities; energy consumption forecasting based on weather, routes, and loads, etc.).

Many operators who are currently focused on better understanding their TCO are lowering their energy costs in different ways that can be categorized as either software-only based, or software and energy storage, and generation based:

- Use software to optimize schedule and charging of the fleet to minimize total costs of electricity. Combine it with time-shifting of other local loads and even use energy stored in electric vehicles to accomplish peak shaving. This approach is possible only when the total amount of energy required for charging all the vehicles, plus minimum facility load during the charging time (distributed over the charging time) is not higher than the total energy available from the utility company.
- In addition to the optimization software, installing additional energy storage and generating capabilities can solve not only the energy availability issue, but in some cases can further cut the total costs of energy, via peak-shaving and other techniques. Here, timing of the upgrades linked to the increase in the number of operational electric vehicles, availability of batteries (possibly recycled from initially deployed electric vehicles) for local storage and expected changes in available rates schedule from utilities need to be considered.

Regardless of the energy availability and associated upgrade costs, the total cost of ownership of EV trucks in most cases is and will be higher for some time. This creates additional pressure on fleet operators to lower their cost of electricity as much as possible.

Balancing these complex requirements such as initial investment, operating costs and costs of energy demands careful analysis and planning using analytical tools. The analysis needs to address both the near-term and long-term requirements using energy supply/demand data and planning, available tariffs, GHG emission data for the relevant utilities (based on demand/timing), and design tools to:

- Minimize near-term and long-term investment risks and costs.
- Decrease operational risks (resilience).
- Optimize Green House Gas emission vs. operational costs such as the:
  - Cost of energy overall.
  - Cost of operating and maintaining electric infrastructure.

Analytical tools need to be flexible enough to allow prioritization of often conflicting objectives. In particular, prioritization between total CAPEX (and its timing) versus OPEX, as well as differentiating between EV's direct CAPEX (or OPEX), OPEX for energy, CAPEX for energy, etc. Similarly, prioritization between total financial impact and environmental impact should also be considered.

Most of the software required for that analysis is the same as the one that needs to be used for "near real time" operational control of EV charging, local load, and local energy storage and generation.

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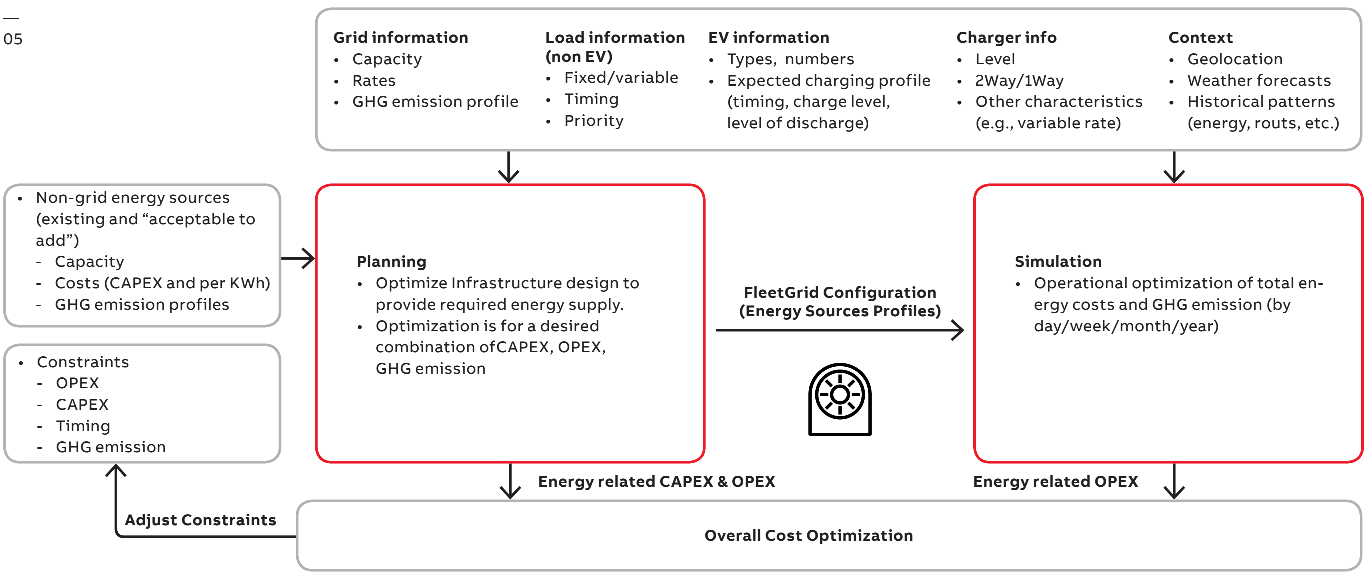

Based on our extensive financial analysis of many different cases, it is critical to make sure that the charging infrastructure supports variable charging rates, especially when the total load from charging electric vehicles reaches a certain critical mass. When possible, an obvious solution to avoid high energy charges is to schedule all charging during the time periods with the lowest energy rates. This by itself, however stops working once the total load exceeds pre-negotiated capacity. Further optimization of total loads across days, weeks, and even months will be needed.

Financial Analysis
We conducted our analysis for different types of facilities, locations, number of vehicles, charging infrastructures, and tariffs, using actual energy consumption. We ran multiple simulations to better understand the impact of different levers that a fleet operator uses to lower the cost of energy required to charge their trucks' batteries. While the levers are simple, their interdependencies create a powerful set of tools that allow significant cost savings.

When deciding on trials, an operator must set specific objectives before selecting a site. Not surprisingly, selection of the site has significant implications on energy costs. Depending on the objectives, simplicity of the energy optimization solution might be of primary concern versus the ability to test much more complex cases. For example, for some sites, optimization of energy costs requires only the simplest scheduling software, while for others, it will require much more complex algorithms and, in some cases, an investment in local energy storage and power generation might also be required to further decrease the annual costs of energy. This also points to other critical elements for the selection of new sites: energy supply and available tariffs.

Our extensive simulations, per chart 06, have confirmed unequivocally that for a given location and specific tariff, the key levers are:

- Time of charging. When do we start and stop charging? This could mean multiple start-stop times for each truck and charging station, and different times for different stations. According to our simulations using just this lever can decrease energy costs in most cases by at least 25%.
- Rate of charging. This seems to be one of the most powerful levers. Software has to be able to dynamically change the rate of charging for each charger. In addition to energy savings, there is evidence that slower charging extends the life of batteries. Charging rate, combined with the time-of-day lever led to annual energy costs difference of over 50%.
- Other loads' control. For example, changing shifts that require use of high energy consumption equipment, changing HVAC setting, etc.

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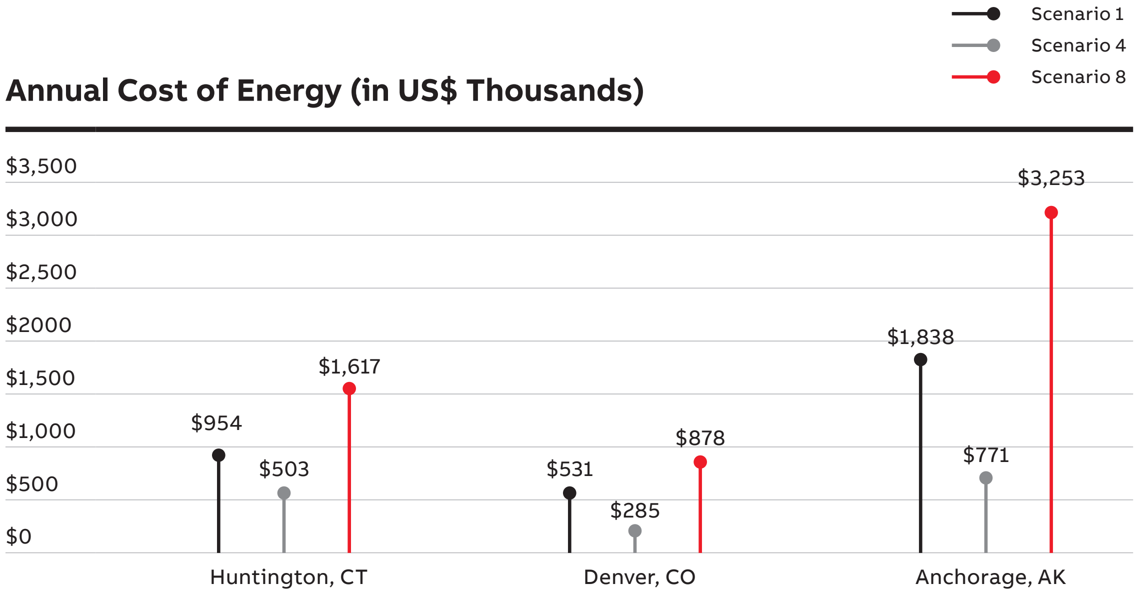
Annual Cost of Energy (in US$ Thousands)



Examples of Annual Costs of Energy at Different Sites
Assumes identical facility energy consumptions with identical trucks and identical usage patterns
Scenario 1: 50 Trucks, 50 Level 3 chargers, no energy storage, no local generation, no optimization
Scenario 4:50 Trucks, 50 level 3 chargers, no energy storage, no local generation, some optimization
Scenario 8: 100 Trucks, 100 level 3 chargers, no energy storage, no local generation, no optimization

- Energy storage. While expensive, this can also be one of the more powerful tools to lower the total cost of energy. For some realistic simulations, we saw payback time of less than 4 years (assuming 10% cost-of-money).
- Local energy generation. Photovoltaic generation and other energy sources can also contribute to lower costs. However, in many cases this investment won't be necessary or even beneficial, unless an additional benefit of resiliency is considered.

The below data represents some key insights: (We ran the simulations for 50, 75, and 100 trucks and for multiple types of chargers. The chart 07 is for 50 trucks and for 50 KW chargers. The conclusions about key cost drivers for other combinations of trucks and chargers are similar.)

Annual Energy Cost (in US$ Thousands)

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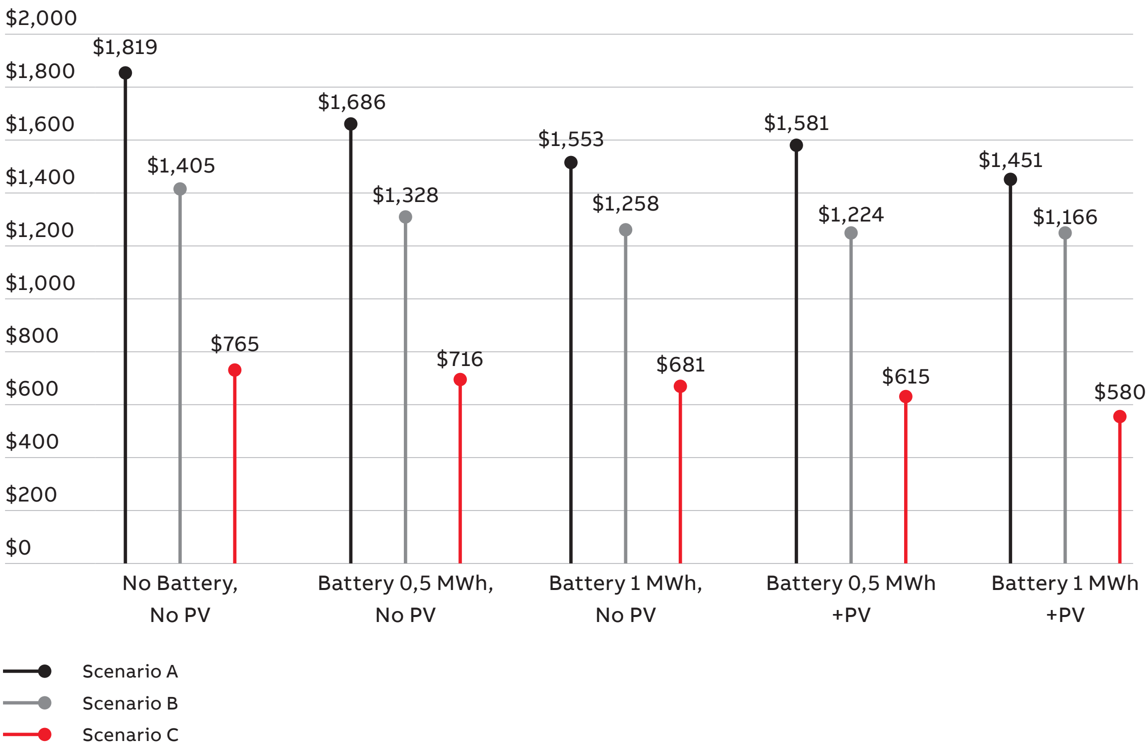
Southern California Annual Total Cost of Energy Facility + Fleet Charging



Scenario A: No optimization
Scenario B: Time-of-day On/Off optimization
Scenario C: Time-of-day On/Off and rate of charging optimization
Assumptions for these simulations: 50 Trucks, facility energy consumption based on real data

Infrastructure Cost Recovery Analysis (Years to recover)

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08

Title	Battery 0.5 MWh	Battery 1 MWh	Battery 0.5 MWh + 600 KW PV	Battery 1 MWh + 600 KW PV
Scenario A	4	4	11	8
Scenario B	7	7	14	13
Scenario C	11	12	17	16

Weighted Cost of Capital at 10%
Economics of batteries can be significantly impacted by their characteristics (e.g., discharge rate)

Conclusions

Fleet operators need to carefully plan their EV rollouts. The requirements and constraints are not static. As additional trucks are deployed with the passing of time, many important variables that are a part of the analysis change. These include energy demand, tariff changes, costs of local storage, capabilities of chargers, costs of local energy generation, etc. Consequently, fleet operators need to:

1. Set clear objectives for the deployment around energy consumption, environmental impact, financial objectives and constraints.
2. Understand short-, medium-, and long-term energy availability and tariffs.
3. Conduct detailed planning of key infrastructure elements based on objectives and identify strategies to meet the objectives by using analytical software to analyze infrastructure deployment strategies. It is critical to conduct the planning analysis by carefully considering the timing of EV's deployment and time-based changes in tariffs, costs and the capabilities of the infrastructure. Carefully consider the timing of photovoltaic and other energy sources deployment, as they can contribute to lowering of costs, and need to be considered in initial and subsequent planning. However, in many cases this investment won't be necessary until the future deployment of additional vehicles, chargers, or changes in tariffs.
4. Use analytical and control software to minimize the costs of energy through (near) real time control of charging (timing and rate), of other loads, of local storage (including EV's), and, if available, of local generation capabilities.
5. Monitor:
    a. Cost of batteries, PVs, and other energy storage and sources.
    b. Tariffs, and assess for additional changes to the existing infrastructure (for example, adding local storage or energy generating capabilities).

To address these complex requirements, EV fleet operators need an optimization software solution that understands tariffs, operational constraints, and the impact of weather on energy consumption by facilities and EVs. Such a solution should also be able to interface with relevant software like route planning and scheduling. ABB's FleetGrid software was designed with those specific requirements in mind and can provide this functionality to EV fleet operators.

Fleet operators thinking long term about their EV strategy also need to consider the operational implications of installing local energy storage, generating energy, and managing capabilities. As the infrastructure becomes more complex and critical to their operations, while also being outside of their core competencies, they should consider potential outsourcing strategies.

This also aligns with another trend that we are observing. As more and more fleet operators and other facilities (e.g., manufacturing) add local energy storage, generating capabilities and local micro grid infrastructure, the face of the global grid will change. Interconnectivity or a network of many microgrids and power generation sources will change the topology of national grids. As local micro-grids become more and more sophisticated, their operations will require skills that are not the core competencies of typical owners/users across many industries. This will create new Energy-as-a-Service (EaaS) opportunities for non-regulated power companies, drastically changing the entire power utility landscape.

Utilities and governments have also significant roles to play. They need to provide enough information about energy availability today and in the future for planning, data on GHG emission correlated to the time-of-day, season, and demand. Similarly, to enable real time (or daily) optimization against GHG, they also must provide daily forecasts based on weather, as well as the current and expected status of the energy generating infrastructure and the grid.

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Electrification of mobility is not only a key priority to comply with increasing regulation but also provides a new market opportunity for established players and innovative new entrants.

Georg Kube
Global Vice President
Industrial Machinery & Components
and Automotive Industry
SAP SE

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I totally support and endorse your white paper and think that there is significant merit in the arguments.

Professor Reza S. Abhari
ETH Zurich

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The direction of travel for EVs is clear but we know from talking to our fleet customers that many are struggling to find their way through the implications of a roll out at scale. New business models to support the emerging EV technology alongside new ways of generating, storing and distributing power are creating opportunities for businesses to make their energy work to achieve their business goals.

Patrick Bevan
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Centrica Mobility Ventures

Let’s write the future of digital industries.
Together.

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