The Viability of Electrification for Industrial Off-Road Vehicles in Construction

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Federal and State legislation has been passed limiting the prospective propulsion options for heavy industrial off-road vehicles that general contractors can operate on the jobsite. The interest behind this research project is the viability of introducing fully electric off-road construction vehicles into the heavy civil construction industry and if the timeline for implementation is realistic or optimistic. As new rules and regulations pertaining to the future emissions requirements of civilian and commercial vehicles effect the country, the construction industry is spending billions in order to develop (and are currently developing) fully electric off-road industrial vehicles (dozers, front loaders, scrappers, dump trucks, etc.) to meet the emissions goals set forth by our governing bodies. In the heavy civil/industrial industry, general contractors rely on their vehicles to be reliable, cheap, and easy to maintain. In this study, six respondents from five different general contractors were interviewed to assess the attitude of the industry from the perspective of the people who purchase, operate, and utilize these vehicles. The results of each interview demonstrate the current questions and concerns regarding the actual viability of an EV replacement paired with the accompanying charging stations and actual impact on national emissions.

Key Words: EV, Electric Heavy Vehicles, Industrial Construction, Electric Dump Truck, Cat 793

Introduction

The construction industry is embarking on a monumental technological jump to upgrade its antiquated diesel-electric industrial vehicles to climate conscious alternatives. Due to the rise of climate conservatism and an overall consorted effort by international communities to limit the expulsion of carbon emissions, the construction industry (more specifically the heavy civil industry) must find innovative solutions in order to remedy the considerable carbon emissions their vehicles produce. One solution that has been proposed and is currently being tested by the major market manufacturers, is full electrification. While current products like the CAT 793 or the Liebherr T 274 run off 85-liter, 16-cylinder diesel engines with hybrid technology, companies are rushing to be the first to introduce a fully electric variant. While the prospect of a fully EV dump truck, dozer, and scraper fleet sounds promising, there are still a multitude of questions that need to be answered before these vehicles are considered viable replacements for an already integrated and cost-efficient solution. Questions like total operating range on a full charge, total cycle hours available, power pack size (kilowatt hours), charging time, and cost compared to alternative, need to be answered before these vehicles are rushed into service. The research in this paper aims to educate the reader on the current information that is available, partnered with interviews and first hand experiences from industry professionals who own, operate, and maintain the current diesel/diesel hybrid vehicles.
Literature Review

Serving professionals in the mining and mineral industry for more than 150 years, the Engineering and Mining Journal is a goldmine for technical information and news regarding the evolution of large industrial construction equipment. Whilst the mining industry is a separate offshoot from heavy civil construction, the two industries share and operate the same vehicles on their sites, but for different capacities. During the MINExpo of 2006, CAT announced it would develop a line of AC electric drive mining trucks starting with two models in the 200-ton plus payload capacity range (Cat plugs, 2006). As the market and demand for BEV’s (Battery Electric Vehicles) grew, CAT upheld its promise and developed an integrated systems base that could be applied to trucks and other vehicles in its changing lineup (Cat plugs, 2006). Currently 2023, CAT developed and delivered a series of hybridized versions of their most popular models, the technology for a 100% electric drive vehicle has not materialized. As theorized by Len Eros, the Global Segment Manager for the Cement, Mining and Minerals industries of ABB, smarter converters, more compact motors, and more advanced batteries are slowly bringing up the performance of electric alternatives in order to be on the same level as their conventional diesel counterparts (Eros, 2020). As technology in the civilian automotive industry pertaining to electric batteries and AC propulsion, the construction industry has made considerable progress. Alas, as construction equipment builders progress, technical and feasibility issues have arisen. An example of one of these issues is explored by Carly Leonida, a technical freelance journalist in the mining industry who points out that the largest unknown in the industry relates to battery replacement cycles, charge rates and operating temperatures (Leonida, 2021).

As progress in the BEV market gains traction and financial support, the study and evaluation of contemporary diesel I.C.E.’s has significantly picked up. In order to develop the metrics necessary to compare efficiencies, government bodies and global committees, like the WCX SAE World Congress Experience, task engineers to develop hard data to test if new emissions standards are meeting their proposed goal. In a study done by Hanwei Zhu, George Scora, Georgios Karavalakis, Kent Johnson, Robert Russel, and Tom Durbin, 10 pieces of Tier 4 construction equipment were tested using a Portable Emissions Measurement System (PEMS). Utilizing 3 excavators, 3-wheel loaders, 2 crawler tractors, and 2 backhoe/loaders, the test was conducted to determine the actual emissions produced throughout the working process (Zhu, Karavalakis, Johnson, Russel, Durbin, 2022). For all types of equipment, the highest emissions were seen for the cold start phase, which showed NOx emissions levels ranging from 3.4 to 6.3 g/bhp-hr, from 15.8 to 26.1 g/kg-fuel and from 107 to 249 g/hour, with an average exhaust temperature around 100°C. The next highest emissions were found for the travel mode. NOx emissions from the idle period ranged from 12.8 to 50 g/hour. NOx emissions from all equipment categories over trench and backfill modes show a range from 0.07 to 0.69 g/bhp-hr, from 0.4 to 3.7 g/kg-fuel, and from 11.4 to 34.2 g/hour (Zhu, Karavalakis, Johnson, Russel, Durbin, 2022). After the conclusion of the test, it was determined that the equipment tested performed better than the standard of 20 mg/bhp-hr with a range of 0.1-13 mg/bhp-hr (Zhu, Karavalakis, Johnson, Russel, Durbin, 2022). This information reveals that Tier 4 vehicles are far more efficient than previous models, but most importantly confirms that emissions regulations have produced efficient diesel vehicles that can be used effectively for the considerable future. Alas, in comparison to BEV’s, Len Eros points out that diesel engines can realistically only achieve around 45% efficiency whereas electric powertrains can reach an energy efficiency of 90% or more.

While the efficiency of an electric battery compared to a traditional I.C.E is a known commodity, the inputs that make these vehicles accessible and feasible is still unknown to the broader construction industry. Carly Leonida focused on the impact of frequent charging cycles on the battery, projecting eventual degradation of the work energy per recharge declining before replacement of the battery system (Leonida, 2021). Furthermore, Miss Leonida points out that the inefficiencies of power generation from diesel generators will compound the inefficiencies of converting the energy generated in AC to DC power. She concludes that BEV’s should only be employed where there is an alternative energy source other than diesel power generation (Leonida, 2021). Moving forward from the charging of the vehicle on site, questions regarding State power grid capacity have arisen. Yue Guo and Saeid Bashash conducted a study for the 2017 American Control Conference where they concluded that California's current electricity infrastructure has the capacity to fulfill power requirement for at least 2 million PEVs without any upgrade, provided that predictive PEV charging optimization and bidirectional V2G integration are enabled and fully practiced (Guo, Bashash, 2017). While 2,000,000 vehicles are a considerable amount of cars & equipment, California currently has 31,014,128 registered vehicles on the road (Department of Transportation, 2011). If the implementation and promotion of electric vehicles continues to grow and surpasses the current rated capacity, there will be an infrastructure problem that will not only impact the civilian market but will considerably impact the construction industries adoption and implementation of future EV equipment.
Due to concerns regarding grid capacity and charging station availability, CAT got ahead of the concerns and developed a hybrid system for their fleet of vehicles. As a major market manufacturer, Caterpillar has sold more than 6,000 mechanical drive trucks greater than 150-ton capacity since 1985. In recent years, the industry’s fleet of active mining-class trucks averages 1,300 to 1,400 units, of which one-third are their electric drive hybrids (Cat Plugs, 2006). Hybridized alternatives offer the best of both worlds, battery motors in the wheels and a diesel generator for power. CAT has seen a decrease in fuel consumption and an overall increase in vehicle efficiency when comparing their traditional diesel with the diesel-electric drive replacements (Cat Plugs, 2006).

**Methodology**

The first phase of data collection necessitated the identification of a variety of heavy civil construction market players to participate in this study. The participants of this study were not predetermined nor were surveys utilized to examine potential participants. For this study it was concluded that six contractor representatives would provide an ample amount of experience, firsthand knowledge, and familiarity with the equipment this study is analyzing. Each representative had at least five years of experience, some upwards of 25 years in the industry. This wide variety provides this study with the necessary experience and vehicle familiarity to identify potential issues with the implementation of battery electric vehicles in the industry.

*Participants – General Contractors*

Bruce W. Daseking, Executive Vice President Business Development. McGuire and Hester

Enrique A. Ivers, Project Manager & College Professor. Heavy Civil Construction, Cal Poly San Luis Obispo

Jeff Grimm, Area Manager. Granite Construction

Josh Pulver, Project Manager. Granite Construction

Kent Beecham, Construction Manager. SierraCon

Sara Clark, Civil Superintendent. Kiewit Infrastructure West Co

The group questions asked to each participant of this study needed to accurately address the vehicles/equipment and potential issues that will impact current federal and state legislation which will impact the heavy civil construction industry. Ten questions were intent on encompassing the necessary topics required for this study. The determination of the questions was to evaluate general contractors’ experience with current diesel vehicles, the inputs that accompany them, their current feasibility/efficiency, and the potential risks and issues regarding the viability of electrifying construction vehicles. The interviews were conducted on Zoom calls and by cellular device. Each interview posed and answered all the questions. The interview duration ranged from 16-75 minutes.

**Interview Results**

**Question 1: What is your position in the construction industry?**

**Beecham:** Heavy Civil Contractor/Owner.

**Ivers:** I’m currently teaching at Cal Poly so that's kind of a unique perspective that comes, being in the industry also, because, you know, I'm working on the industry side as well. Right now, I'm working, managing, and making proposals. I’m currently working on joint ventures helping put together proposals, kind of bridging the, the technical, uh, gap between the estimating team and the proposal writing team.

**Daseking:** So, I’ve been in the industry for 40 years. I've been doing it for a long time. I am with McGuire Hester right now. McGuire Hester's, a 200-million-dollar heavy civil construction company based here in Alameda with an
office in Sacramento. My current position is Executive Vice President of Business Development. I've held lots of positions here. Start off as a project manager, estimator.

Clark: I'm a civil superintendent.

Pulver: Project Manager for Granite construction heavy civil contractor

Grimm: I'm an area manager for our Fresno area. So, I'm responsible for our operations here in basically Central Valley, California.

Question 2: What is your familiarity with large industrial vehicles (Dozers, Dump Trucks, Skid steers, Motor Graders, etc.)?

Beecham: I was born on them.

Ivers: Most of the projects I've been on have, have had that type of equipment on there.

Daseking: So I'm very familiar with a lot of the standard equipment, and some of the specialty stuff. As you know, McGuire & Hester, we play in the dirt, we do anything that's outside. From bulldozers to scrapers to big excavators to backhoes, rollers, you name it. We do a lot of paving work. So, we've got the paving machines, the paving rollers, a lot of dirty work. Blades and scrapers, dozers, all that stuff. And then we do landscape as well. So, it's trenchers and everything.

Clark: I'm familiar with them, especially since being a civil superintendent, we do dirt work all the time. The last project I was on was small, just because it was in a neighborhood and there was another job site that was a part of the same project that was a lot bigger, and they had way more room for stuff. So, they had, I would say, bigger pieces of equipment and just like a little bit bigger have work to do. But I'm very familiar with dozers, dump trucks, large excavators, stuff like that.

Pulver: I don't operate them, but I use them in my job every single day.

Grimm: Very familiar. So yes, equipment we use every day. And, and it's something you know, heavy equipment is a passion of mine. That's how I ended up in this business.

Question 3: In your experience, what is the importance of cycle times and vehicle readiness?

Beecham: First, it's all down to efficiency. It's all about having things ready to rock and roll. That comes down to good maintenance. Second would be to not overestimate equipment’s and human’s touch ability. So, say if you think we can get this cycle done in one half hour time and that's how the operator wants to do it, but you know reality sets in, and it might be 40 minutes.

Ivers: Yes, it's very important. Cycle time and readiness are obviously important. It's something that's going to vary a lot from project to project, and from the material that you're working with. It's very important to be able to estimate an accurate number. The consistency of the cycle times is important to account for as well. Right? So, there's accuracy versus consistency, and you need both. You don't want any downtime and that, that goes back to consistency. Yeah, it's great to have a piece of equipment that can blow away anything else that's out on the job site, but if it's only working less than 95% of the time, it's causing you problems and costing the project money.

Daseking: It's huge. So as an estimator, when I would review a project with somebody, if it was an underground pipeline job, I would try to figure out productions and what the one thing that holds them back. The one thing that drives the production in the crew, whether it's physically putting the pipe in the ground, if it was a big piece of RCP pipe, you know, it takes big, heavy lift. Or is it really a light pipe? Doesn't matter. Is it putting trench in the ground? Is it back filling, whatever? What, what is the controlling factor? And a lot of times for an underground job, it's cycle time.
Clark: So, when we bid on a job and put the estimate out there for an owner using our cycle times, it puts us on the right track for a schedule and making sure that we get the job done. Having a good productivity factor is very important, which ties into cycle times and makes sure that we get the work done on time. So that way we make money.

Pulver: So, cycle times are very important, that's going to derive a lot of different factors. For cycle times, you think of like scraper spreads, moving large amounts of dirt. If you don't know what your cycle times are, you don't know how much dirt you're moving per hour, the amount of dirt that you're moving is going to tell you how much water you need to feed the dirt, and how big of a compactor or multiple compactors that you're going to need to run. So, cycle time is very important. You got to know those numbers because it directly correlates to the other activities happening. Vehicle readiness is the same thing. So, there's very few operations where a piece of equipment and an operator just go out there by themselves and do the work themselves. They have support, whether it be a couple of laborers on the ground, grade centers, trucks running, a dirt haul, loading excavator, and even dirt into a truck. So, if that piece of equipment is not ready, or is down or not fueled, it's going to have compounding issues with the rest of the support that's needed.

Grimm: I mean, that's crucial to what we do, right? Our equipment is integral to making our productions. It's all about cycle times. So, whether it's tracking how fast the pavers go when we're paving the highway, or making sure that we're maintaining paver speed, anytime we go to any operation that involves equipment or a production tool of some sort, cycle time is crucial. And you know that the equipment's readiness and ability to run it as it is needed to run throughout the whole shift is critical to us making our production. like I said, we have a target every day. Let's say, we're going to go pave 1500 tons for the day. Well, we're tracking all day long, if we only made paved 1300 tons, we didn't make money that day. If we paved 1500 tons, we made budget. If we paved 1700 tons, then we made some extra money that day, right. So, apply that to a scraper spread, a motor grader making finished grade scrapers, moving dirt. It's a universal truth.

Question 4: What factors do you (or your firm) prioritize when selecting vehicles for a job? How important is vehicle optimization?

Beecham: It comes down to experience in knowing what a job needs or doesn't need. Sometimes you must make do with the equipment that you have. So, say you need a certain size or certain machine that you would like to use, but it's just not in your fleet. So, you scratch your head and make it work and get by with what you currently have. Or do you truly need to go out there and get a rental? It all comes down to a little bit of experience and optimization.

Invers: Cost is a driving factor. Optimization is important because it reduces operation costs and increases productivity. There’s also an impact on safety, and that’s one of the aspects that’s critically important.

Daseking: I'll go back to my trench example, you're loading an excavator, loading it to a truck, and then calculating how far that truck must go? Additionally, part of that truck is labor, mainly the driver. Usually a big chunk of, believe it or not, is what that overall cost is for that truck. So, you want to get the greatest number of yards in that truck to get. Moved by that one guy, right? So, vehicle selection is, is paramount. The other part of it is can you get that truck into the site. Is it a small road? You know, you can't take a semi end dump in their cause it's too, the roads are too narrow, can't get in, or they got a back end. It takes too long to go back in. So, vehicle selection is, is huge.

Clark: It's important. So basically, it ties into when we're putting an estimate together for a job in general. We'll call on SMEs, subject matter experts, and get some of their opinions. When I started out estimating, I didn't really know what piece of equipment to pick. So, I would call on those guys and make sure that we were using the right piece of equipment for the job. So, it's important when just starting out in the estimating phase. Because you don't necessarily know what the work is going to look like once you get out there to do it. Like you have an idea of what equipment to use in your head, but then you go out there and it's totally different. So, it's very important to do that. We use those estimates when we're estimating, but then when we go out there and see the actual performance. We call on a lot of the field guys expertise because they've been in the industry for so long. For example, my superintendent on the last projects that I was on before I got promoted. He's been in the field for 50 years and knew exactly what he was talking about. So, whenever I need advice, Ron is going to be the guy I call. Go to the old guy.
**Pulver:** So, selecting the right tool for the job, right? I mean, you hear that and not just with equipment, it's just the right tool for everything is huge. You don't want to have undersized or oversized equipment. Undersized equipment is going to hurt your production, which is hurting your money. Oversized equipment is going to hurt your money because you've got too large of a tool, which is usually going to cost more money. You have a lot of factors from the square footage of your site, how much can it move around to the bodies that you can get out on site? Sometimes you can't get the right guy to operate the right piece of equipment and you have got to suffer with a smaller piece that someone else can operate. I've had that happen before. Not ideal but it does happen.

**Grimm:** We're tracking our progress against the budget at a minimum every day. Sometimes we track it by the hour, not on the grade, depending on the operation. Often on paper, there's a perfect tool. Let's talk about scrapers for a second. So, you know, maybe the perfect tool on paper is 657, twin engine scrapers. That would yield the quickest cycle time and the lowest unit cost. But maybe those aren't readily available, or maybe we can't justify the mobilization cost to bring those in from a couple states away, let's say versus using some 631 Open bowl scrapers that we have here in the Central Valley. For example, say we decide what the optimum tool is. Then we plan around that and then we adjust from there based on other factors. A prime example is we needed to strip some overburden at our plant here in Coalinga this spring. We would like to utilize some 651’s to balance out the scraper fleet because some of the scrapers that we had here needed to go to Arizona for a job. So, we didn't have as many scrapers as we needed. So, we said, hey, we'll pull some 651’s in from Sacramento. But they were up on a job on highway 20, up in the mountains, but they were under 20 feet of snow, so that we had to adjust to the different tool set.

**Question 5:** For a typical project, does your company have the tendency to rent or purchase their equipment, and how long does the ownership period last for purchased equipment?

**Beecham:** In our scenarios, it’s preferred to own. An exception to that is when you probably won't ever use it again. Or if you use it in the future, it'll be minimal. If you can see the equipment being used further down your pipeline, then we're going to keep it. It makes sense to purchase an additional one instead of renting. It just depends on maintenance and how well the equipment's working for you. I was just on a blade that's from 1969 a few days ago. So, if it works, it works. It’s been working for 60 years!

**Ivers:** On many of our projects in the United States, we subcontract or partner with contractors who have their own equipment yards. For example, a lot of the dams that we are pursuing or have built recently, the embankment dams, we'll partner with Sukut. Sukut Construction has a massive fleet of scrapers and dozers, so they'll go and self-perform that, and we'll provide technical experts that know dams inside and out. We don’t have big equipment yards. Um, I think we have something kind of like that in, um, in Texas because we have so many projects in Texas. Okay. But typically, the piece of equipment, unless there's another job site that's ready to utilize it right now, we get rid of it at the end of the project.

**Daseking:** So, we're a unique company. We've been around since 1926, so we're financially sound. We do rent equipment, more on the smaller side, but on the bigger stuff we'll purchase. It depends on how long the job is. We did a project at the Port of Oakland where we're moving a million yards of dirt right along the estuary. We bought this excavator. It was a 300,000-pound excavator, uh, called a PC 1000. The bucket on it was six yards to eight yards. It was huge. We purchased that excavator for that job. We put it in the price, and we had another project that it went to right after that. We were fortunate. Once we finished with that, we sold the equipment. So, we do typically purchase. We are savvy about spending money. I mean, if we could make it work that we own the equipment and keep it busy, we're going to buy it. We have a fleet of, I don't know, 60 backhoes right now.

**Clark:** We have a lot of equipment that's already purchased because it's cheaper to keep reusing that piece of equipment, especially if it's not a very long job. I mean, obviously, the more you use a piece of equipment, the more it's going to depreciate, and all that stuff is going to need more maintenance over time. But I work for Kiewit. So, we typically have a yard located near wherever we're at. For example, in Northern California, our yard is in Vallejo. We store a lot of our equipment there and our maintenance guys come out of there too, for whatever the project is. We tend to use our own equipment that we’ve already bought. Depending on the project, if it's like a specialty piece of equipment or something that another job already has, then we will rent a piece of equipment.

**Pulver:** We rent and purchase equipment. Granite is a nationwide company. I'm out of the Sacramento office. We have our own equipment tied to our office and we have what we call our Valley region, the Sacramento, Fresno,
Stockton offices. We all share the equipment. Granite has something called our pool equipment, which is the large, big iron stuff that you don't use very often like the 657 scrapers, the stuff that you're not using every single day, and they're very expensive to run and very expensive to operate. One day, they might be in California, and the next day, they might be in Arizona, and the next day, they're going somewhere else. So, you must reserve them. If you’ve got a job coming up, you got to say, “I'm going to use our pool equipment”. From a rental standpoint, we don't own every single piece of equipment, we own a lot of the stuff that's used every single day on dirty jobs, you know, loaders, excavators, rollers. But we don't own a lot of smaller excavators. They're meticulous to maintain. It's better just letting the rental companies deal with that. So, we rented those out. Sometimes, if six jobs need the same size excavator, well get two of them to send out to two jobs, and then four jobs are going to get unlucky and must rent. So, it's just kind of a supply and demand type of deal. We're a $4 billion company, we do double line depreciation. I mean, they start getting crazy, but we have equipment that we had to get rid of in the last couple years because of the carb compliance. So, it's all tier four. But we still have skip loaders that are 20 years old!

Grimm: We sometimes buy, sometimes lease, and occasionally we’ll rent so we do all three. Let's use skip loaders, for example. Here out of Fresno, we own five or six skip loaders. And in the middle of August, sometimes we'll just go rent a couple more. And then after that month, that peak demand is over, so we just go back to our Five, right, so if our need is going to be short, we'll just do rentals. If it is a piece of equipment that's not easily rentable, we'll go buy it or do a long-term lease. So, an asphalt paving machine, for example, you don't go down to United rentals and rent an asphalt paving machine, right. We typically lease and then buy out the lease on all our favorites. In terms of how long we keep the tools that we buy, let's say it's a midsized excavator, right, a cat 335 or some cat 336, something like that, we'll probably run those things out to maybe 900-1000 hours, and then they'll start to need major component rebuilds. Do we want to spend the money, especially with what we've been faced with in California, which is the root of your project here. What we've been dealing with, up till now until this new, fun regulation popped up, is we've been working towards getting into tier four final compliance with our fleet. We've been working towards the 2024 deadline. And so there's tools that are maybe at tier one, tier zero or tier two, and maybe we could rebuild that tool, or maybe we could go dump 100 grand to that tool and get another 5000 hours out of it. But we're going to have to get rid of it by 2024 anyway. So sometimes what we're doing is either move it to a different operation, like in Arizona, Utah, or out of state…less regulation, right, or we'll just sell it and replace it with a tier four. Time before replacement is commonly 10,000 hours for most tools. But there's other tools like a D10 dozer, or plant loaders like a 980 or 988 loader. We will run those out to maybe 15,000 hours and then do what's called a second life. We'll send them in to caterpillar and they'll rebuild all the major components, put a fresh paint job and stickers on and all that kind of stuff. And it's a third of the cost of buying it.

Question 6: On a typical construction project, where/how does your company source its diesel (in general i.e., gas station, fuel truck, etc.), and how often is fuel a concern?

Beecham: Fuel can vary a lot with prices. So, it'll vary parts when you're working on the estimation side. But if it's a small job, you could truck it in with a tank in your pickup truck bed. But if it is a big enough job, you want a tank on site. In terms of terms of delivery, we have a larger tank on the ranch. We fill up weekly or whatnot.

Ivers: We have tanks too. So, the fuel truck will come and fill up whatever equipment is easy to fill up. But we'll have tanks on site and then the fuel truck will fill up those tanks. Additionally, we'll have the crew leads or the foreman with tanks on their trucks as well.

Daseking: We have a fleet of fuel trucks that go to a main facility. The facility fills up and then delivers the fuel. Most of our equipment is roadworthy. We're also getting diesel at a lower rate. The price is huge and as the chief estimate for the company. I oversee putting in our equipment rates and our fuel rates. There were times when I didn't change the fuel rates for a couple years, and then these last couple years I've changed almost four times. The infrastructure is there to take care of it.

Clark: So, depending on the project we will keep a fuel cell directly on site that we can pull from. Then we also have the maintenance guys that come out and fuel up that piece of equipment.

Pulver: So, we have the lube trucks and fuel trucks that run around to all the jobs to fuel up every single day. Also, we have some of our foreman trucks that have fuel tanks on them. So, we can just top it off with the 10-15 gallons of diesel that it needs every single day or whatever it is, but typically it's all run through fuel trucks.
**Grimm:** So typically, on an average job, we’ll have fuel delivered in a tanker to either our main yard, or if it’s a big enough, we’ll have a 10,000-gallon diesel tank on the job, and have fuel delivered there. So those trucks hold, I want to say it’s 9000 gallons, maybe it’s 2000 gallons either way. They all have a lot of fuel, but less fuel than what a tanker brings us. I wouldn’t say that to date we’ve had very much concern about fuel availability. In 2021/2022 there were some concerns about fuel prices. I was tough last year. It’s not cheap to do in California. There’s a whole bunch of environmental permitting and hoops you got to jump through to, and you know, secondary containment things you got to set up and yada, yada. So, it's, it's not so easy.

**Question 7: Are you familiar with EV’s and the upcoming requirements for heavy industrial vehicles to convert to full electrification?**

**Beecham:** I don't have the time or interest or care to you to be, to even, even investigate that at all. It might be something, the news or occasionally, but, uh, yeah.

**Ivers:** 2035, right? So, yeah to answer your question, I’m familiar with EVs. Those requirements are, are constantly changing in very, um, from geographically location, geographic location. I can't say that I’m familiar with every planned requirement now. When we bid on our jobs, we obviously meet the requirements that are the regulatory requirements for the area that we’re working in.

**Daseking:** Yeah, and it concerns me. I think it's 2035.

**Clark:** A couple of our company owned vehicles for upper management are all electric. And it's interesting hearing some of the managers talk just because some of them commute far. And they can barely get to the job with enough electrical charge in their car. So, I don't know how feasible this would be for a huge piece of equipment. Especially If our managers can barely get to the office.

**Pulver:** I'm very aware of electric vehicles. I am aware of electrification by 2035.

**Grimm:** Yes, I am familiar with California’s 2035 net zero goal.

**Question 8: Due to the nature of battery powered vehicles, do you have any concerns or questions regarding the charging and maintenance of these vehicles?**

**Beecham:** It’s all big machinery. It's made to be diesel ran. The infrastructure and means of execution for vehicle delivery and usage has been catered to diesel for the past 100 years. If I can’t rely on the equipment to be ready to go at a moment’s notice, then there is a major issue. There's a lot of engineers out there that probably could solve the problem, but I'm old school and I don’t have the time or manpower to completely up end my fleet of vehicles for an unproven technology.

**Ivers:** I think it's going to be difficult to implement on job sites. I believe that there's also going to be some concerns. I guarantee there is not an excavator out there that's been used for more than three months that doesn't have the paint worn off on the side of the cab because it's rubbing against stuff. You know there's a higher risk of damage to heavy equipment on the job site. So, are the batteries designed to be able to accommodate that? I think it's not going to be the same as in a passenger vehicle, right. I think the other issue is every construction site is different. That’s what makes construction, that's what distinguishes it from manufacturing or mining. Manufacturing and Mining is a very cyclical, repeating. Assembly lines function off repetitive processes. And because of that, I think there's going to be challenges posed to implementing. The charging and maintenance of the equipment is another major concern. I think the one area where you probably will see it, and it's going to be a test ground for construction, especially heavy civil construction, is in the mining industry. So, my bigger concern though is um, a lot of these pieces of equipment have enough fuel to go through a whole shift, off for break, then the next shift, or at least to the first break. If the equipment doesn’t match the diesel/diesel hybrid counterparts, how can a general contractor or superintendent reasonably make the decision for the EV?

**Daseking:** I think we all know that we can develop a piece of equipment that will be used. You brought up mining equipment. So, what separates us from mining equipment? Mining equipment is on a single site that they could set
up a charging station easily and go to it every day. Where our jobs are all over the place. For some of them It might be there for a while. It will be hard to justify putting a charging station in for an extra cost to my project. So, the infrastructure's not there for us to take advantage of onsite charging. You put a dozer out on a project and it's ripping hard material and it, it'll burn traditional fuel (diesel) like crazy, right? Suddenly, if you're doing it on a battery power and you're putting it under a large load, using a lot of horsepower and charge, theoretically it's going to drain the batteries quickly. I don't know how long those batteries are going to last or how long the charge time will be without on-site charging. If I must resort to using a diesel generator to keep my vehicles ready, it's counterintuitive to the legislation.

Clark: I would still currently say yes, just because of kind of what I said earlier, like, if we're having trouble getting to work using, I guess, like a smaller battery, it would just be interesting to see how the longevity of it would be for a bigger one. Obviously, they're doing all this testing. If you're working on an operation that says it's like a double shift, and you only have a certain number of pieces of equipment and if it dies, you must sit and wait for that thing to charge. In comparison to traditional diesel, you could just fuel it right back up in 5-10 minutes. So that would be where my concern is. I think you would have to account for that in the estimate. But that could also drive up the cost of the estimate, and then you may not win the job. And so that just goes into a bunch of other factors that we traditionally don't think about currently.

Pulver: Charging, being a big one. Again, I'm going to go back to the job I was just on. I was on a 15-mile highway job through downtown Sacramento with no power in some of the areas. We've got jobs that are very remote and have no power at all anywhere close. So how are you charging the vehicles in that case? So now you're bringing generators on site and running diesel generators to charge electric equipment. How fast do they charge? If you show up the next day, and that thing's only got four hours with a charge, well, that's just eaten right into your pocketbook. I mean, you're shutting down a crew because you don't have the equipment ready to go. Maintenance is one thing, but things change every single day. We've got a crew that understands how to maintain tier four equipment, but now we must train them in completely different equipment. Obviously, there is a learning curve with everything else. But I don't know enough about electric vehicle maintenance. Just coming from what I've seen in the news and Instagram posts, and everything was like Tesla's and people hitting 80,000 miles and having to get a new battery put in, which is half the price of the car itself. Cars, you drive, let's call it, two hours a day. And construction equipment is running eight hours a day. So, it’s going to burn out four times faster than Tesla’s 80,000 miles, and you're going to hit 80,000 miles on what, four years?

Grimm: It's going to vary on the job. But getting line power from PG&E these days in California is not easy to do. It's expensive, and it takes forever. So, if you're not going to be set up in one spot for more than a year, if you're not going to be set up for an extended period, and you don't have an extended period to procure that power, we're just running off diesel generators. So, for example, now, there are some restrictions in California where you can't run diesel generators, mobile diesel generator can't be stationary for more than 12 months, right, because then it becomes stationary. But we just did a job, a little bit south of here, and it wasn't a remote job at all. It was right off highway 99 south of Fresno in a populated area. But the power, the quantity of power we needed to run our concrete batch plant wasn't available at the site. So, we ran it off diesel generators.

Question 9: Does the possibility of a 30% tax credit on the vehicle’s purchase price incentivize your firm to choose an electric alternative? If so, explain your reasoning. If not, what are your reasons for choosing the current diesel/ diesel electric options?

Beecham: I mean, look at all his headaches that they're having PG&E, with the timeline for procurement and the equipment being so expensive. Dealing with the timeline of PG&E and the expense of the equipment leads me to be apprehensive of the switch. You know, electricity isn't cheap either, so I just don't see that being economical for a construction site.

Ivers: I think ultimately at the end of the day, is that 30% going to outweigh the cost associated with this? Okay. It's going to be a bottom-line number that needs to be competitive with traditional models.

Daseking: So yes, a 30% tax advantage would help us. It depends on how it's applied. If it's a corporate tax it'll be a little bit different for us. We're fortunate we possess the money to do it and we keep it up. So yes, we would be very interested in the 30% break on the price. With that being said, we have a hybrid excavator that we've had in fleet for
five years now. The operators like it. It's interesting. I think there's the tradeoff that we could go hybrid instead. Hybrid first and then go full battery at some point. The infrastructure must catch up. The equipment and the technology need to catch up. We move equipment at night because it goes from one job during the day. We move it at night to another job and it starts work the next morning again. So, where do you charge it at that point?

Clark: The tax incentive you would think would be like a good incentive to do an electrical vehicle. But I think part of the problem with that is, if you don't have that grid, or if you need temporary power, then it's a very long process with PG&E, because we're going through that right now on my current project is we're paying PG&E to do the design and everything of these temporary power locations.

Pulver: I think that our decisions as granite will be based more on equipment capability, serviceability and reliability, more so than some kind of incentive. Right. And so, it's just we don't buy the cheapest equipment as it is. We don't necessarily shop. We do I mean price is a factor. And, yeah, it's uptime, reliability, availability of parts, all those kinds of things. And we all know that the first offs, right, you know they're often plagued with problems right there. And so, I think that the construction industry, particularly heavy civil, are not early adopters of technology. And they're not early adopters of change. And so, there's not going to be a whole bunch of people running out, saying, oh, let's buy this because we're going to save 30%, right, they're going to be like, we're going to let somebody else try it first and see, see, you know, wait till they get it right.

Grimm: I mean, let me preface everything I'm going to say with you know, granite is all about sustainability. It's one of our core values. And so, we're on board with figuring this out with industry, right? So, I don't want anything I'm going to say to be construed as “Oh, yeah. Is that I think it's a bunch of malarkey”. Granite doesn't think it's a bunch of malarkey. Let me say it that way. Okay. But let's talk about reality. We have serious concerns about the infrastructure. How this is all going to work, right? I'm involved with some industry groups that have gone to the PG&E’s types, and they said we're a decade or decades away from an infinite power infrastructure that will support a grid system that can deliver the power right there. We've still got to figure out where the power is coming from. Because we don't have enough power to do what we’ve got going on today. At the same time, they want to eliminate gas stoves, right? And, and they want to eliminate gas water heaters, and they want everything to be all the homes to be electric, they want all the cars to be electric, and want all the heavy-duty trucks to be electric, the power that exists to support that does not exist. So, I think that my prediction is that the regulatory environment is not going to change in the foreseeable future, they're going to try to force this upon industry. And it's going to be a giant experiment. And then in the 11th hour, when it's obvious that we're not there yet, it's going to get modified.

Question 10: In your professional opinion, do you believe electric industrial vehicles are the true replacement for diesel/diesel electric?

a. If so, how soon do you foresee electric industrial vehicles becoming commonplace on the jobsite?

b. If not, what do you believe is the future of heavy industrial vehicles?

Beecham: I'm a burning diesel kind of guy, so I'm diesel all the way. I can see the electric stuff picking up you know. Commercial jobs or smaller things like a little mini skid steer you know, we could probably work to that kind of thing. And just smaller scale projects they can probably use it. But, you know, if you're on a big cutting bill or major dig or anything like that, you, you are going to need the real deal.

Ivers: I think they are the replacement. I think that the time span of it's going to vary a lot from the job site to when it is going to be commonplace on the job site. Uh, is it going to be commonplace on a job site in San Francisco where you're building a hotel or New York City or Miami or something like that. Yeah, I think it'll be commonplace in five years. When you're talking about a project that is a dam at 9,000 feet elevation in the middle of Colorado. Which is an hour and a half or more west of Denver. I don't know if you would see battery electric vehicles out there. Uh, in 30, 40, 50 years, yeah. Could be that long.

Daseking: It's inevitable. I think that technology needs to catch up to what the needs are. And, you know, California can't say you want to, you got to do this by 2035. I understand that you have to set a goal, but you also have to be realistic. The technology's going to catch up, but you can't say switch if it's not there. I do believe that there's going to be some hybrid version up until a certain point, and then technology's going to catch up and it's going to make it worthwhile for diesel engines to go away.
Clark: Honestly in my head batteries and diesel are kind of level playing field just because obviously diesels bad for the air and the environment and all this stuff but then when you dispose of batteries, they have a long decomposition process and many toxic elements in the batteries. So, I don't think that they're the answer. I think they're more of a quick solution right now because everyone thinks it's greener. But it may not be. I don't have a good answer for what your solution would be. Because it's not diesel, it's something different. Maybe hybrids?

Pulver: Electric, at least in the next decade, I don't see being a viable option. I don't think we have the grid to support it, or the plan from what I've seen, that can support going fully electric. I mean, I see these things every day, like I was telling you earlier, we got, we got fleets that are running 2000 Plus gallons a day a diesel. I don't know how you substitute 2000 gallons of diesel for electric, I mean, all they're going to do is go burn 3000 gallons of diesel at the electric generator plants and feed it to you. So, I would say, I don't know how far out that is honestly. Nowhere soon, but to the point of hybrid. I know like I've seen those 944s' that we have, talking with my shop superintendent, it seems like that the capacity for those hybrids works. The reason it's in that big equipment is because they need the big equipment to make it profitable, making it worthwhile trying to shrink that same system down into smaller equipment is not as effective. The cost outweighs the initial cost of building which then outweighs what it's going to generate.

Grimm: You know, there's going to be big companies like Granite, they're going to say, hey we're big, and we can afford to go invest in this to a certain degree. We're not going to just flip the switch; I don't think and be 100% reliant upon EV's. There'll be a lot of other smaller companies that that just sit back and wait. For Granite, we are 100% committed to sustainable development and adherence to federal and state legislation, but I don’t believe the EV’s will be ready for usage in the construction industry just yet. These vehicles still need to be developed and tested to see the true performance comparison. If the EV’s do not meet the standards set by the diesel/diesel hybrids, and have a higher operating cost or investment due to the cost of the vehicle and the accompanying charging stations, then I do not see the industry meeting the 2035 goal.

Interview Question Analysis

After concluding the interview process with the six participants, a general attitude towards the viability of electrified construction vehicles became apparent. Starting with question number one and two, each participant had at least 5 years of experience and all had familiarity with the potential equipment proposed for electrification discussed. While each participant had differing positions on the jobsite, each possessed first-hand experience coordinating, working on, or ordering equipment for a project/jobsite. For question three, each participant stressed the importance of time and its effect on a project’s profitability.Each cycle on the jobsite is strategically calculated to the second in order to keep the job on target to meet specified performance goals. During the bidding and planning stage, equipment is selected from the general contractors’ vehicle yard or selected from a heavy vehicle subcontractor. On the topic of vehicle selection (question three), each participant emphasized the selection of the correct vehicle in order to meet the material movement requirements. Alas, due to the level of vehicle ownership differing due to company size and capital, in some instances project managers may have to settle for a vehicle that is readily available. Ease of transportation and equipment cost per cycle are the largest factors when selecting a vehicle. Expanding on ease of transportation, many of these vehicles are shared throughout the entire respective company’s fleet, so a job may require the transportation of a Motor grader or Scraper from Flagstaff Arizona to Sacramento California or vice versa. In response to question four, the amount of large equipment owned by each general contractor depended on the size and scope of work specialized in. Each respondent worked for a large general contractor, yet the level of vehicle ownership varied between complete purchase of or renting the equipment. If the general contractor decided to purchase the equipment, the ownership period ranged from 10 years to 30 years depending on the equipment type and size. Due to the nature of industrial/heavy civil construction, site access to fuel varies from scheduled fuel delivery through the usage of subcontracted/owned fuel trucks, to the installation and utilization of an onsite diesel fuel tank. Diesel fuel was not a concern for any of the respondents. The offroad diesel, otherwise known as red diesel, is widely available and has been optimized for access and delivery all over the country. Onsite tanks or fuel trucks are adopted and used by each of the respondent’s respective companies. The ease of access and relatively inexpensive fuel drives the ability for these companies to operate in a timely and cost-efficient manner. Each respondent was familiar with electric vehicles and understood the requirements of the upcoming federal and state regulations regarding emissions and drivetrain. Concerning the nature of fully electric alternatives to conventional...
diesel vehicles, all the respondents had high degrees of concern with an emphasis on range, charging, and equipment cost over replacement. The major concern of the respondents focused on the aspect of charging the large batteries that are required to power these vehicles. Due to industrial/heavy civil sites typically being out of range from major civic centers or areas with connected power, the concern in respect to how each vehicle will be charged without the use of additional diesel generators or an onsite charging station became clear. If the site does not have an onsite charging station, it would need to be contracted and built by the respective power supplier of the area. Three respondents used experience from previous jobs of similar requirements and spoke on the long approval process and overall duration it added to the project in order to wait for the power system to be built and online. Furthermore, the inclusion of a new series of power lines or underground conduit contributes to more expenditure and may not offset the savings projected by using an alternatively powered vehicle. The respondents called back to question three of the interview and feared that with longer charging times and vehicle assessment periods, additional EV vehicles may have to be transported out/rented in order to meet the demand/output requirements met by the conventional diesel vehicles. Another point of concern was the range achieved by these vehicles. Since heavy civil work typically involves a large amount of earthwork and grading, the performance of the battery’s underload will be lower than typical moving periods. If the range is not adequate or does not match the conventional diesel, then it does not make fiscal sense for these large contractors. Each respondent and their company vehemently stressed the importance of environmentalism and meeting the technical requirements of federal/state legislation. Alas, their concerns about the viability of implementation were valid. If electric alternatives are to be implemented as theoretically hoped by the passed legislation, the current power grid needs to be substantially upgraded in order to accommodate the large energy requirements of not only the vehicle, but the accompanying charging stations. While the cost of these theoretical vehicles is not available, using the civilian market as a point of reference, the electric versions of these vehicles will most likely have a higher starting price when compared to the traditional diesel variants. The proposition of a 30% tax rebate was supported by most of the respondents, but the major concern posed called back to the charging times and availability of on-site power. If the charge times set the schedule back and interrupt the cycle times, then the overall cost savings from the rebate will not be offset by the incurred costs of longer projects. Finally, the consensus in respect to the timeline of when the respondents think these vehicles will be implemented ranged from being inevitable to not viable for the industry. The respondents who sided with inevitability surmised that the technology will be developed, but not within the respective timeframe due to the concerns regarding the power grid and access to electricity in remote areas. While the feasibility of creating these vehicles is theoretically possible, an EV alternative marketed to the construction industry at the time of writing this has not been proposed or tested. On the other hand, the other respondents concluded that with over 100 years of experience with diesel equipment, the market and its associated general contractors would need a viable proof of concept and tested cycle times to even consider the possibility of replacing hundreds of millions of dollars’ worth of equipment in the industry. There are currently far too many unknowns regarding the potential range, charging requirements, and cost for the industry to even consider replacing the existing equipment.

Conclusion

The heavy industrial/civil construction industry depends on its vehicles in order to construct and maintain the society we live in. These vehicles need to be robust, reliable, and cheap to operate/maintain for a general contractor to take on the cost of investment. After speaking with the industry professionals who operate, repair, and coordinate these pieces of machinery, there are far too many variables regarding the batteries and how to charge them to consider these vehicles viable. If a general contractor does not have access to on-site charging through a connected power grid, the environmental benefits of the EV’s will be negated due to the forced utilization of diesel generators to charge the batteries. Furthermore, if the EV vehicle is incapable of maintaining a range that is competitive or matching to the diesel/diesel hybrids during cycle times and under load, then general contractors will avoid them as long as possible. A generational jump in battery technology needs to be achieved in order to power and operate these vehicles in an efficient manner. Consequently, the idea of construction equipment becoming EV is valid, but the inputs needed to propel these vehicles to the top of the industry is not sufficient and is currently severely lacking. At the time of study, there are only two examples in the heavy mining industry (dump trucks) that are testing the technology. Compared to the heavy civil industry, the mining industry is a test bed for new technologies due to the controlled and cyclical nature of mining. Since neither of these technologies are commercially available, and are currently only in the experimental stage, it can be concluded that EV alternatives for scrappers, dozers, motor graders, etc. are not viable. The current legislation, federal or state, is fast-tracked and optimistic when compared to the actual capacities of the United States’ power grid and the currently available battery technology.
Future Research

Technology and battery development continues to progress at a breakneck pace. The evidence and statistical data used in this research project represents the period in which it was conducted and lead to the conclusions that have been made. Akin to the Prius in the late 90’s or the Tesla of the late 2000’s, battery technology will continue to develop and could reach a point where the technology is feasible and compactable enough to integrate with current or future industrial vehicle design. Investigating the true performance and integration of these technologies in the construction industry in the coming decades will be an encouraging counterpoint to this conclusion of this project.

References


