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Norway's electric vehicle revolution: Lessons for British Columbia

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Issue

- Norway has similar population, mountainous geography & hydroelectric profile to BC
- Norway has more than 74,000 electric vehicles on its roads (>30 times the number in BC)—three years ahead of schedule
- More than 20% of all new vehicles sold in Norway are 100% electric
- Norway's new goal is 200,000 electric vehicles (7% of total existing vehicle fleet) by 2018

British Columbia has the highest per-capita electric vehicle (EV) sales, according to the provincial Ministry of Energy and Mines, and the largest charging infrastructure[1] in Canada. Much of this can be attributed to the province's Clean Energy Vehicle (CEV) Programme, which from 2011 offered $5,000 towards the cost of a new EV, and investments in charging stations and hydrogen fuelling stations. The rebate was exceptionally popular, and the cash that Victoria set aside to fund the rebate was exhausted by early 2014.

By the end of the CEV's first rebate period, more than 1000 charging stations were installed[2] in BC and 950 EVs[3] purchased—a number that includes 100 percent battery-powered cars such as the Nissan Leaf and Mitsubishi i-MiEV as well as the Chevrolet Volt, a plug-in hybrid vehicle that has both a large battery and an internal combustion engine.

EV sales in BC are now enjoying a resurgence thanks to the government's $10.6 million funding renewal (from April 2015) for the CEV programme, which offers rebates of up to $5,000 for the purchase or lease of new battery electric, and plug-in hybrid electric vehicles and up to $6,000 for a hydrogen fuel cell vehicle. As with the first iteration of the programme, the rebate is not open-ended, but available only until the funds set aside for the programme are exhausted.

As of September 2015, BC had approximately 2413 registered EVs[4] on the roads, with sales accounting for less

than one percent of total personal vehicle purchases. Norway, however, has the highest market penetration for EVs in the world, with the EV market share hitting a high-watermark of 26.5 percent of new vehicle sales in the month of March, 2015[5] (20% battery electric; 6.5% hybrid) and more than 20 percent consistently since January, 2015.

While BC is more than twice as large as Norway, there are many similarities. Norway has a comparable population to BC (5.1 million vs 4.6 million inhabitants); it shares a similar mountainous geography with fjords punctuating the coastline; it has a latitudinal span (14 degrees) that is little different from BC's 11 degrees south to north; and it has a similar hydroelectric profile. So how is it that Norway has achieved such a remarkable EV penetration, but not British Columbia?

Rapid public-sector-led charging infrastructure build-out

- Nationwide charging station build-out ended 'range anxiety'
- Norway has >5,600 public charging stations; BC has <600

Domestic analysts agree that the build-out of charging infrastructure has been a vital measure in the elimination of 'range anxiety'—the fear of running out of electrical charge prior to the destination being reached. If charging stations are not conveniently at hand, it can also limit the use of most EVs for long-distance trips. Thus even households with EVs will still tend to use conventional vehicles for some of their driving needs. Indeed, surveys of Norwegian auto consumers had shown that range anxiety, or *'rekkeviddeangst'* in Norwegian, was the single greatest barrier to the purchase of an electric vehicle.

In 2009, the Norwegian government funded a nation-wide build-out of EV charging infrastructure via Transnova, a public agency set up to demonstrate and build out clean transport projects, at a cost of NOK60 million (US$7.4 million)[6]. That effort coincided with a charging infrastructure initiative by the city of Oslo. Prior to this time, EV charging outlets were scarce. But from 2009 onward, charging points rapidly became commonplace across the country. In the first year, the number of public charging points climbed from 500 to 2500 and by the end of 2014, Norway was home to over 5,600 Level 2 public plug-in locations (6,500 including private charging points), including 92 fast-charging stations and 84 super-fast-charging stations[7]. At the time of writing, BC has roughly one-tenth of that charging capacity: 550 Level 2 (240 volt) stations and 12 operating fast charging stations[8].

Perks, not just incentives, & open-ended tax relief

Beyond charging infrastructure, the Norway government achieved a cross-party consensus that established a series of incentives to drivers of all-electric vehicles[9], although to call them 'incentives' misses how in reality they are fantastic perks any driver would love to have:

- EV drivers may use bus and taxi lanes
- EV drivers pay no parking charges anywhere in the country
- Electric vehicles go on ferries for free
- EV drivers pay no road tolls
- municipal recharging is free
- no tax on new EVs (Value-added tax [VAT] and registration taxes—making electric vehicles price competitive with conventional cars)
- annual driving fee is $73 compared to $524 for a regular car
- EVs are exempt from company car tax

The three most important incentives for uptake, according to a 2015 European Union analysis[10] of Norway's

EV regime, have been the VAT exemption, access to bus lanes and free toll roads. Crucially, unlike BC's rebate scheme, the tax relief is open-ended. In addition, the analysis found that modest adjustments to the car taxation regime could make exemptions and incentives revenue-neutral, thus achieving substantial CO_2 reductions at little government cost.

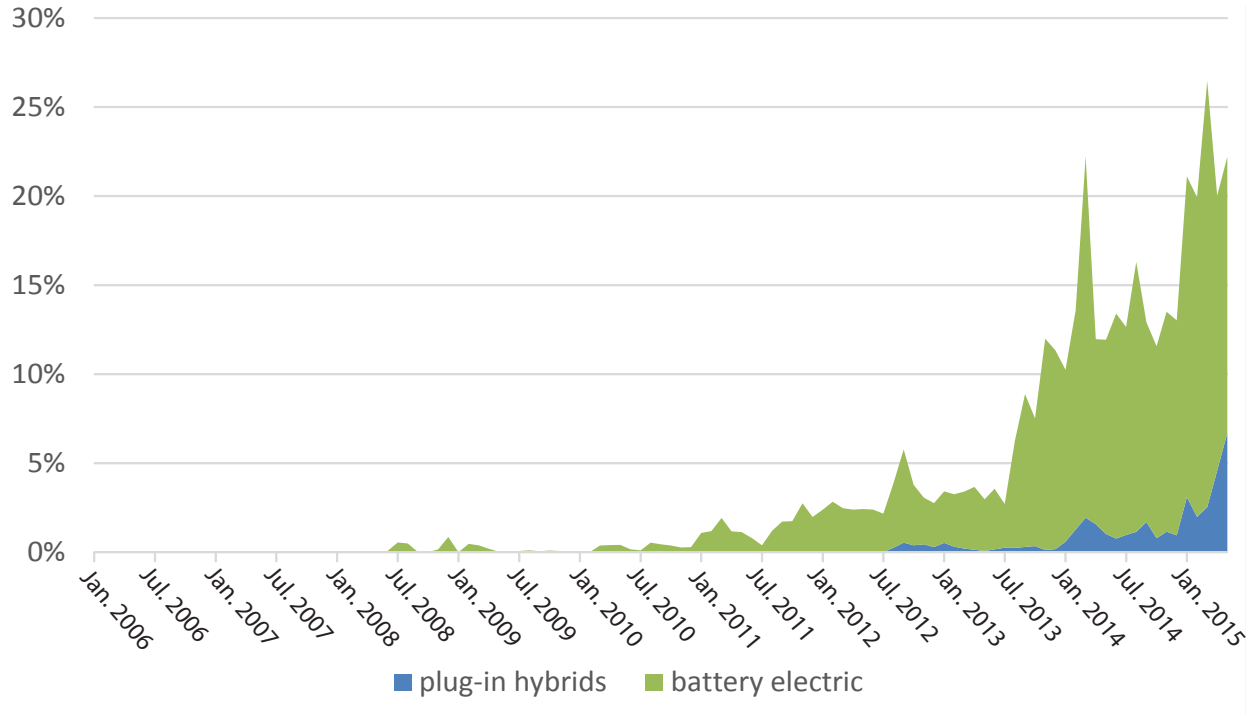
The same study found large regional differences in the benefits users report from the different perks. For example, bus lane access is crucial in the capital Oslo, while ferry savings are more important in driving uptake on the coast. The EU analysis argued that because EV uptake is spreading even in rural areas where perks such as bus lane access are meaningless, incentives are also successful in raising awareness and in kick-starting the market.

Note that plug-in hybrids have not hit the same peaks as all-electric vehicles as they are not eligible for the same tax exemptions and incentives.

Additional factors of success

The greater availability in recent years of desirable vehicle options from manufacturers has played a significant role as well on the supply side of the equation. Note that automaker availability of EVs in the Norway and European markets started in 2009, compared to 2011 in Canada. In March, 2014, the Tesla Model S broke the 28-year-old record for monthly sales of a single automobile model in Norway, regardless of power source, with 1,493 units sold, beating the Ford Sierra, which had sold 1,454 units in May, 1986.[11] Manufacturers cannot currently supply enough EVs to satisfy the Norwegian market.[12]

In addition, cross-party consensus on EVs has permitted the policy to continue even after the social-democratic-led administration that pioneered the approach was replaced in 2013 by a conservative-led coalition. The current government is reportedly very proud[13] of its world-leading policy.



Electric vehicle porportion of new vehicles sold 2006-2015
Source: Norwegian Ministry of Climate and Environment

It is important to recognize that it is not only city-dwellers who are purchasing EVs. In 2008, four out of every five EVs were sold in the capital, Oslo. By 2013, this figure had dropped to two out of every five.[14] In Norway, EVs are as much a rural as an urban phenomenon.

Perks as important to consumers as tax relief

- While the perks do not save consumers a large amount, the convenience they offer has a profound psychological effect

Interestingly, some other European countries such as Sweden, Denmark and Germany have experimented with tax incentives, but hardly at all with Norway-style perks, and have seen nowhere near the same level of uptake, suggesting that the perks offer strong psychological value to the citizen, despite their financial value being considerably smaller than the tax relief.

In 2013, the daily Budstikka newspaper tested how long it took to get to work in the morning rush hour from a suburb near Oslo Airport to a borough in the west of the city, comparing travel times for conventional and electric vehicles. Due to EV access to bus lanes, the former took 51 minutes and the latter 19 minutes.[15] Norwegian analysts are convinced it is the perks rather than the tax incentives that have been most critical to the country's EV revolution.

These analysts describe a take-off phenomenon where in a brief period of time, everyone knew a friend, family member or co-worker who drove an EV and then felt they had to have one too in order to 'keep up with the Joneses', or in this case, the Johansens. That emerging trend coincided with price reductions that manufacturers were able to offer domestically due to higher market volumes and competition for customers.[16]

Norway's investment costs

The financial subsidies were initially due to be phased out either in 2018 or once the country reaches a specific penetration rate for EVs—50,000 vehicles. However, as of March 2015, the country was home to 52,865 plug-in electric vehicles (49,296 all-electric and 3,569 plug-in hybrids), according to Grønn Bil (Norwegian for "Green Car"), hitting the target three years ahead of schedule (indeed, by September the figure had grown to 74,282)[17] As a result of the premature success, in May, the government overhauled its policies. Tax exemptions have been prolonged until 2017, with a gradual phase-out scheduled from 2018. Free parking and access to bus lanes will now be decided by local authorities. In addition, a tax proposal rewarding all low-emission cars—beyond merely electric vehicles—is currently under consideration by the governing conservative coalition, basing tax rates on emission levels than, as previously, on horsepower. The longer-term target is to see 200,000 EVs on the roads by 2020, but at current uptake rates, that goal may be achieved much sooner.

As of 2014, the programme had cost the public purse US$450 million, according to the Norwegian Ministry of Climate and Environment, including US$7.4 million for charging station infrastructure[18]. Just under US$350 million of this is a result of foregone VAT and registration tax revenues, with about a fifth of the sum represented by forgone ferry, parking and road toll revenues.

National-level policy requirements

- Norway is a nation; BC is a province

Most of Norway's EV-related policies are constitutionally unproblematic for a Canadian provincial government

to legislate, but one aspect can only be implemented by the federal government: Norway has a car import tax that is scaled in relation to emissions of carbon dioxide CO_2 and NOx (mono-nitrogen oxides NO and NO_2, which contribute to smog formation in areas of high vehicle traffic) as well as vehicle weight. This policy rewards smaller, low-emission imports.

Challenges

- municipal buy-in
- ferry-operator loss of revenue
- diminished benefit from perks as uptake increases
- lack of charging stations in apartments
- electricity grid reliability

Note that many of the challenges are the result of the unexpectedly rapid success of Norway's EV policies, which now need to be augmented to bring market penetration to the next level.

For the EV perks to be effective, Norwegian analysts have concluded that it is vital that there be good cooperation between municipal and higher levels of government, as some perks are in the power of one but not the other to offer.

With growing EV penetration, bus lanes have become more crowded, and there has been some loss of revenue for ferry operators. Application of similar perks in British Columbia would require the government in BC to compensate BC Ferries or otherwise make allowances for revenue losses. In addition, owners of conventional vehicles have become disgruntled at the lack of parking spaces and the lack of a parking time limit for EVs, although this has also provided an incentive toward the purchase of an EV.

Despite high interest in electric vehicles from residents of apartment and condominium complexes, fewer than five percent of building owners or strata councils in Norway are even considering installing charging infrastructure. The government is due to intervene shortly to correct this constraint via a series of rebates and incentives.

The biggest challenge however comes from the increased demands on the electricity grid, a difficulty that all jurisdictions around the world will eventually have to face as they transition away from fossil-fuel based light vehicles.

Effects on the electrical grid

- even low rates of EV penetration have negative impacts on grid reliability
- grid stresses can be countered with smart-grid, smart-charging strategies—but only up to moderate penetration rates
- at moderate to high penetration rates (>50%), even smart charging cannot handle the additional stress
- battery-swapping would eliminate the problem of system stresses
- without "huge" energy storage capacity, the additional electricity needed overall (not just at peak times) cannot be met by wind power generation due to its intermittency

Norway's EV revolution has been so successful that questions about negative impacts on electrical grid operation have become live rather than theoretical issues.

A 2013 analysis of large-scale integration of EVs deploying models involving data from Nord-Trondelag Elektrisitetsverk, a regional power company and operator of the nation's power grid, demonstrated that at a nation-

wide penetration rate of 7 percent (200,000 vehicles), vehicle charging demands will breach voltage variation restrictions.[19] The scale of the problem varies depending on where the vehicles are situated physically at any one time. If as few as six, closely congregated vehicles charge near a sensitive node at peak times, this may place more local demand than the system can handle. However, if vehicles are less physically concentrated, the system can handle up to 20 percent penetration without system reliability breaches occurring.

For low and moderate levels of fleet penetration, these voltage fluctuations can be successfully mitigated with smart-grid and smart-charging strategies.[20] This involves deployment of smart meters, digitally optimized load-balancing (in which for example consumer and industrial appliances communicate with the utility, and are switched on or off by such a network to run at off-peak hours), and innovative energy storage systems. The use of "end-charge" timed programming, for example, involves customers setting a preferred time for the charging to be complete. The start-time is then randomised so as to prevent large numbers of vehicles from coming online at the same time and avoiding power-load spikes that can negatively affect local distribution. Scenarios assuming 20 percent penetration showed that by deploying such techniques, the added load does not seem to put more stress on the system than it can handle. In the BC context, such technologies giving the utility control over charging of vehicles remotely could actually serve as an 'off-peak load opportunity'. During non-peak times, the grid goes underused. At these low and moderate levels of EV market penetration, smart-grid systems could serve to channel this excess into car batteries, without requiring increases in generation and transmission capacity.

However, for scenarios that envisage 50 percent fleet penetration rates or above—the medium-term goal of any transport electrification policy—even with smart-charging strategies, the charging load presents the Norwegian system with too much stress. Other strategies, including upgrades to distribution networks, battery-swapping (see below), and inductive (wireless) charging, may be necessary.

These findings dove-tail with PICS projections from 2009 that found that with the above-mentioned smart methods of charging strictly during off-peak times, a strategy known as 'valley-filling', there is no immediate threat to the *supply available* in the network from EVs at the early stages of adoption[21]. Real-world experience from Norway demonstrates that as market penetration increases beyond these early stages, threats from the related but separate issue of reliability of distribution networks with respect to voltage management do materialize.

Scenarios that invoke wind-generated power to meet the additional load associated with a 20 percent EV penetration rate found that it could meet the challenge in winter but not during the rest of the year when wind generation is more intermittent. During such times, "huge capacity storage systems" would be needed to cover the additional load requirements. Indeed, with just an 18 percent penetration rate, the capacity of the storage systems would have to be "extremely high", according to Norwegian researchers.

An EV penetration rate of 100 percent in Norway would require 7 TWh of additional power annually (not including energy efficiency savings in the broader economy, which could reduce this figure), or around five percent of the country's total electricity production.[22] For a domestic comparison, it is projected that BC's proposed Site C hydroelectric dam will produce 5.1 TWh annually upon completion.

Achieving 100% electrification: Still a long road ahead

Note that the Norwegian 200,000 EV target represents only about 7 percent of the country's roughly 2.5-million-strong car fleet. BC has a similar light-vehicle profile, with 2.95 million cars currently registered. There is still a very long way to go.

Moreover, Norway has not had anywhere near the same success with electric vans as it has had with cars, with sales in the low hundreds.[23] However, this may have to do with the limited market availability of such vehicles.

Supply-side policies targeting manufacturers thus may be necessary alongside demand-side policies focused on citizens. In addition, policy-makers are currently considering what sort of incentives or regulations should be put in place to achieve greater EV sales to private businesses and public bodies, i.e., the 'fleet market', which has been slow to see widespread EV penetration.

Furthermore, the Norwegian government recognizes that for still wider uptake to occur, consumers will increasingly have to view EVs as the superior option in the absence of perks, tax incentives or subsidies. Access to bus lanes ceases to be a perk, or even meaningful, once large numbers of cars are driving in them, for example. Crucial to the next stages in market penetration will be advances in battery technology that radically reduce cost. But such cost reductions are dependent on economies of scale resulting from a much larger EV market than Norway alone can deliver. That is to say, to achieve the ultimate goal of complete (near 100%) electrification of the vehicle fleet, Norway will be reliant on most other countries adopting similar policies.

Battery swapping vs super-fast chargers

While charging overnight is usually sufficient for most households, on the road, the time it takes to charge is much longer than filling up with gas, which makes EVs more limiting to taxi drivers, urban goods delivery vehicles, ambulances, and a range of other workplace-related vehicle uses. It is widely regarded[24] by analysts in Norway that the length of time required to recharge is has become the biggest barrier to wider uptake now that range anxiety has been largely eliminated. However, positive experiences in New York, Amsterdam and a number of British cities with innovative and cleverly located fast-charging infrastructure have proven to reduce this limitation.

For example, as of 2015, Schipol Airport, a major European air hub, only allows electric taxis to pick up passengers. In order to accommodate this, the airport joined with researchers from Delft University in a EU-funded partnership to develop a smart, optimally balanced fast-charging system[25]. These chargers typically demand a great deal of power, so much so that a complete transformer substation would normally be needed to service them—at an enormous cost. The Delft researchers' smart-charging technology eliminates this requirement while reducing charging time to such a level that electric taxis can now perform the same number of daily cab rides as diesel taxis.

Installation of a national network of superfast charging stations would cost an estimated NOK 40 million (US$5m). But even here, drivers still have to wait from 20 minutes to an hour while the battery recharges—a much slower task than filling up with gas. Battery swapping eliminates this difference. With an average swap time of three minutes, this actually clocks in at a little bit faster than the average time that it takes to fill a tank with gas. There are other benefits: the batteries can be charged more slowly in the intervals between use, which improves battery life and thus cuts down on the carbon emissions resulting from the production of the batteries.

In addition, battery swapping enables the separation of the investment in the car from the investment in the battery, just as a conventional car is not sold with fuel. This would make the initial cost of an EV very competitive with conventional vehicles, as the production of a battery represents as much as 50 percent of the cost of the vehicle.

The Norwegian government's clean-energy agency Transnova is engaged in battery-swapping test projects, but in the near future there will be significant barriers to this as an option. The main obstacle is cost. The battery-swapping service-provider must maintain a large inventory of batteries, and that obligation represents a major capital investment.

A lesser worry is the requirement for battery standardization, to make swapping simple and hassle-free. Standardization of recharging outlets and plugs is similarly required and the EU is in the process of legislating just

such standards following the pattern it established when it legislated common Europe-wide mobile-phone adapter standards.

Future research

Further research will be required to assess a detailed quantification of grid impacts in BC under different EV adoption scenarios; which smart-grid technologies are appropriate; and how the Norwegian system of perks could be adapted to the BC context.

Recommendations

Norway's experience offers **six key lessons** for BC:

1. Public-sector-led build out of nationwide (province-wide) charging stations helps overcome 'range anxiety'.
2. Provision of highly desirable perks such as free ferries, free charging, free parking and access to bus lanes is a key driver of uptake.
3. Open-ended tax-relief for electric vehicles is a key driver of uptake.
4. Municipal-provincial cooperation would be necessary to deliver the perks.
5. There must be cross-party consensus to maintain support should the government change.
6. Over the medium term, smart-charging infrastructure and distribution network upgrades must be rolled out to overcome grid stresses.
7. Long-term energy planning must take into account that 100% penetration of EVs in the light-vehicle sector will consume some 7 TWh of electricity annually.

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