



# ERC

ENERGY RESEARCH CENTRE  
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# **The potential of electric vehicles to contribute to South Africa's greenhouse gas emissions targets and other developmental objectives**

## How appropriate is the investment in electric vehicles as a NAMA?

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# Executive summary

**Transport consumes 28% of final energy in South Africa, 97% of which is in liquid fuels, and subsequently contributes 13.1% of South Africa's greenhouse gas (GHG) emissions. The sector is vital for economic development (Cohen 2011, Merven et al. 2012). As the demand for transport services is expected to grow, the industry needs to reduce its significant environmental impact and at the same time deliver improved mobility in a way that contributes towards South Africa's sustainable development objectives.**

This case study forms part of a larger project involving the application of the Action Impact Matrix (AIM) methodology for assessing relative impacts of a variety of GHG mitigation options in South Africa. It aims to understand the potential of stimulating the local market for electric vehicles (EVs) and developing the local electromobility industry to contribute towards reducing GHG emissions and contributing towards South Africa's other developmental objectives. The focus is on private EVs (and largely passenger ones). Electric trains and other forms of public transport have not been explicitly considered. For simplicity the study has not considered hybrids, plug-in hybrids or alternative technologies such as hydrogen fuel cells.

**In meeting the aim, this study poses the following two key questions:**

1. What are the potential impacts (GHG emissions and other developmental impacts) associated with the increased use of EVs and with the development of an element of the e-mobility value chain in South Africa?
2. How could the government create an enabling environment that stimulates the local EV market and allows the successful development of the local e-mobility industry?

These questions are difficult to answer as impacts depend on the story that unfolds. This study considers two distinct aspects of the story: stimulating the EV market by getting more vehicles on the road in South Africa; and developing the e-mobility industry to achieve socio-economic benefits through local production of an element or elements of the e-mobility value chain. The study draws on literature that explores the possible impacts, the specific potential for developing the local industry based on a review of the global value chain literature in the context of the automotive sector, and how the government could create an enabling environment to achieve the potential benefits. This was supplemented by interviews with key stakeholders and the presentation of initial results during a stakeholder workshop on the application of the AIM methodology.

In terms of the regulatory and policy context, there does not appear to be a coordinated approach to stimulating the EV market and promoting the local industry. The Department of Transport is broadly supportive of e-mobility but does not see it as a priority area. The Department of Trade and Industry is calling for greater local production in the EV value chain but the Automotive Production and Development Programme (APDP) does not mention electric vehicles and so it appears that the EV Industry Roadmap (under review) is not regarded as a core approach to developing the broad automotive industry. There appears to be intention to take steps towards greater e-mobility in the country (through the proposed purchase of 3000–5000 EVs per year by government from 2015) but that this is rather an attempt to make an investment without taking significant risk, to assess impacts and technology options, and to allow flexibility to adapt to changing market conditions and technologies. This model is supported by the Technology Innovation Agency which acknowledges the need for innovation to happen on the ground. The Department of Environmental Affairs includes EVs in the flagship programmes aiming to 'encourage new energy efficient-vehicle technologies, such as electric vehicles, by setting procurement objectives for acquiring such vehicles' (DEA 2011). The result is a 'living lab' approach which will



allow the country to keep abreast of developments, be ready to move in the direction of greater e-mobility but not to invest too heavily in this area while there is significant market risk and uncertainty. The shortcoming with the current regulatory context is the lack of coordination and integration within and across departments.

Based on a scenario that considered the government's intentions and what was seen to be feasible, the study found that investing in stimulating the local market, especially in the longer term, is expected to generate significant sustainable development benefits. This would reduce emissions (even with the current grid) and contribute to energy security by providing a storage facility that can help smooth consumption of Eskom electricity and potentially facilitate decentralised electricity generation (e.g. through solar panels). Electric vehicles are also more efficient on a joule per kilometer basis than conventional vehicles and result in reduced exposure to volatile oil prices, reduced oil imports, no local noise or air pollution and lower running costs. Electric vehicles do, however, cost more and there is no obvious poverty alleviation benefit. Added to this are consumer concerns around range, reliability and performance but many of these concerns could be overcome through a targeted behavioral change campaign. The South African government should therefore devote resources to creating an enabling environment for purchase and use of EVs on South Africa's roads.

The appropriateness of investing in the e-mobility industry is less clear. The most important lesson from the GVC literature, in terms of the EV industry development, is that the virtuous cycle of development can only be achieved if the local domestic market is sufficiently large to attract significant investment in the first instance. The study did not find that planned approaches are likely to generate the sort of demand needed to stimulate the local industry. This, coupled with uncertainty around the global future demand for EVs, suggests that significant investment in this industry would not result in adequate developmental benefits. In the short term, prioritising the production of niche vehicles and public transport vehicles (not included in the scope of this study) could present opportunities for the development of the local industry with subsequent benefits. In instances where the application requirements meet the EV capabilities, and the EV is cost-competitive, demand could grow in the short term. South Africa could position itself to meet this growing demand locally.

Based on these findings, it was recommended that the South African government invest in getting more electric vehicles on the roads. This is technologically feasible and would be appropriate. To do this they would need to create an enabling environment that provides incentives for EV purchase, infrastructure investment and R&D, together with the investment in EVs for the public fleet. This would need to be supported by an awareness raising / behavior change campaign together with the development of a smart grid, 'cost-of-use' tariffs and other measures to manage the impact of the vehicles on the electricity supply infrastructure. Further efforts to develop a low carbon grid would maximise benefits. With regard to developing the local industry, government should pursue the 'living lab' approach to ensure the industry can adapt should market factors change. This should be coupled with diversified investments in different technologies and a focus on niche vehicles in the short term, which have real potential for achieving developmental benefits, although not at a significant scale.



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# 1. Introduction

*Whether we like it or not hybrids [and electric vehicles] are coming to South Africa – Yotish Sewgoolam (Technology Innovation Agency)*

Transport consumes 28% of final energy in South Africa, 97% of which is in liquid fuels, and subsequently contributes 13.1% of South Africa's greenhouse gas (GHG) emissions. The sector is vital for economic development (Cohen 2011, Merven et al. 2012). As the demand for transport services is expected to grow, the industry needs to reduce its significant environmental impact and at the same time deliver improved mobility in a way that contributes towards South Africa's sustainable development objectives.

This case study forms part of a larger project involving the application of the Action Impact Matrix (AIM) methodology for assessing relative impacts of a variety of GHG mitigation options in South Africa. The aims of the broader project are to:

- enhance capacity of stakeholders in South Africa to apply AIM methodology for climate change mitigation planning;
- develop, through the use of AIM, policy options to integrate climate change mitigation into national sustainable development planning in South Africa;
- assess the contribution of AIM in fostering action to integrate climate change into sustainable development planning in South Africa.

The AIM tool, developed by MIND, has been successfully applied in many countries and is now recognised as a major approach to integrate climate change response policies and measures into sustainable development strategy.

This element of the project aims to assess the impacts of electromobility relative to the other mitigation options. In doing so the intention is to understand the evolution of the electric vehicle (EV) context in South Africa (the impetus for investing in EVs and past, current and future policies, plans and programmes for electric vehicles); identify potential impacts associated with the electromobility industry development and greater use of EVs in South Africa (GHG emissions and other developmental impacts); and to critically assess the South African approach to investing in electromobility and EVs in particular. The focus is on private EVs (and largely passenger ones). Electric trains and other forms of public transport have not been explicitly considered. For simplicity the study has not considered hybrids, plug-in hybrids or alternative technologies such as hydrogen fuel cells.

## 1.1 The transport sector and automotive industry context

Transport energy demand is expected to more than double by 2050. Consequently, CO<sub>2</sub> emissions will do the same unless a number of energy saving policy interventions are adopted (Merven et al. 2012). Various other interventions, such as shifts from road-to-rail and greater use of public transport, are also needed. However, if South Africa is going to contribute its fair share of the climate change mitigation effort then additional measures will be needed. Electromobility (e-mobility) presents a potentially important option for reducing GHG emissions from transport and contributing to energy security. Whether e-mobility can contribute to South Africa's other developmental objectives depends on the extent to which the country can develop the local e-mobility industry.

South Africa's automotive industry is the largest manufacturing sector in the country. It contributes an estimated 6–7% of national GDP (Deloitte, 2012). Activities in this sector include production of vehicles, vehicle components and related retail, distribution and servicing activities. There are import linkages in the sector that result in a significant multiplier effect in the metals (steel, aluminium and platinum), plastics, leather and textile industries (Deloitte, 2012). Local production is undertaken by subsidiaries of global automotive companies, manufacturing vehicles for the local and export markets. There are an estimated 200 local component manufacturing companies active in South Africa (Deloitte, 2012). There is evidence of growing investment by original equipment manufacturers in the industry due in large part to the attractive incentive programmes in South Africa (Deloitte, 2012). Thus far no OEMs have considered producing EVs in South Africa. The extent to which local manufacturing of EVs and their components (or other elements of the e-mobility value chain) can be competitively undertaken in South Africa is uncertain.

## 1.2 Key questions

1. What are the potential impacts (GHG emissions and other developmental impacts) associated with the increased use of EVs and with the development of an element of the e-mobility value chain in South Africa?
2. How could the government create an enabling environment that stimulates the local EV market and allows the successful development of the local e-mobility industry?

These questions are difficult to answer as impacts depend on the story that unfolds. The story is highly uncertain due to uncertainty in demand (global and domestic demand), technology uncertainties (which mobility technologies are likely to be successful), environmental uncertainties (climate change and other pollution requirements), developmental necessities (changing developmental objectives) and the time periods over which changes in these variables will occur.

This study considers two distinct aspects of this story:

- stimulating the EV market by getting more vehicles on the road in South Africa; and
- developing the e-mobility industry to achieve socio-economic benefits through local production of an element or elements of the e-mobility value chain.

These aspects are considered separately, but linkages are considered as the local demand affects the local e-mobility industry and any desires to develop the local industry will require the development of the local market. Drawing on a review of the literature and interviews with key stakeholders, this study then considers the potential impacts of the two aspects of the story. Impacts associated with the increased use of EVs are modelled using assumptions based on the literature and stakeholder interviews. An assessment of the global value chain (GVC) literature in respect of the automotive manufacturing industry, together with other literature and the findings from the interviews, forms the basis for determining the potential for developing the local e-mobility industry. Based on the answers to the key questions, the study then considers whether the development of the EV market and/or the local EV industry could be considered as a responsible use of national resources and what the requirements would be to maximise the potential benefits.



## 2. Methodology

This study comprised three distinct phases. The first phase involved a targeted analysis of the literature. It was targeted in terms of a focus on electric vehicles (mostly looking at passenger vehicles) within the context of climate change and specifically the identification and prioritisation of Nationally Appropriate Mitigation Actions (NAMAs). This considered the possible impacts, the specific potential for developing the local industry based on a review of the GVC literature in the context of the automotive sector, and how the government could create an enabling environment to achieve the potential benefits.

The literature review was supported by a number of interviews with key stakeholders in the country (the second phase). The list of stakeholders interviewed is included in Table 1. The interviews were conducted over a two-month period. The interviews were semi-structured and tailored to each specific stakeholder. A full list of interviewees is provided in the Appendix.

**Table 1: Institutions from which stakeholders were interviewed**

Stakeholder category	Institution
Government department	Department of Environmental Affairs (Climate Change Monitoring & Evaluation; Climate Change Mitigation)
	Department of Trade and Industry
	Department of Transport
Public institution	Council for Scientific and Industrial Research (Battery Research Centre)
	Technology Innovation Agency
	Eskom (Research training and development)
International agency	GIZ (TRANSfer)
Civil society	World Wide Fund for Nature
Academic Institutions	University of Cape Town (Energy Research Centre; Department of Economics)
	University of the Western Cape
	University of the Witwatersrand (Centre of Material and Process Synthesis)
Private sector	Grid Cars (private electric vehicle manufacturer)
	Honda
	Nissan
	Optimal Energy (previous employees who worked on the Joule programme)
	Sasol

The third phase involved the presentation of the impacts associated with a specific scenario for electric vehicle penetration in the country and any industry development associated with such investments. As part of communicating the story behind the scenario an initial summary of the case study presented in this chapter was also presented. Participants were asked to provide feedback by critically assessing assumptions and findings, and where appropriate, providing information to help fill gaps.

## 3. Literature review

The review of the literature considered firstly what the possible impacts could be associated with both increasing the number of EVs on South Africa's roads and developing the e-mobility industry. Secondly the GVC literature in the context of the automotive sector was assessed to inform the discussion around the potential of developing the e-mobility industry. Finally the review concentrated on potential investments in creating an enabling environment to understand how the South African government could potentially achieve benefits associated with stimulating the EV market and developing the e-mobility industry in the country.

### 3.1 Impacts

Potential impacts will depend on the scenario that unfolds. The development of the local industry depends largely on the extent to which the local/regional market develops. Table 2 provides a summary of the potential impacts associated with increasing the number of EVs on South Africa's roads and developing the local e-mobility industry.

**Table 2: Summary of impacts associated with the EV market and industry development**

Impacts associated with increased use of EVs		Impacts associated with e-mobility industry development	
+	<b>Improved energy security:</b> EVs are 9 – 17% more energy efficient than ICEVs (well-to-wheel) (Saber & Venayagamoorthy 2011); can smooth consumption (if charged off-peak) and can be used as electricity storage facilities. Some negative short-term impact on energy security if EVs are charged during peak periods.	+	<b>Development of locally relevant technologies:</b> the industry can ensure that technologies meet South African specifications and standards to avoid being stranded with an expensive technology that does not work properly in the Southern African context.
+	<b>Reduced local air &amp; noise pollution:</b> no emissions at point of operation	+	<b>Reduced costs:</b> Local production can potentially reduce input and component costs.
+	<b>Reduced exposure to oil price volatility &amp; reduced oil imports</b>	+	<b>Greater localisation:</b> development of elements of the e-mobility value chain is possible but unlikely to deliver significant benefits. Greatest potential may be in niche vehicles (small volumes) and potentially in components (such as the lithium ion batteries)
+	<b>Uncertain (likely positive) GHG impacts:</b> divergent views from significant mitigation potential (Winkler 2007) to lower CO <sub>2</sub> but higher CO <sub>2e</sub> emissions (If NO <sub>x</sub> is included) to no meaningful impacts (Doucette & McCollach 2010). Significant benefits are expected as electricity generation becomes less carbon intensive over time.	?	<b>Uncertain (possibly positive) job impacts:</b> IPAP2 (DTI 2010) predicted 160 000 direct jobs from 2010 – 2020 (this is unlikely). If local demand is locally supplied then there will be no significant net impact in jobs (substitution of skills to produce a similar product). Net job creation is possible if South Africa increases vehicle / component manufacture for export (unlikely and would not employ low skilled people). There would be a minor negative impact on jobs if all EVs (and technology) were imported.



<b>+</b>	<b>Lower operating costs:</b> 75 – 99% lower operating costs than ICEVs (depending on peak or off-peak charging)	<b>0</b>	<b>No impact on poverty and inequality:</b> The automotive industry does not and is unlikely to employ low / no skilled labour.
<b>0</b>	<b>No impact on poverty and inequality:</b> No significant impact on the poor and most benefits will accrue to higher income deciles.	<b>-</b>	<b>Some loss in value-add:</b> minor negative impact if all vehicles (and technology) are imported
<b>-</b>	<b>High capital costs:</b> 32- 64% premium on vehicle costs (Duvenage 2012; Winkler 2007) and significant upfront infrastructure investments (depending on the market demand scenario)	<b>-</b>	<b>Opportunity cost:</b> government revenue is invested in supporting the industry (e.g. subsidizing local production) at the expense of supporting other, more labour intensive sectors.
<b>-</b>	<b>Environmental pollution:</b> component disposal (especially batteries)		
<i>Note: the size of the symbols refers to the relative size of the impacts. This assessment was based on the data obtained from experts and from the literature review.</i>			

Uncertainty in the local market, coupled with high levels of uncertainty in the international markets, makes it difficult to predict these impacts. In the long term many of the negative impacts will be reduced (as capital costs are expected to reach parity or be lower than internal combustion engines) and positive impacts will increase (especially as the grid becomes cleaner). Further detail on each of the impacts is provided in the section below.

## 3.1.1 Increased use of EVs

The benefits presented are all possible should adequate intention and resources be devoted to achieving this outcome.

### Improved energy security

This represents potentially the greatest benefit. There are three factors driving this potential benefit: from the well-to-wheel EVs are more energy efficient on a joule per kilometre basis; the batteries in EVs can store electricity and any surplus can be fed back into the grid during peak periods (helping to smooth electricity consumption if vehicles are charged during off-peak periods); and as a storage facility EVs could facilitate decentralised electricity generation (assuming institutions are put in place that allow for decentralised generation with the ability to feed back into the grid)<sup>2</sup> (Duvenage 2012; Saber & Venayagamoorthy 2011). All of these options would help reduce the demand for energy in the country and the electricity storage benefits would help manage the demand for Eskom-generated electricity (especially peak demand). Table 3 illustrates the energy efficiency of EVs relative to other vehicles and fuel types. The table illustrates that with the current grid dominated by coal-fired power stations the efficiency of EVs is higher than that of ICEVs. The addition of more efficient electricity generation to the grid (through increased renewables) would increase the relative efficiency of EVs even further.

<sup>1</sup> Interview 13.

<sup>2</sup> It is not currently possible for privately generated electricity to be fed back into the grid other than through the RE IPPPP.



Scenario	Original resource	Production	Distribution	Vehicle	Total (well-to-wheel)
Percent of energy utilised					
Imported petrol	Oil well: 95%	Refinery: 90%	Liquid fuel infrastructure: 97%	Petrol car: 18%	15%
Locally produced petrol	Coal mine: 97%	Synfuel plant: 40%	Liquid fuel infrastructure: 97%	Petrol car: 18%	7%
Locally produced electricity	Coal mine: 97%	Power station: 35%	Electricity grid: 95%	Electric car: 75%	24%

Table 3: Wells to Wheels Operating Energy Efficiency of different vehicle and fuel-type options

Source: adapted from Snyman (2012)

Eskom has a capacity challenge. A coal-fired power station cannot be simply switched on and off as it takes time to power up and power down. Eskom tries to match supply and demand however there are situations where supply exceeds demand such as during the night where demand is low. If charged at night, EVs could smooth the flow of electricity consumption throughout the day/night (Duvenage 2012). This depends on the charging options but ‘smart charging’ would be possible. This would improve the efficiency of Eskom by consuming electricity that is currently wasted. One interviewee suggests that there would be enough off-peak capacity to sustain six million vehicles with South Africa’s current electricity generating approach.<sup>3</sup>

There is the potential for a negative short-term impact associated with the demand for electricity rather than liquid fuels. This is unlikely to be significant as the short term demand is expected to be low and provided the charging demand is not clustered (concentrated in specific areas) Eskom would not need to invest in additional distribution infrastructure and generation capacity.<sup>4</sup>

Reduced local air and noise pollution

Electric vehicles produce no pollution at point of use. This is particularly valuable in applications such as game viewing (where quiet is valued) and indoor applications (where air pollutants cannot be diluted in the atmosphere) (Maia et al. 2011).<sup>5</sup> Reduced air pollution is also valuable in the context of South African cities that suffer from significant air pollution problems. Although the latest ICEV technology has very low emissions, local penetration is still limited and in-service testing of prevailing emissions control technology is non-existent.<sup>6</sup>

<sup>3</sup> Interview 13.  
<sup>4</sup> Interview 6.  
<sup>5</sup> Interview 13.  
<sup>6</sup> Interview 12.

### Reduced exposure to oil price volatility and reduced oil imports

Oil prices are volatile and sudden changes can have significant negative impacts on the economy. The transition away from ICEVs would reduce the need to import oil and to produce synthetic fuels in South Africa. This reduces the need for investment in refineries (presumably offset by investments in electricity generation) but also reduces the national exposure to these price shocks. The government of Chile (2012) estimates that 70 000 EVs in the Chile context would reduce petrol consumption by 380 million litres and diesel consumption by 150 million litres, reducing exposure to volatility of oil prices.

### Lower operating costs

Lower operating costs are an undisputed benefit (according to the interviewees). EVs are cheaper to maintain and the energy costs (even with rising electricity tariffs) are lower due largely to the higher energy efficiency of EVs (see Table 3). Local estimates of EV operating costs relative to ICEV operating costs range from 75% to 99% lower (depending on whether tariffs are peak or off-peak) (Duvenage 2012; Maia et al. 2011, Snyman 2012). International studies suggest these costs as being 50% (USPS-OIG 2009 (in Government of Chile 2012)) lower than ICEVs.

### Uncertain (likely positive) GHG impacts

The literature suggests divergent views regarding the mitigation potential of electric vehicles in South Africa especially considering the current carbon-intensity of the grid. This study finds evidence to support the assertion that the likely impact is positive even with a carbon-intensive grid, and that the benefits would become significant as more renewable electricity sources are included the grid.

The key aspects to consider in this debate are the carbon-intensity of the grid, the amount of energy used by EVs relative to ICEVs, the ability to gain efficiency improvements and the carbon intensity of the fuel used by ICEVs in South Africa. Table 4 presents a summary of results from three studies that assessed the mitigation potential of EVs in the South African context specifically. All studies show that the grid scenario has a significant impact on the full environmental impact of electric vehicles (Maia et al. 2010, Liu et al. 2012). As the grid becomes less emissions intensive over time, the positive benefits will become more significant.

Table 4: Mitigation potential of EVs relative to ICEVs from different studies

Source	Mitigation potential	Explanation
LTMS (Winkler 2007)	34.6 kgCO <sub>2</sub> e saved per passenger kilometre (GWC ).	Assumes: <ul style="list-style-type: none"> <li>• EVs take up 10% (2008 – 2016) and 60% (by 2030 – 2050) of passenger kilometre demand.</li> <li>• Average occupancy rate of 2.1.</li> <li>• In the case of nuclear and renewables dominated grid, renewables make up 27% by 2030).</li> <li>• Total mitigation potential: 450 MtCO<sub>2</sub>e (2003–2050) (GWC) &amp; 6 255 MtCO<sub>2</sub>e (2003–2050) (nuclear and renewables dominated grid)</li> <li>• 480.8 kgCO<sub>2</sub>e saved per passenger kilometre (nuclear- and renewables-dominated grid).</li> </ul>
	480.8 kgCO <sub>2</sub> e saved per passenger kilometre (nuclear- and renewables-dominated grid).	
Liu et al. (2012)	65% to 115% increase in CO <sub>2</sub> e per kilometre travelled (current grid in 2030).	<b>Excludes process emissions from synthetic fuels in relative emissions calculation. Identify a reduction in CO<sub>2</sub> but due to a significant increase in NO<sub>x</sub> the relative CO<sub>2</sub>e is higher.</b>
	25% to 41% increase in CO <sub>2</sub> e per kilometre travelled (policy adjusted IRP grid in 2030).	
Grid Cars <sup>8</sup>	Up to 32.5% decrease in CO <sub>2</sub> e per 100 kilometres travelled (current grid).	Assumes charging off-peak utilising a 'commuter' model developed by Grid Cars (a more efficient mobility option where the application and the vehicle technical capabilities are more effectively matched).

In a study in the US, the environmental impacts of all electric vehicles became comparable to, or somewhat higher than, those from petrol, where coal- and natural gas-fired power plants account for the majority of total generation (National Research Council of National Academics 2009). Huo et al. (2010) studied the environmental implications of electric vehicles in China, where improved but still low efficiency and heavily polluting coal-fired power plants make up more than 80% of the total generation. They concluded that, in 2008, electric vehicles in China did not promise much benefit in reducing CO<sub>2</sub> emissions, compared with conventional petrol vehicles and petrol hybrids. The study also revealed that electric vehicles could increase SO<sub>2</sub> emissions by three to ten times and also double NO<sub>x</sub> emissions compared with petrol vehicles, if the electric vehicles were charged using the current grid in China.

<sup>7</sup> Growth Without Constraints Scenario.

<sup>8</sup> Interview 13.

The coal-to-liquids (CTL) process is highly carbon-intensive (the ERC's SATIM model uses 119 kton CO<sub>2</sub>/PJ versus 3–7 kton CO<sub>2</sub>/PJ for conventional crude oil refineries (Energy Research Centre 2013)) and synthetic fuels (from CTL and gas-to-liquid processes) represent a significant portion (36%) of South Africa's total liquid fuel consumption (Liu et al. 2012). Studies take this into consideration to varying degrees when comparing EVs and ICEVs in South Africa. The variation is in part due to availability of data on the carbon-intensity of the synthetic CTL process. Liu et al. (2012) for example, do not account for these emissions. Due to data availability and reasons of simplicity they assume that the introduction of EVs in South Africa will initially replace only the market share of the imported conventional liquid fuel that is made from crude oil. The LTMS by contrast includes process emissions from synthetic fuels in their calculation of the relative impacts and it is this, in part, that explains the significant difference between the study results depicted in Winkler (2007).

At a small scale (where no additional investment in electricity supply would be required), vehicles charged during off-peak periods could utilise surplus electricity that would otherwise have gone to waste. This provides potentially substantial mitigation benefits if successfully implemented. Another potential benefit is that it is easier to control one point source of emissions (e.g. at the point where electricity is generated) rather than many point sources (e.g. the ICEVs burning liquid fuels) (Kendall 2008). Finally, it was generally found through interviews that petrol and diesel vehicles will have greater limits in terms of efficiency improvements than EVs over time.

Key to achieving the environmental benefits is that the vehicles needs to be 'right-sized' based on the commute and technological requirements. This maximises vehicle efficiency. This, together with smart charging and lowering the carbon intensity of the grid, will result in potentially significant mitigation potential.

### Higher capital costs

Electric vehicles are more expensive than ICEVs. South African studies suggest this varies from 32–64% premium on vehicle costs (Duvenage 2012; Winkler 2007). Internationally premiums are 20–40% compared to conventional vehicles (Government of Chile 2012). Batteries account for the large majority of these costs. Some argue that the lower operating costs (for the owner) would make such an investment worthwhile. Others argue that the payback period is beyond the reasonable life of the vehicle. It is expected that the cost of EVs will decrease over time as more R&D is invested into EV technologies. Several studies predict that in a 10-year time frame the cost of batteries will fall and reach parity with conventional vehicles (Deloitte 2010). EVs may possibly reach below parity but the timing of this depends on how the market develops. At this point it would no longer be necessary to provide incentives to promote demand (Government of Chile 2012).

One way of mitigating the negative cost impacts on consumers, however, would be to develop a new model where people do not own cars but rather share them through a scheme administered by government or private companies. This would allow for the 'right-sizing' of vehicles according to their intended application but would require a total transformation of the model for personal transport where currently consumers value owning vehicles for status and other intangible reasons that do not promote efficient and cost-effective mobility.

### Environmental pollution

Component disposal is a concern, especially regarding the batteries that contain hazardous waste. Efforts are underway to mitigate this risk through reuse and recycling. Battery second and third life is receiving attention both as a way of mitigating environmental risks but also looking to provide an electricity storage facility to promote energy access in rural areas.

### 3.1.2 Impacts associated with e-mobility industry

The potential for developing a local industry is far more uncertain than the potential for stimulating the local market for EVs. As such, the potential impacts associated with local production in the e-mobility value chain, are unclear.

#### Developing locally relevant technologies

If technologies are developed or adapted locally over time, the industry can ensure that technologies meet South African specifications and standards. This would avoid being stranded with an expensive technology that does not work properly in the Southern African context. The value placed in this benefit by stakeholders indicates a perception that the transition towards e-mobility in South Africa is likely, especially in the longer term. This speaks to the need to be 'EV ready'.

#### Reduced costs

Some interviewees argued that locally produced components (or other elements of the value chain) could be substantially cheaper, particularly where South Africa owns the intellectual property.

#### Greater localisation

Development of elements of the e-mobility value chain is possible but unlikely to deliver significant benefits (especially in the short term). The greatest potential may lie in niche vehicles (small volumes) and potentially in components (such as the lithium ion batteries). Greater localisation would, among other things, contribute to an improvement in the trade balance according to the IPAP2 (DTI 2010).

When looking for localisation by OEMs and other internationally owned companies, there is a balance to be found between wanting to maximise local production by requiring a high percent of local content in vehicles manufactured in South Africa and providing incentives that attract foreign direct investment.

#### Uncertain job impacts

Job creation represents the greatest potential benefit if South Africa manages to develop the industry and export significantly. The scenario around the development of the local market is very important. If EVs are largely imported and replace locally produced ICEVs then the impact on jobs would be negative. If imports replace imported ICEVs then there would be a net zero impact on jobs. If vehicles would be locally produced then the impacts again depend on the vehicles that are substituted. Locally produced EVs substituting for locally produced ICEVs would lead to a net zero impact on jobs. Locally produced EVs that substitute for imported ICEVs would have a net positive impact on employment. This highlights the importance of the type of EVs that the country should look to manufacture if it wants to promote local employment through the EV industry.

Maia et al. (2011) suggest that South Africa has the potential to host an electric vehicle plant alongside a lithium-ion battery-manufacturing factory. They estimate direct job potential associated with EV and lithium ion industries in South Africa at 475 net direct jobs in the short term, 1 803 in the medium term and 11 428 in the long term. This assumes the construction of a plant, O&M of the vehicles (one additional job per 76 vehicles), and manufacturing of vehicles and batteries (one new job per 49.5 vehicles and 750 jobs per 55 000 batteries manufactured). Their analysis of potential job creation is predicated upon information drawn from various sources.



IPAP2 (DTI 2010) predicted 160 000 direct jobs from 2010 to 2020 (based on estimated investment levels exceeding R20 billion, expected to take place between 2011 and 2015), with an expected further annual R3 billion for the following six years (2015–2020) (DTI 2010). The DTI is in the process of revising its position as these numbers are currently seen to be unlikely especially in such a short time frame.

### Loss in value add

If elements of the e-mobility value chain are largely imported, and if these goods and services substitute locally produced goods and services, then there will be a decrease in local economic activity. The extent of this loss in value add depends on the scale of the EV market.

### Opportunity cost

Government revenue is invested in supporting the industry (e.g. subsidizing local production) at the expense of supporting other, more labour intensive sectors. Benefits from local e-mobility industry development seem unlikely to be significant so it may be better to invest scarce public resources in other areas that more effectively contribute to South Africa's developmental objectives.

## 3.2 Global value chain analysis in the automotive manufacturing industry and the implications for the development of the e-mobility industry in South Africa

Conceptual frameworks and exploratory theories for understanding the global automotive industry vary. One of the core approaches adopted in the literature is global value chain theory (Gastrow 2012). The global economy is increasingly structured around GVCs, accounting for a rising share of international trade, global GDP and employment (Gereffi & Fernandez-Stark 2011). In GVCs, power relationships are key in determining who successfully captures the gains in terms of national economic development, capability building, employment and poverty reduction. As demand for EVs grows internationally the framework offers an approach to understanding and anticipating where the benefits of EV production may lie within the global economy and how South African firms can gain access to markets and increase benefits.

The GVC methodology is a tool to help trace the shift in global production, link geographically dispersed activities and actors of a single industry, and determine their roles in country development (Gereffi & Fernandez-Stark 2011). The GVC framework focuses on sequences of value added. There is little research that applies GVC analysis in the context of EV production. However, the dynamics in the conventional automotive industry can provide useful lessons in understanding the future of the EV industry. Rather than a contribution to the GVC literature, this study represents a scoping of the potential of EV use and production in the e-mobility value chain to contribute to sustainable development given the current and potential context in South Africa. The approach considers the GVC framework and utilises findings of the GVC literature to inform the potential of EVs in achieving the potential impacts highlighted above. Recommendations are also made based on GVC in the automotive industry literature.

There have been a number of developments in the automotive industry with likely impacts on the EV industry. To a large extent, production has been kept close to end markets because of both political and cost factors. Political factors, for example, relate to the implications of public perceptions regarding the detrimental impact on local industries of importing vehicles. Cost factors relate to the benefits of lean production and savings associated with reduced transport (Gastrow 2012; Sturgeon & van Bieseboeck 2010). Additionally, vehicle customization favours geographic proximity

to markets. Therefore market size largely dictates the potential for an industry's growth (Sturgeon & van Bieseboeck 2010). Gastrow (2012: 5900), in discussing trends in the automotive sector in developing countries, suggests that if the local market is sufficiently large and stable to attract significant investments it can become possible for local firms to supply assemblers directly, leading to a 'virtuous cycle of development'.

A few mid-sized developing countries such as South Africa have been able to support the assembly of vehicles, becoming a final assembly hub for the wider region (Sturgeon & van Bieseboeck 2010). Thus, an adequate regional demand for EVs could provide industry opportunities for the country. These final assembly plants can support local supply chains. For example, bulky components such as seats have tended to be built close to assemblers and end markets (Gastrow 2012; Sturgeon & van Bieseboeck 2010). While there is potential to supply GVCs, more power is in assembly and with the OEMs.

Recently the buying power of emerging economies has resulted in a general shifting of markets from West to East (Gastrow 2012). Further growth is expected in the East and therefore new production is expected largely in the East.

Use of the GVC methodology has increasingly incorporated environmental and social dimensions, in addition to the principle focus on economic and competitiveness issues (Gereffi & Fernandez-Stark 2011). Economic upgrading stimulates innovation and competitiveness and social upgrading promotes decent employment. There is little literature on how these two interact, but it is expected that the relationship may not always be positive (e.g. economic upgrading could result in fewer jobs) (Gereffi & Fernandez-Stark 2011, Olson 2013). Hence, although a valuable tool in assessing the potential for value added in the global EV value chain, the framework does not necessarily provide insights into the full sustainable development implications of different industrial policy approaches. This speaks to the need to conduct additional analysis into the sustainable development impacts, as outlined in this study. The focus should be on engaging in the phase of the value chain that maximises financial gains but also social and environmental gains (Olson 2013).

### 3.3 Achieving the potential benefits by creating an enabling environment

Government and other stakeholders have an important role to play in creating an enabling environment for each side of the story: stimulating the market and developing the e-mobility industry. The literature suggests that the technology to support EVs works. Experience shows that support will be necessary until economies of scale reduce costs and enable EVs to compete with conventional vehicles (Government of Chile 2012).

Accenture (2011), based on an assessment of global case studies of plug-in EVs, suggests the biggest challenges going forward relate to the need to increase the scale of use, drive down costs (of the vehicles and the cost of private investment in infrastructure) and the difficulty in controlling charging and its impacts on the grid. The report highlights some of the mechanisms being developed, both by governments and the private sector, to overcome these challenges. To increase scale, the study suggests consumer purchase subsidies and tax incentives to encourage PEV take-up, and work schemes encouraging employees to purchase PEVs and providing them with the required charging support (Accenture 2011). Targeting EVs for the public fleet would represent a direct way of stimulating the market by government. Reducing cost is dependent on government's general role in supporting the creation of markets. In this context the private sector would need to develop mechanisms such as reuse of batteries at service stations, provision of in-vehicle services to recoup some of the investment cost, and disaggregation of cost of battery from initial purchase price (Accenture 2011). To facilitate greater control, the report suggests the provision of in-vehicle services to encourage connectivity to the grid and more competitive tariffs for managed charging (Accenture 2011). This would require a regulatory environment that allows for 'time-of-use' tariffs. These aspects are considered in more detail in section 6.1.



Creating an enabling environment for the development of local e-mobility industry requires, first and foremost, that efforts be undertaken to stimulate the local market. Direct initiatives to stimulate the industry should build on existing systems (i.e. the APDP discussed later). From the GVC literature, achieving the potential benefits and upgrading requires a diverse mix of government policies, institutions, corporate strategies, technologies and worker skills (Gereffi & Fernandez-Stark 2011). The experience of successful suppliers in developing countries suggests the need for establishing an environment capable of achieving worldwide quality standards, improved productivity, and the acquiring of design capabilities to garner more power in the emerging EV GVC (Sturgeon & van Bieseboeck 2010). These aspects are considered in more detail in section 7.3.

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<sup>9</sup> The process by which countries, regions or economic stakeholders improve their positions in the global economy. A “virtuous cycle off development” refers to a self-propagating advantageous situation (i.e. a chain of positive outcomes leading to further positive outcomes).

## 4. The context for electromobility development in South Africa

Electric vehicles and the development potential of the e-mobility industry have been the primary e-mobility focus in South Africa. This section considers the drivers for greater use of EVs and the development of the e-mobility industry in South Africa, how the country approached these issues in the past, and what are the current and anticipated policies, plans and programmes related to e-mobility.

### 4.1 The impetus for promoting electromobility in South Africa

E-mobility has gained attention as a strategy to mitigate GHG emissions and decrease petroleum dependency in the context of increasing global vehicle demand (Government of Chile 2012). Transport is a major source of GHG emissions but also a principal source of air pollution that affects human health. A transition to e-mobility and a greater use of EVs in South Africa has the potential to deliver significant environmental and health benefits. Around the world, electric vehicles have captured a small, yet growing, share of the market (Maia et al 2011). Key benefits are seen to be the GHG mitigation potential and greater energy efficiency compared to traditional internal combustion engine vehicles. This is driven by a combination of regulatory pressure, the increasing business case and greater pressure on resources.

In Europe, for example, OEMs must reduce the CO<sub>2</sub> emissions of their fleet by 40% to meet EU targets. Optimisation of ICE powertrains is not sufficient (without universal downsizing of the fleet to sub-compact and compact level) to meet the 130gCO<sub>2</sub>/km by 2015 and the 95 gCO<sub>2</sub>/km target for 2020 and OEMs face stiff penalties if they fail to meet these targets (Rechel 2011). In the US, President Obama announced in August 2009 a \$2.4 billion investment to drive the development of the next generation of electric vehicles in the USA. The aims of the investment are also to support the growth of domestic jobs, reduce the use of petroleum, reduce GHG emissions and advance the USA's economic recovery, national energy security and environmental stability (Liu et al 2012: 1). Various Federal laws and incentives have been set up for EVs (Alternative Fuels Data Center 2013). The Government of Chile (2012) lists a number of examples of governments and companies cautiously moving forward in the promotion of EVs and investment in charging infrastructure.

KPMG reports that EVs will not exceed 15% of yearly global new car registrations before 2025 (KPMG International 2012). Others are more optimistic. Rechel (2011) suggests that even the most conservative forecasts predicted the global EV/HEV (hybrid electric vehicle) production to grow fast. With the increase in EVs (and HEVs) the EV/ HEV component market is expected to reach €50 billion per year by 2020 (Rechel 2012). Dargay et al. (2008) predict an increase in the global stock of EVs to 2.0 billion in 2030 from 812 million in 2002. They predict 77% to come from developing countries. However demand has been lower than expected (News24 2012). Key concerns affecting the demand include that EVs take too long to charge, their range is too short and they cost too much.

A reasonably common statement is that 'increasingly, environmentally aware consumers tend to prefer vehicles that have a minimal adverse impact on the environment' (Maia et al 2011: 116). However, it does not appear that a significant number of people are currently willing to pay the premium relative to ICEVs. Few analysts are confident when predicting the future demand for electric vehicles: there are great levels of uncertainty. KPMG International's yearly Global Automotive Executive Survey found that, compared with previous years, the 2012 findings showed that automotive experts do not have a clear idea of the direction in which the industry is heading (KPMG International 2012). Hybrids are expected to lead the market and attract the most investment in the interim. However, in China and Japan,

a significant number of analysts expect full EVs to be the most popular option followed by fuel cell vehicles, according to KPMG (KPMG International 2012). KPMG, along with some of the study interviewees, expect fuel-cell vehicles to be a more promising prospect than battery-electrified cars, especially in the emerging BRIC nations (KPMG International 2012).

Even with the high levels of uncertainty it is clear that e-mobility will play an increasingly significant role in the future. If South Africa wants to be competitive in the industry it needs to start making investments that will stimulate innovation and precipitate investment in technologies. However, with uncertainty regarding the future of EVs as a technology option, the country should be wary of committing significant resources to one technology. To stimulate the industry and to achieve the other potential benefits of increased use of EVs, the South African government will need to create an enabling environment and invest in the vehicles and infrastructure necessary to stimulate the market.

## 4.2 Previous policies, plans and programmes

South Africa started investigating EVs in the early 1970s (during the first oil crisis) at the CSIR, where researchers developed the current Li-Ion and ZEBRA battery technology, now sold throughout the world (Jennings 2011). Interest in electric vehicles faded when the fuel crisis subsided. Interest was renewed in the 1980s, first through the National Energy Council, then Eskom and again in 2008 through SANERI (South Africa's National Energy Research Institute). The Eskom programme developed a number of EVs ranging from e-bikes to a 20-seater game-viewing vehicle. More recently the Industrial Development Corporation (IDC), together with other government support, invested in the design and concept model of a five-seater, five-door passenger car named the Joule (Jennings 2011).

South Africa's success in the automotive industry was the driver behind efforts to develop an e-mobility industry in the country. The government supported the development of an EV industry by including the commercialisation of these vehicles in its second Industrial Policy Action Plan (IPAP2).<sup>10</sup> This included key action programmes in the automotive products, components, and medium and heavy commercial vehicles sector. The intervention included the provision of appropriate support to encourage local manufacture of EVs and related components, installation of infrastructure for such EVs, creation of testing facilities, provision of demand stimulation mechanisms and public education on the use and benefits of alternative-energy-source vehicles (DTI 2010). Led by the Department of Trade and Industry (DTI), the plan was supported by the Department of Transport (DoT), the Department of Science and Technology (DST), provincial governments and targeted Metros (DTI 2010).

A key programme in this strategy was the IDC-funded electric car: the Joule. Optimal Energy, the developers of the Joule, had to close its doors in June 2012, following its failure to secure the estimated R7-billion in funding required for the development and industrialisation of the Joule (Kotze 2012). There is broad disagreement regarding the reasons for the failure of the Joule. The Technology Innovation Agency (TIA) CEO argued that the car had been developed in isolation: no investment in recharging infrastructure had been made and so no-one was interested in buying the car (Campbell 2012). Some suggest the lack of clarity around the roles of different stakeholders (public versus private) contributed to the failure of this programme, but that it provided valuable lessons regarding the model for funding the EV industry in South Africa. Others suggested that the commercial risk was too high (Cokanye 2012).

Kobus Meiring (Optimal Energy CEO) said there was a strong view in the motor industry in South Africa that the industry should not try and do any development work locally but leave it to other countries, such as Japan or Germany (Cokanye 2012). The thinking behind this was that South Africa could not leap-frog into competing with the big international OEMs that already have such brand and reputational value. Others remain supportive of the fundamental idea and argue that there is room to compete against the big international OEMS (evidenced by the increasing number of EV players

in Asian markets).<sup>11</sup> In the specific case of the Joule the programme needed a savvy business partner and, of course, an additional bullish investment to get the product to commercial scale.

TIA, one of the original co-funders, is the current owner of the Joule. TIA has no intentions of developing the car any further but is looking to test and harvest the technology and e-mobility value chain aspects associated with the programme.

### 4.3 Current and planned policies, plans and programmes

There does not appear to be a coordinated approach to stimulating the EV market and promoting the local industry. The DOT is broadly supportive of e-mobility but does not see it as a priority area.<sup>12</sup> The DTI is calling for greater local production in the EV value chain but the Automotive Production and Development Programme (APDP) does not mention electric vehicles and so it appears that the EV Industry Roadmap (under review) is not regarded as a core approach to developing the broad automotive industry. There appears to be intention to take steps towards greater e-mobility in the country (through the proposed purchase of 3000–5000 EVs per year by government from 2015) but that this is rather an attempt to make an investment without taking significant risk, to assess impacts and technology options, and to allow flexibility to adapt to changing market conditions and technologies.

This model is supported by the TIA, which acknowledges the need for innovation to happen on the ground. This ensures the space to test what will work in the local context but also the flexibility to adapt based on market developments over time. The TIA model focuses on the full e-mobility value chain rather than the vehicle itself. It aims to invest in proposals that are innovative, promote socio-economic development and that will be commercially viable.

The DOT regards e-mobility as a long term strategy. They acknowledge that the transition towards greater e-mobility will happen but it is not prudent to focus on it now – especially with such uncertainty. The current focus is on short-to-medium-term gains but taking steps to ensure some movement towards greater e-mobility.

The DEA includes EVs in the flagship programmes noting that the Transport Flagship Programme will 'encourage new energy efficient-vehicle technologies, such as electric vehicles, by setting procurement objectives for acquiring such vehicles' (DEA 2011). The DEA believes that a transition to electric vehicles in South Africa is one of the best solutions to cut down on CO<sub>2</sub> emissions, in line with the aims of the National Climate Change Response policy, and ensure implementation of the resolutions of many climate change conferences (DEA 2013).

The DTI target of 3000–5000 EVs publicly procured per year in 2015 is a soft target. This investment will incur costs with regard to setting up the supportive infrastructure and the premium charged on the vehicles. Government has not adequately assessed the viability and the costs and benefits of this investment. There is also no clear idea of the vehicles or technologies that would be adopted although the intention in the short term is to import vehicles such as the Nissan Leaf. The window from now to 2015 will be used to do this analysis and to prepare for implementation. While there is risk, uncertainty and a general lack of information around e-mobility in the country, this approach, together with efforts by the TIA and other agencies conducting research in this area, will hopefully provide useful lessons to make an informed strategic decision in the future.

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<sup>10</sup> The Department of Trade and Industry releases its Industrial Policy Action Plans to outline the direction in which the department wishes to push South Africa's industrial capabilities. The IPAP2 is moving towards the systematic promotion of green and energy efficient goods and service.

<sup>11</sup> Interview 9.

<sup>12</sup> Interview 3.



The result is a 'living lab' approach which will allow the country to keep abreast of developments and be ready to move in the direction of greater e-mobility but not to invest too heavily in this area while there is significant market risk and uncertainty.

The shortcoming with the current regulatory context is the lack of coordination and integration within and across departments. The DOT has not been properly consulted regarding the EV public procurement targets nor is it involved in any significant plans to stimulate the local market in the future. Without a local market, high levels of localisation and value addition will not be possible. This 'testing' phase may prove beneficial but in the longer term greater coordination of different departments and other stakeholders will be necessary. The current policies, plans and programmes are assessed in more detail in the section below.

### 4.3.1 The Automotive Production Development Programme (APDP)

The APDP replaced the Motor Industry Development Programme (MIDP) from 1 January 2013. The MIDP provided substantial monetary benefits to improve the international competitiveness of the industry and to produce cheaper cars for the local market. However the export focus could not be sustained due to World Trade Organisation prohibitions on export subsidies arguably provided by the MIDP. Together with other shortcomings this precipitated the development of the APDP. The objectives of the APDP are to create an environment that will enable registered light motor vehicle manufactures to significantly grow production volumes and enable component manufacturers to significantly grow value addition, thereby leading to the creation of additional employment opportunities across the automotive value chain. The intentions of the APDP are to produce 1.2 million vehicles per year by 2020; and to increase local content (Deloitte, 2012). Deloitte (2012) attributes large capital investments in the industry to companies wanting to gear up for the APDP. Planned investments by automotive assemblers and component supplier companies is R12 billion as a result of the Automotive Investment Scheme (part of the APDP). Of importance, in the context of this study, is that the APDP does not include a programme for the development of the e-mobility industry. The EV industry development is, oddly, going to be included in a separate development programme as outlined in the proposed EV Industry Roadmap.

### 4.3.2 Electric Vehicle Industry Roadmap

The EV Industry Roadmap for South Africa was launched in May 2013. At the time of writing, the DTI was engaging industry stakeholders on the map and inviting public comments into the matter. Twelve departments were involved in developing the roadmap including the DTI, DST, CSIR and the IDC. The Roadmap identifies eight key areas (DTI 2013), discussed below.

#### Support the EV industry through stimulating demand

The interviews suggested that government may focus on achieving this through a preferential public procurement programme (however this is not explicitly mentioned in the EV Industry Roadmap). The suggested target is to procure between 3000 and 5000 EVs annually for the government fleet from 2015. This is based on an assessment of the types of new vehicle purchased that could be substituted with EVs. Practicalities around implementation (including budgetary impacts) have not been assessed and will be considered in the period up to 2015.

#### Tax incentives

Various benefits will be designed to incentivise the purchase of EVs and may include personal income tax rebates,

reduction of VAT on retail selling price, reduced vehicle registration costs, etc.

### **Public awareness and education**

Consumer acceptance is seen to be critical to increasing demand. A campaign will focus on the promotion of the benefits of EVs.

### **Investment support**

This aims to include an amendment of the Automotive Investment Scheme (AIS) of the APDP to provide 35% cash back for EVs (compared to the 30% cash back incentive for ICEVs). The Roadmap calls for the reduction in qualifying annual units per plant producing EVs from 50 000 to 5 000.

### **Research and development**

The aim is to encourage R&D activities that will lead to a reduction of component costs (of the battery in particular). There is still uncertainty around which technologies to support.

### **Provision of regulatory framework**

This aims to develop the legislative framework required for the safe manufacturing and operation of EVs in South Africa.

### **Management of electricity infrastructure**

The aim is to introduce preferential tariff schemes and intelligent charging methods to encourage off-peak charging of EVs and also to optimise electricity usage during charging. In the absence of public charging infrastructure, the promotion of home charging will be advised until public charging becomes viable. Eskom has undertaken to look at reduced tariffs for EV charging (development of intelligent charging systems to trace EV charging at night).

### **Urban infrastructure support**

This aims to promote the preparation of metropolitan municipalities for the introduction of EVs across the country by increasing the level of integrated planning in the areas of urbanisation and transportation.<sup>17</sup>

## **4.3.3 National Electric Vehicle Technology Innovation Programme**

The Technology Innovation Agency (TIA) launched an eMobility programme in March 2013. The programme provides a collaborative environment for entrepreneurs, equipment manufacturers, technology companies, higher education institutions and science councils to accelerate the development and commercialisation of new technologies, processes and services. The aim is to address the current charging infrastructure and energy storage technology challenges that are critical to the support of a viable electric vehicle industry in South Africa.

The TIA is focused on the e-mobility value chain, specifically looking at infrastructure requirements and energy storage facilities (batteries) rather than the vehicle itself. This programme is intended to support the local market for EVs and ultimately, if proven to be viable, to support the export of e-mobility value chain products (other than the vehicle itself) to international markets. The key drivers of this approach relate to cost reduction, job creation and to adapt and implement technologies so that they meet local specifications and standards.

In certain instances (such as with certain charging components) the cost of imported products is considerably higher than it would be to produce the products locally. In such cases where the technology is relatively simple and the country has the capacity to produce at the appropriate standards, significant cost savings could be achieved. Local production would support local job creation and, should local component producers be able to sell into international markets, substantial job creation could be achieved in the longer term. Local innovation is also seen to be important in ensuring that South Africa is not left behind and forced to adopt technologies that are expensive and may not be suited to the local context (and therefore not meet local specifications)

The approach acknowledges the need for a living lab where innovation happens on the ground. This ensures the space to test what will work in the local context but also the flexibility to adapt based on market developments over time. The risk and uncertainty in the international EV market may necessitate such a flexible approach to developing the local industry.

The TIA is working closely with international governments particularly in Finland, India and the UK. The aim is not just to learn from their experiences but to adapt them for the local context. There is a particular interest in following a similar model to Finland's. The TIA model is to invest in proposals that are innovative, promote socio-economic development and that will be commercially viable. Funding is provided from idea to commercialization. In doing so the intellectual property and the production is done 'in-house'. To support this, TIA wants to have a world-class testing infrastructure for testing these e-mobility value chain technologies. Efforts are also underway to partner with infrastructure component and battery technology companies (e.g. with Willard on battery R&D and manufacturing)

### 4.3.4 The Department of Environmental Affairs' EV programme

The minister of Environmental Affairs launched the DEA's Green Cars (Zero Emission Electric Vehicles) programme on 26 February 2013 (DEA 2013). The initiative seeks to ensure that South Africa practically contributes to the reduction of environmentally harmful gases, by promoting the use of cleaner sources of fuel by the automotive industry. The small fleet of 14 vehicles will be fully charged by solar energy, from solar panels housed at the DEA's head office.

Economically, the Zero Emission Electric Vehicle Programme is also meant to ensure that South Africa keeps the pace of the technological developments in automotive manufacturing against her international counterparts. The DEA suggests that this will simultaneously address other global concerns such as energy security, as oil wells are expected to dry up in the next 50 years.

Although at the scale of a pilot programme, it is not clear how the initiative is related to the joint government initiative included in the DTI's Electric Vehicle Roadmap. All vehicles are imported (the Nissan Leaf) and the model of charging the vehicles from solar panels is unlikely to be scalable in the short-to-medium term and thus would unlikely lead to local industry development. It may be that the government's model is again to make a small investment with the hope of gaining valuable lessons to be able to stimulate the rollout of EVs at a significant scale on South Africa's roads.

### 4.3.5 The Department of Transport

The current focus in the DOT is not on e-mobility. There is considerable uncertainty regarding the future of Evs, but the DOT asserts that there are challenges and opportunities that the department knows require resources and where the potential benefits are clear. The DOT sees e-mobility as a key longer term strategic option and will devote some resources to ensuring South Africa is EV ready in the long term. Current focus areas (with a strong climate change



mitigation aspect) include: promoting public transport (e.g. bus rapid transit (BRT), Gautrain, etc), investigating the potential of gas-based liquid fuels (compressed natural gas and liquefied petroleum gas), and shifting from road to rail. Key drivers behind these initiatives include mitigation potential, improving access and mobility, reducing exposure to volatile fuel prices and reducing the cost of transport, especially for the poor who spend roughly a third of their income on transport (Department of Transport 2006).\*

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<sup>15</sup> Interview 2.  
<sup>16</sup> Interview 2.  
<sup>17</sup> Interview 2.  
<sup>18</sup> Interview 3.

# 5. Developing e-mobility in South Africa

The development of e-mobility in South Africa has the potential to meet a range of policy objectives related to transport and industrial policy. This study partly separates interventions in the transport sector from those in the manufacturing sector although the success of each intervention is related to the other, at least in part. To achieve increased use of EVs the local market needs to be developed. The technology could all be imported or, where possible, developed locally. Local demand could provide the impetus to develop local production with the potential to export to the growing international markets for EVs. This study considers these two strategic options independently.

# 6. Stimulating the EV market

The key barriers preventing the increased use of EVs include the higher price of EVs, consumer perceptions (infrastructure and servicing concerns, range anxiety and other behavioural barriers), a lack of understanding of the potential benefits if implemented carefully (energy efficiency and security, lower environmental impacts, reduced imports of liquid fuels affecting the country's balance of payments) and the need for a critical volume to stimulate the industry. However, if the South African government chooses to prioritise getting more EVs onto the road it can. The process for achieving this is depicted in Figure 1.

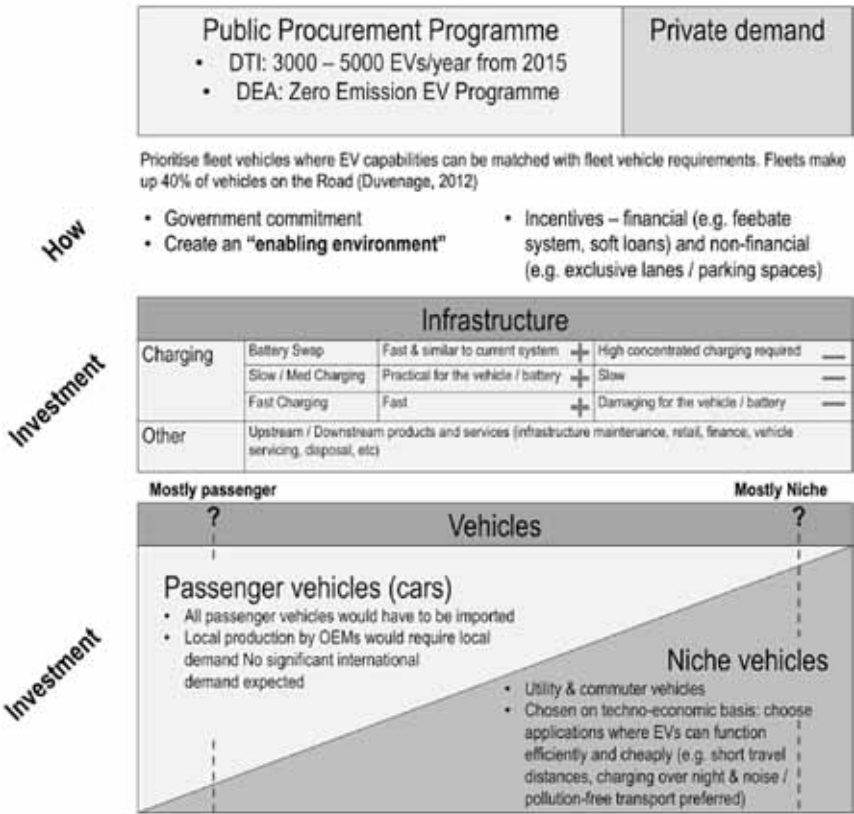


Figure 1: Conceptual framework for stimulating the EV market in the South African context

First there is a need to stimulate demand by creating an enabling environment. This can be achieved in a number of ways. Through its public procurement processes government can drive this agenda as it has done with other agendas (such as BBBEE and more recently the prioritisation of socio-economic development through the RE IPPPP). A commitment to purchase EVs for the government fleet could stimulate a significant demand, although questions have been asked about the ability (financially) and extent of high-level

political buy-in to make this happen. Private demand could be stimulated through financial and non-financial incentives and a general regulatory environment that facilitates investment in all elements of the EV value chain.

An investment will be required and this will depend on the number of targeted vehicles on the road. Investment in infrastructure is unlikely to be significant at low penetration rates (rates of demand) but at a more significant scale careful decisions would need to be made regarding the most appropriate infrastructure investments. The investment in

vehicles needs to be matched to the intended application and it is here that there is potentially a significant opportunity to match the technical capabilities of certain EVs with the applications that would allow the realisation of cost and efficiency benefits discussed in later in this study.

## 6.1 Creating an enabling environment

Government has an important role to play in providing an enabling framework for programmes targeted at specific technologies, subsectors and regions. Incentives can be introduced to stimulate investment in EVs and EV infrastructure. These would need to be supported by awareness raising and knowledge development to overcome some of the perceived concerns relating to EVs.

### 6.1.1 Incentivising investment in EVs and EV infrastructure

Incentives could be financial and non-financial. Non-financial incentives could include the provision of exclusive parking, exclusive lanes, free city access (e.g. not having to pay the e-toll in Gauteng) or the linking of the purchase of EV to provision of a slow charging station in home (e.g. Spain). Regulatory interventions could include the introduction of minimum emission standards for vehicle fleets (Government of Chile 2012). Financial incentives could include soft loan schemes, various tax incentives and subsidies for vehicles and charging infrastructure. An example would be a feebate system, which imposes a fee on new, high emitting vehicles and simultaneously provides a rebate on the purchase of low-emitting vehicles. A key benefit of this is that the policy is revenue-neutral (Government of Chile 2012). There are no strong incentives for EVs yet in South Africa (Duvenage 2012).

### 6.1.2 Awareness raising and knowledge development

EVs currently do not perform as well as ICEVs in terms of range, refuelling times and reliable support services across the country. Moreover consumers are unsure about the benefits and have concerns around safety and reliability (Government of Chile 2012). However many of these drawbacks are not as significant as most consumers think (Accenture 2011). Most passenger car applications do not require the range provided by ICEVs, for example (particularly in the context of urban commuting). Reliability can be improved in the case of battery swapping, for example, where the customer would never get stuck with a bad battery and, increasingly, charging options are being made available that overcome the various charging concerns.

Many interviewees noted the need to overcome psychological barriers as a key component to stimulating the EV market. As part of the DEA's Green Cars Programme, government will roll out a consumer education and awareness campaign to popularise the uptake of the EVs.

## 6.2 Investing in infrastructure

This is seen to be one of the key barriers to develop the market: for example the Leaf needs a specific charger and is actively lobbying government to put up the infrastructure before Nissan can import significant numbers of the vehicle. The KPMG Global Automotive Executive Survey (KPMG International 2012) and Maia et al. (2011) highlight the infrastructure requirements (and costs) as a key challenge in driving the local EV market. However many interviewees argued that the infrastructure requirements are often exaggerated and that such investments are not likely to represent a significant challenge to implementation. Infrastructure investment for vehicle alternatives (ICEVs) would require a doubling of the liquid fuels infrastructure by 2050 plus the added cost of decentralisation (Merven et al 2012).



It is unclear as to which infrastructure option or combination of options will be the preferred one. This depends a lot on consumer psychology and what will be convenient for the consumer. There are advantages and disadvantages to the different charging options. Battery-swapping stations equipped to physically swap batteries provide a similar 'refuelling experience' to conventional vehicles and customers will not own a bad battery. The disadvantage is that the concentrated charging of these batteries would put pressure on the grid and may require further infrastructure investments. This disadvantage is, however, contested especially when considering that investment in the alternative liquid fuel stations is costly and has high barriers to entry associated with environmental impact assessments and permits. The cost of hydrogen infrastructure rollout is likely to be even more expensive. Medium-speed charging is the most practical for the vehicle, taking about one hour. High-speed charging is gaining in popularity but concerns remain regarding the impact on the car and the battery. Slow charging (e.g. at home) is a good base option and can be very practical if vehicles can plug into the normal socket. The extent to which charging can be controlled (spatially to manage impact on the grid infrastructure and temporally to encourage off-peak charging) will have significant impacts on the costs and benefits associated with getting more EVs on South Africa's roads.

### 6.3 Investing in vehicles

The Nissan Leaf is being imported into South Africa but the motivators behind this initiative appear (going by interviews)<sup>20</sup> to be based more on improving the company's reputation as a responsible corporate citizen. Ford has also admitted that hybrids are produced for public relations purposes rather than profits (Olson 213). To meet a commercial driver for OEMs to import EVs into South Africa, experts suggest a critical local demand threshold is required. Some stakeholders suggested a minimum threshold of between 5 000 and 10 000 EVs per year – this estimate includes many assumptions and uncertainties, so determining an accurate number is difficult. The threshold to stimulate local production (entice OEMs to set up factories and assembly plants in South Africa) is much higher and is related to incentives included in the APDP (50 000 vehicles per plant) although the EV Industry Roadmap does envisage a significantly reduced quota of 5 000 vehicles (DTI 2013). If this were to come into effect it might make production in South Africa more appealing to vehicle manufacturers despite the volumes remaining small.

Through a significant public procurement programme the required threshold could be reached creating momentum for both the market and potentially the development of the local industry. This is being proposed in the Electric Vehicle Industry Roadmap for South Africa where government plans to purchase between 3 000 and 5 000 EVs annually from 2015. The DOT acknowledges that this approach is the best initial option as there are EV applications for certain fleets.

Will this be enough to stimulate the local market? The number is based on what is perceived to be possible. The current procurement of vehicles by government is approximately 15 000 per year. This fleet is made up of 135 different models of vehicle and only a small portion of these has appropriate EV substitutes.<sup>21</sup> If supplemented with private demand this could stimulate the local market but not necessarily provide enough of a demand to stimulate significant local production (the threshold for stimulating the local industry is explored further later in the report).

An alternative, as suggested in Figure 1, is to focus first on niche markets ('low-hanging fruit') before prioritising passenger vehicles.<sup>22</sup> Niche vehicles, chosen where they can meet the technical requirements of a specific vehicle application, overcome many of the perceived challenges associated with electric vehicles. EVs would be chosen where the range does not exceed roughly 150 km, where charging could happen at a central location overnight and where other technical requirements (such as power, carrying capacity, speed, etc) could be met.

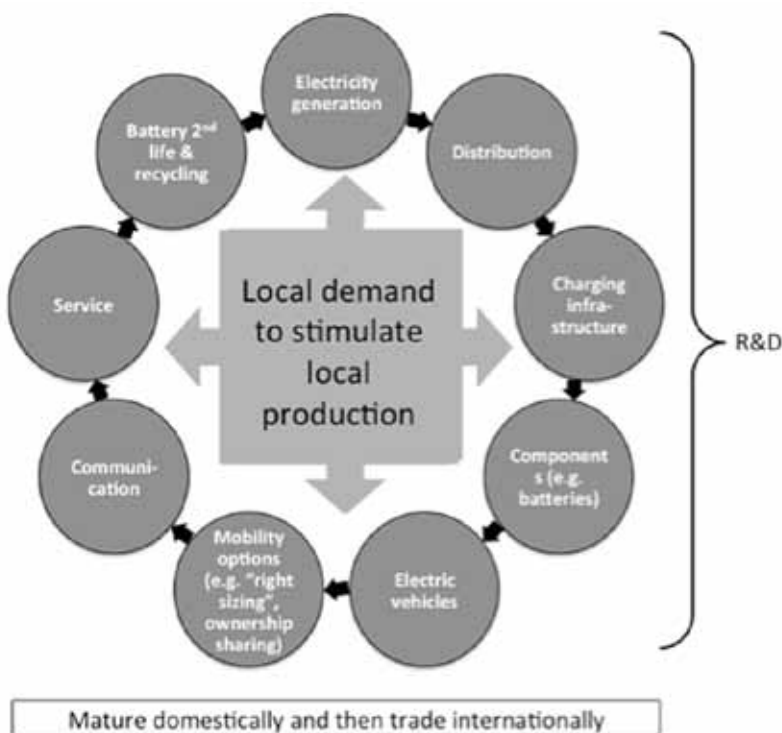
Passenger vehicles are very inefficient. Firstly, they are equipped to carry two or more people but often only carry one. Secondly, a passenger vehicle is often needed in a variety of applications such as short-distance commuting and

long-distance holiday travel, urban and off-road driving, and sometimes to be used as a utility vehicle. This requires technical specifications to meet all these applications and so for any given application there will be capacity that is not being utilised. In this context public transport and vehicle-sharing most likely represent the greatest opportunities for achieving efficiencies.

The bottom line is that technologies are available to get EVs onto South Africa's roads. If the South African government prioritised investing in an enabling environment and the infrastructure and vehicles then stimulating the local market is possible. Whether the demand would be enough to achieve significant benefits through local industry development is more uncertain.

## 7. E-mobility industry development

Stimulating the local e-mobility industry is driven by the objective of creating jobs and stimulating economic activity in the country. It is not clear, however, which aspects of the e-mobility value chain South Africa should invest in to achieve this objective. Figure 2 illustrates the e-mobility value chain.



**Figure 2: E-mobility value chain in South Africa**

Adapted from Rechel (2011)

<sup>19</sup> Interview 12.

<sup>20</sup> Interview 15.

<sup>21</sup> Interview 2.

<sup>22</sup> Interview 13.

Key considerations in deciding where (and to what extent) to invest in the value chain include:

- Potential linkages: which elements can better support and stimulate existing and potential up-stream and down-stream industries?
- Comparative advantage: in which elements does South Africa have the skills, knowledge / Intellectual Property, natural resources, institutional arrangements and other conditions necessary for local production to be competitive both in the local market (relative to exports) and in the international markets?

A short assessment of a number of the elements prioritised previously and for future priority areas is provided below. Although the TIA has made explicit its intention to consider and support innovation in any element of the e-mobility value chain, this research revealed a focus in South Africa on the vehicle and vehicle components (specifically the battery).

## 7.1 The vehicle

Economic activity, and job creation benefits in particular, will depend on the extent to which the purchased EVs are imported or locally produced. Passenger vehicles would need to be imported at least in the short term. The original intention was to develop EVs locally (e.g. the Joule) and therefore own the intellectual property but, for reasons outlined above, government has moved away from this strategy. As South Africa is no longer focusing on developing and producing the EV itself, any local benefit from passenger vehicles would come from enticing OEMs to produce locally. The predominant model for OEMs is to set up production close to the market. Unless local demand reaches a critical threshold it does not make sense to locate production in South Africa. The automotive industry requires economies of scale for plants to reap maximum benefits (Maia et al 2011)

The production of niche vehicles, chosen on a techno-economic basis present opportunities, although not at the sort of scale that the DTI had originally envisaged for the industry. Techno-economic reasons refer to instances where the cost and technical capabilities meet the application requirements and where some of the benefits of EVs (such as no local air and noise pollution) are valued.

### A proposed approach to the local production of niche EVs

This model, proposed by Grid Cars,<sup>23</sup> suggests an innovative approach to local production of EVs that aims to stimulate job creation and local value addition particularly in lower income communities in South Africa.

Key to this approach is the use of a simple technology. Components would be produced at a central location and deigned for decentralised assembly. Due to their simplicity these vehicles would be assembled in townships. Checks and balances, provided by the central producer, would need to ensure quality and reliability. Depending on the ownership model they could be rented out and run in the township. Local community members would be responsible for maintenance.

If successfully implemented such a scheme could have job creation and poverty alleviation benefits in addition to the benefits associated with the increased use of electric vehicles.

<sup>23</sup> Interview 13.

<sup>24</sup> Interview 4.

## 7.2 Components (battery)

Batteries have a similar challenge when it comes to owning the IP or attracting international producers to set up plants locally but there are some additional potential opportunities. The production of lithium ion batteries (as a component in the e-mobility value chain) may prove a viable option for developing the local manufacturing sector. South Africa has a patent on lithium manganese dioxide, which is currently the cheapest, and preferred cathode technology used in lithium ion batteries. South Africa is also the world's largest producer of manganese and so there may be the potential to obtain this input at favourable prices. In a lithium ion battery using the lithium manganese dioxide technology, the ration of manganese to lithium is 2:1. However, manganese is considerably cheaper, limiting the potential benefit that favourable manganese prices would make to the overall competitiveness of the local battery production. A further factor in favour of local production is the potential local and regional demand associated with lithium ion batteries outside of the EV application. The demand for lithium ion batteries, as a store of power, will increase as small-scale generation of electricity from solar increases in Southern Africa (is is fair to say). Storage of renewable energy and storage as a back-up in times of uncertain electricity supply could also increase the demand for lithium ion batteries domestically.

The country has the capacity to produce these batteries at a significant scale. Delta EMD, currently the second largest producer of manganese dioxide batteries (disposable batteries) could adapt to producing lithium ion batteries relatively easily should there be an adequate demand. The opportunity for beneficiation of manganese is low. Only about 6% of manganese production ends up in non steel production, so the manganese industry does not see demand from this sector to be a game changer in this industry. However, if the lithium ion battery production industry were able to buy lithium at a relatively lower cost, then local production of the batteries may be possible.

Others suggest that this argument does not hold and that there is no clear reason (at this stage) as to why a company would invest in battery production in South Africa rather than in another country with better location and other relevant characteristics. Government has had a discussion with battery manufacturers to set up a factory here but at this stage additional subsidies would be required until local demand reaches a critical threshold.

## 7.3 How to achieve the benefits from local e-mobility industry development

To achieve benefits from local production the first priority is to stimulate local demand. The best way to stimulate local production is to create a local demand, to mature domestically and then trade internationally (Mkhize 2012). Additional incentives may be required to overcome barriers that may still exist even with increasing local demand (or if local demand does not meet the critical threshold) and, where possible, efforts should be made to own the intellectual property associated with different elements of the e-mobility value chain.

As in the case of the market stimulation, incentives should be both financial and non-financial. Existing incentive schemes (for the automotive industry in general) include:

- Automotive Investment Scheme (AIS) – targeted cash grants to support growth and development of the automotive sector.
- Manufacturing Competitiveness Enhancement Programme (MCEP) – support that encourages facility upgrades that sustain employment and maximise value-addition in the short term.
- Science and technology R&D incentive (S11D of the Income Tax Act) – tax allowance to encourage private sector investment in scientific and technological R&D activities.

- Industrial policy projects (S12I of the Income Tax Act) – to support Greenfield investments (new projects) and Brownfield investments (expansions or upgrades).
- Manufacturing Investment Programme (MIP) – targeted grants to stimulate and promote investment, BEE and employment creation.

The only scheme, at this stage, that provides additional incentive for the production of EVs above ICEVs is the AIS. A 35% cash back incentive is provided for EV production compared to the 30% for ICE vehicle production. Maia et al (2011) support the DTI's intention to relaxing the Automotive Production Development Programme (APDP) qualification requirements of 50 000 units per annum in the case of electric vehicle manufacturing. In the early stages, a local plant could find it difficult to reach the projected targets for various reasons. In the case of the EV, Roadmap does not include any local content requirements. It is the intention of the DTI to engage with NAAMSA members on what an appropriate local content requirement would be.

There was a lot of pressure on the developers of the Joule to choose a technology and focus on it. However, in the automotive industry this is not quite so simple. Firstly there is no automotive development in South Africa from scratch (no new model development). All OEMs are foreign-owned and the R&D happens overseas. OEMs want to sell in the South African market but the government calls for localisation. OEMs then seek the local supply of certain components. The OEMs own the intellectual property of the components, however, and due to the nature of products local production is often highly specialised. Unlike many other sectors, parts production in the automotive sector is customised, with little opportunity for generic parts industries (Gastrow 2012). This modularity in the value chain limits the power of suppliers, has limited economies of scale (in production) and economies of scope (in design) and therefore limited the gains that suppliers can capture. This has meant that the current vehicle parts industry in South Africa is not necessarily capable of supplying new manufacturers of EVs nor does component manufacture, within the current system, provide good opportunities for generating significant local value. This also limits the development of local competence that would add value in other applications. For example, the developers of the Joule found that many of these technologies and skills could not be utilised to produce components for the Joule.

The intellectual property would need to be locally owned and other measures in place to ensure that the benefits are kept local (Swart 2013). The challenge is that any aspect of the production that is seen by the OEM to be 'core competence' (e.g. the production of the drive train) would, in the case of a class leading product, be bought by the OEM. However the OEM would likely buy the whole company (ensuring it owns the intellectual property but is also able to adapt the technology for other applications and markets). The intellectual property would again be foreign-owned.

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<sup>25</sup> Interview 10.

<sup>26</sup> Interview 10.

<sup>27</sup> Interview 2.

## 8. An electric vehicle scenario in South Africa

The AIM methodology required a specific scenario to be presented to enable comparisons of impacts across the range of mitigation actions considered. Due to the high levels of uncertainty regarding the future market for electric vehicles and the electric vehicle industry in South Africa, many possible scenarios could have been considered. The scenario chosen for this analysis was therefore based on the most plausible outcomes defined according to the intentions communicated in various government policies plans and programmes, stakeholder perceptions, the literature and experiences in other countries. Assumptions are presented in Table 5. It must be highlighted that this represents only one possible scenario and that current and emerging opportunities and challenges (such as implementation barriers or the development of new, more effective technologies or alternative technologies) would impact the extent to which the scenario proves to be realistic.

**Table 5: Scenario assumptions**

Variables	Assumptions
Time period	2013 – 2030
The electric vehicle market (penetration)	Annual purchase of 4 000 electric vehicles through the planned Public Procurement Programme (3 000 – 5 000 annually is the target and stakeholder opinions differ on the likelihood of reaching this target) and 1 500 private electric vehicles per year (based on stakeholder opinions), rising by 10% per year.
The electric vehicle industry (local production)	It is assumed that all vehicles will be imported. The local demand is not big enough to stimulate local production. Some (insignificant) loss of jobs and economic value add is expected as the imported electric vehicles would substitute for locally manufactured vehicles (therefore the demand for locally manufactured vehicles would drop very slightly).
Costs	<p>Average premium on electric vehicle costs of R 80 000, declining at 10% per year (Duvenage 2012).</p> <p>1 level II charging station (charging for between 4 &amp; 8 hours) per two electric vehicles rolled out in line with demand. It is assumed that some charging through connecting to the current system will take place (requiring no significant capital investment in infrastructure).</p> <p>Rebates, charging infrastructure grants and other (administrative and MRV costs) incentive costs of approximately R 142 000 per EV (based on Government of Chile estimates).</p> <p>Discount rate of 10%.</p>



Emission assumptions (CO <sub>2</sub> e)	<p>Emissions factors per electric vehicle are derived from the LTMS estimates (Winkler 2007). Two different emission factors were applied for the periods 2016 – 2020 and 2021 – 2030, acknowledging the change in the energy mix over time.</p> <p>Average kg CO<sub>2</sub>e saved per vehicle was based on an average occupancy estimate of 2.1 (LTMS uses person kilometers as the unit of measure for transport demand).</p> <p>Savings are based on using electricity from the LTMS reference case grid (Growth Without Constraints). The emission reduction benefits would therefore be higher as more renewable / low carbon energy generation is included in the mix.</p> <p>Other air pollutants are not captured separately.</p>
Use assumptions	<p>All vehicles are charged off-peak (therefore requiring no additional electricity generation or grid investments).</p> <p>Batteries act as a store of electricity that supplements building use during peak times (results in consumption smoothing).</p> <p>Smart grid elements are in place but assumed that electricity cannot be sold back into the grid (this would result in no significant investments in solar PV taking place in this scenario).</p>

The key assumptions in this scenario are the timescale over which the electric vehicle market and industry are developed, the ability of government to procure the targeted number of electric vehicles annually, smart grid elements and other incentives being in place to ensure optimum use and vehicle charging, and that various institutions and regulations are in place to ensure successful implementation. These and other assumptions have not been tested (through the use of sensitivity analyses, for example) as the results of this very basic modelling exercise are intended to contribute to a greater understanding of the potential impacts relative to other mitigation options. A more comprehensive modelling exercise is required to determine the real mitigation and developmental potential of electric vehicles in South Africa for a range of possible scenarios.

## 8.1 Scenario results

The results of the scenario are presented in Table 6. These impacts were presented to the workshop participants.

**Table 6: Extract from the mitigation Action Impact Matrix**

Key challenges				Mitigation action
<i>Explicit low carbon development goals</i>	Explicit LCD targets	LCD targets	Source	Electric vehicles
Climate change mitigation	Emissions reductions	Reduce emission through mitigation actions by 34% by 2020, 42% by 2025	National Climate Change Response White Paper (2011)	R54 000 / tCO <sub>2</sub> e*



Socio-economic development	Poverty	Reduce poverty from 39% to 0% of the population living below the national poverty line (R418/ month (2009 prices))	National Development Plan (2012)	None
	Inequality	Income inequality (as measured in Gini) should decrease from 0.7 to 0.6 by 2030	National Development Plan (2012)	Negative (minor): Benefits will accrue to rich more than poor deciles.
	Jobs	Reduce unemployment from 25% percent (in 2010) to 15% in 2020. Create 300 000 jobs in the 'green economy' with 80 000 in manufacturing and the rest in construction and infrastructural.	New Growth Path (2010)	Negative (minor): imported vehicles (and components) replace some locally produced vehicles (and components).
	GDP	An annual GDP growth of 5.4% by 2030	National Development Plan (2011)	None (minor potential for negative impact if a significant demand for imported EVs (and associated components) replaces locally produced vehicles (and components). Potential benefit from reduced exposure to volatile oil price and improved balance of payments associated with reduced importing of oil (minor).
Energy security	Renew-able energy	10 000 GWh (0.8 MtCO <sub>2</sub> e) renewable energy contribution to final energy consumption by 2013, to be produced mainly from biomass, wind, solar and small-scale hydro	White Paper on Renewable Energy (2003)	None (there is potential for distributed electricity generation (e.g. solar PV) for own use or to feed into the grid)
	Other energy mix	9.6 GW of nuclear; 16.3 GW of coal; 17.8 GW of renewables; and 8.9 GW other by 2030	Integrated Resource Plan (2011)	Positive impact (minor): consumption smoothing (off-peak charging and batteries act as a store of electricity to supplement use during peak demand periods)
<p>* This number is significantly higher than the R 607 (at a 10% discount rate) assumed by the LTMS (in the GWC scenario). The difference is largely due to scale (the LTMS assumed a much larger number of EVs in the country and this had knock on impacts in terms of investments in liquid fuels refining).</p>				

Feedback based on the presentation of these results to the stakeholders at the workshop was used, together with the interviews to inform the recommendations below.

## 9. Recommendations

A number of recommendations can be made based on the outcomes of this study.

### **Invest in EVs**

There are potentially significant benefits associated with increasing the number of EVs on South Africa's roads. The GHG mitigation potential in particular is significant in the context of the transport sector's contribution to South Africa's emissions and where demand for transport is expected to grow significantly. EVs also have greater efficiency potential than ICEVs and reduce exposure to the price of oil which is likely to continue to increase (and remain volatile). Technologies are being developed and improved and lower future costs will make EVs an attractive option. South Africa needs to be EV-ready.

### **Create an enabling environment**

Establish incentive schemes and start building human resources to supply and support the EV fleet in South Africa. Government saw its role in the development of the Joule as providing support for prototyping and then support for production. The cost (and risk) of commercialising the technology was the private sector's responsibility. Most of the support provided by DTI is provided once production is underway and most of the risks have been mitigated or overcome. There may be a gap in terms of providing some of the initial support or leveraging government support (and intentions to create a market) to 'de-risk' some of these initial investments.

### **Adopt a living lab approach**

Government has already indicated its intention to better understand the market and to use the information to define financial incentives and other tools to stimulate the EV market at a significant scale. This is also particularly important in the less certain EV industry.

### **Diversify investments in the e-mobility industry**

The Joule highlighted the need not to focus efforts on only one technology. In an industry characterized by great uncertainty, a diverse investment approach is necessary. This is consistent with TIA's approach.

### **Prioritise a smart grid**

A smart grid allows for intelligent charging, manages the risks and enables good system design to ensure maximum benefits are obtained from EVs. Initially, smart metering of charging which communicates with municipal system operators could be installed in domestic distribution systems in areas where EV uptake is likely to be large. This would allow for incremental 'smartening of grid'.

### **Raise awareness and develop knowledge**

Consumer acceptance is critical. There is a need to design a very careful awareness raising, education and marketing campaign associated with the plan to stimulate the market. The South African government acknowledges this but it needs to be emphasized that considerable resources need to be devoted to this.



## **Right-size vehicles**

To benefit from improved efficiency, EV specifications need to be matched to specific applications where the business case is strong.

## **Develop a low-carbon grid**

A cleaner grid results in greater benefits. As the grid becomes lower-carbon over time the business case for investing in EVs will become stronger.

## **Focus on niche vehicles in the short term**

South Africa could possibly produce niche vehicles to supply the local and, potentially, export markets. Niche vehicles are typically chosen on a techno-economic basis: based on whether they meet the technical requirements like range and based on their cost. There is the potential to be competitive in the production of these vehicles as status and brand reputation are less important attributes than in the passenger vehicle market.

## 10. Conclusion

The potential benefits of e-mobility are significant but depend on the design of the overall system. The cost of government support for the EV market and industry should not exceed the value received by the consequent reductions in negative environmental impacts and employment and social gains (Olson 2013). Investing in stimulating the local market, especially in the longer term, is expected to generate significant sustainable development benefits. The GHG mitigation benefits will accrue even in a carbon-intensive grid and these benefits will only increase as the grid becomes cleaner over time. Infrastructure investment costs are likely to be lower than many people expect. This is especially important when considering the significant costs and externalities associated with new and replacement liquid fuels infrastructure as the alternative. Many of the perceived challenges, such as safety, charging time and costs, do not represent significant challenges and so awareness raising and education of the benefits is necessary to encourage consumers to buy EVs. Although the range of EVs is suitable for certain applications, an improvement in this aspect (without negatively affecting the safety performance) is key to overcoming range anxiety especially in the higher income markets that are willing to pay a premium for range convenience. Although no significant direct impacts on poverty and inequality are anticipated with the stimulation of the local EV market, the other benefits will likely outweigh the costs especially in the longer term. The South African government should therefore devote resources to creating an enabling environment for purchase and use of EVs on South Africa's roads.

The appropriateness of investing in the e-mobility industry is less clear. The most important lesson from the GVC literature, in terms of the EV industry development, is that the virtuous cycle of development can only be achieved if the local domestic market is sufficiently large to attract significant investment in the first instance. The government should focus its efforts in this regard, first and foremost.

The potential to achieve significant benefits from the e-mobility value chain may differ in the long term and therefore government's approach of creating a 'living lab' to enable the country to keep abreast of developments, be ready to move in the direction of greater electromobility but not to invest too heavily in this area while there is significant market risk and uncertainty, is broadly appropriate. The shortcoming with the current regulatory context is the lack of coordination and integration within and across departments. Without a local market high levels of localisation and value addition will not be possible. This 'testing' phase may prove beneficial but in the longer term greater coordination of different departments and other stakeholders will be necessary.

In the short term, prioritising the production of niche vehicles and public transport vehicles (not included in the scope of this study) could present opportunities for the development of the local industry with subsequent benefits. In instances where the application requirements meet the EV capabilities, and the EV is cost-competitive, demand could grow in the short term. South Africa could position itself to meet this growing demand locally.

The new EV Industry Roadmap, in particular, is a positive move towards stimulating the local market (demand) through various measures. There is a concern, however, that if efforts to develop the industry are not successful, the DTI may reduce its efforts in this area, leaving a vacuum when it comes to stimulating the local market and getting more EVs onto South Africa's roads. There does not appear to be an adequate focus on stimulating the local market and getting EVs onto South Africa's roads particularly in captive fleets.

Ultimately, however, a transformative approach to mobility is required if we are to achieve maximum benefits. Vehicles need to be matched to their intended applications. EVs provide an opportunity in this new system to meet the country's mobility needs more efficiently than conventional vehicles, with fewer negative impacts and greater sustainable development benefits. This model would require a new approach to the way we value mobility – one that is predicated on the prioritisation of techno-economic considerations in the production, sale and purchase of vehicles.



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## Appendix: Full list of interviewees

Interview	Institution	Individual
1	Department of Environmental Affairs (Climate Change Monitoring & Evaluation; Climate Change Mitigation)	Thapelo Letete; Director – Climate Change M&E  Mactavish Makwarela: Director - Climate Change Transport Mitigation
2	Department of Trade and Industry	Tinyiko Mafuwane
3	Department of Transport	Thamsanqa Mohlomi: Climate Change Deputy Director General
4	Council for Scientific and Industrial Research (CSIR) (Battery Research Centre)	Mkhulu Mathe
5	Technology Innovation Agency)	Yotish Sewgoolam
6	Eskom (Research training and development)	Amal Khatri
7	GIZ (TRANSfer)	Prema Govender and Gwendolin Aschman
8	World Wide Fund for Nature Africa	Louise Naude: National Climate Change Officer
9	University of Cape Town (Energy Research Centre, Department of Economics)	Anthony Black
10	University of the Western Cape	Gerhard Swart
11	University of the Witwatersrand (Centre of Material and Process Synthesis)	Xinging Lui
12	University of Cape Town (Energy Research Centre)	Adrian Stone
13	Grid Cars (private electric vehicle manufacturer)	Carel Snyman
14	Honda	Graham Eagle: Director of Sales and Marketing
15	Nissan	Joggie Mentz: Overseas Programme Director
16	Optimal Energy (previous employees who worked on the Joule programme)	Mwendwa Mutisya; Denis Owaga
17	Sasol	Cavin Hill