

PATHWAYS project

Exploring transition pathways to sustainable, low carbon societies

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Country report 7: The Dutch mobility system

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Executive summary

The purpose of this document is to develop forward-looking, qualitative scenarios describing alternative socio-technical pathways for the Dutch land-based passenger mobility domain. Concretely, we use the quantitative scenarios created in Work Package 1 (WP1) as starting point and - by following the logic of Pathway A and Pathway B - develop imaginative, yet plausible storylines of what (socio-technical) changes would need to occur in order for these low-carbon scenarios to happen. We hence offer *endogenous* underpinnings of the quantitative patterns and emphasise, for instance, the role of different actor groups, struggles and conflicts, or lock-ins. To do this, we build on empirical data generated in PATHWAYS D2.1, D2.2 and D2.3, mobilising the same analytical categories. We develop one scenario for Pathway A and two alternative scenarios for Pathway B.

To analyse tensions between the future model scenarios and our earlier WP2 findings on niche momentum within the mobility domain in the Netherlands (NL), we identify so-called ‘transition challenges’ (the constraints and possibilities) faced in trying to achieve the low-carbon pathways:

Innovation /Challenge	Pathway A	Pathways B: - B1: Public Transport - B2: Slow Modes	Constraints
<i>ICE:</i>	Pathway A suggests a sharp reduction in ICE journeys from 2020 and phasing out of ICE journeys by the 2040s. This requires a reversal of current trends, which have seen an increase in ICE (stabilised in recent years).	Pathway B suggests different paths: B1: involves an initial sharp decline (halving 2015-2030), substituted by carsharing and public transport. After plateauing 2030-2040, a further sharp decline to 2050. So this effort is quantitatively comparable to pathway A, with a different sequence. B2: involves an extremely rapid and continuous phase out by 2035.	Inertia / stability in automobility regime are still substantial (although they seem to be levelling off already). >> The challenge is to make ICE less attractive (than other alternatives) Dense entrenched infrastructure webs (e.g. roads, petrol stations, manufacturing facilities) Policy/ manufacturer coalitions committed to incremental efficiency improvements
<i>HEVs</i>	Pathway A envisages an increased role for HEVs, between 2020-2030 (in parallel to but slightly before BEV) then levelling off and slightly declining as it is clearly taken over by BEVs.	B1: – relatively small proportion of HEVs kicks in very late (from 2035) as a way to compensate for the last phase of ICE decline. B2: rapid increase 2015-2020, to make up for ICE decline, then levelling off and slowly declining as slow modes experience a significant increase from 2035.	Costs (largely batteries) of HEVs remain higher than comparator ICE vehicles. >> The challenge is to increase markets in order to scale up production and drive costs down Range anxiety. Although this is not really a problem, it still is a behavioural obstacle to greater adoption. >> Challenge is to increase potential user exposure
<i>BEVs</i>	Pathway A suggests a key role for BEVs in the medium and long-term, with a steady growth from the mid-2020s up to nearly 40% of lifestyles.	BEVs account for very few journeys (near imperceptible) for both B1 and B2, which means that there is no significant challenge, although it means that current momentum should be seen as a passing	Cost: significantly higher (batteries, early days for genuine mass production). Both can be overcome with substantial initial support (early adopters and incentives such as tax exemptions), which can then support technology learning.

		hype	<p>>> A policy problem concerns the phasing of support and its retraction.</p> <p>Convenience/desirability: range anxiety remains important.</p> <p>>> The challenge is both technical (better batteries and charging) and psychological (exposure)</p> <p>Batteries and raw materials. As BEVs become more desirable, the industry may face issue concerning resource availability for Li-Ion batteries requiring further alternatives.</p> <p>Building an industry. To support all of the above, there needs to be an active industrial strategy away from ICE towards BEVs, with an ensuing competitive race, which we are already starting to see.</p> <p>Integration with electricity. While this seems not to be a huge challenge, it may lead to fundamental re-structuring of both industries, with opportunities for new transversal roles</p>
<i>HFCVs:</i>	n/a	n/a	
<i>BIOFUELS:</i>	Pathway A suggests a stable 5% share of biofuels 2015- 2035, with a subsequent decline to insignificance by 2050.	Both B1 and B2 suggest a stable share of biofuels at around 5% of trips.	No real transition challenge.
<i>PUBLIC TRANSPORT:</i>	Pathway A suggests lifestyles dominated by public transport account for around 5% of trips across the time period, without any significant change.	<p>B1: Substantial and steady growth in trips, rising from 5% to nearly 30% of trips by 2050</p> <p>B2: increase (from next to nothing) to nearly 10% by 2030 and decline thereafter</p>	<p>No challenge for Pathway A</p> <p>Infrastructural capacity stress for pathways B (public transport). Given that network is well developed, the issue is mainly due to its overexploitation, innovation in logistics, and user-oriented strategies.</p> <p>Spatially selective prioritisation of parts of the network. Need for local expansions in more remote connections (e.g. buses) and combinations with convenient slow modes (e.g. cycle hire).</p> <p>Dominance of ideology of private mobility</p>
<i>SLOW MODES:</i>	Pathway A suggests no change: slow modes accounts for around 45% of households across the time period	<p>B1: no change: slow modes accounts for around 45% of households across the time period</p> <p>B2: no change until 2030: slow modes accounts for around</p>	<p>No challenge for Pathways A and B (public transport)</p> <p>Shift from substantial role in mobility in terms of trips, to substantial role in terms of distance covered.</p> <p>This implies a relative shortening of distances covered, which clashes</p>

		45% of households, and then gradual increase to nearly 80% by 2050	with the dominance of a culture of long-range mobility. Infrastructure may feel some stress, particularly in commuting strangleholds.
CAR SHARING:	In Pathway A car sharing accounts for a very small share of trips	B1: significant role, rising rapidly 2015-2020 to over 15% to make up for privately-owned automobility, and then gradually reducing to under 10% by 2050, thanks to the increasing significance of public transport, and to a lesser extent HEVs. B2: slight increase (peaking at nearly 5% by 2030)	Significant re-alignment of socio-cognitive understandings of car use as access to shared care (as opposed to permanent availability of privately owned) Need for significant reconfiguration in conceptions of users, business model, tracking, monitoring and payment infrastructure and a mix of new and incumbent actors Most logistically challenging in lesser dense areas, where vacant vehicles may be beyond access.

This brief analytical summary allows us to link the quantitative CO reduction scenarios with the qualitative socio-technical scenarios developed in this document.

For our first scenario (Pathway A), we divide our storyline into three main periods (2015-2025, 2025-2035, and 2035-2050). For our second and third scenario (Pathway B1 and B2), we tell the story along two main periods (2015-2030 and 2030-2050), as presented and summarised below. The difference in periodisation is justified by the fact that the lesser uncertainties around pathway A, which allows a more detailed exploration, and hence a finer decomposition of the time horizon. Pathways B1 and B2 are comparatively more speculative and related to higher uncertainties, because they rely on much deeper cultural shifts.

Our methodical approach is to ‘tell the history of the future’, meaning that our detailed scenario descriptions are written in past tense.

Scenario 1 (Pathway A): The rise of electric mobility

In Pathway A, increasing importance is placed on the environment, but car-based mobility prevails. BEVs initially compete with hybrids but win in the long run as BEVs’ range problems are solved by more infrastructure and user familiarity leading to higher perceived convenience. For Europe, initial increased costs of BEVs through batteries are a concern, but outweighed by environmental concerns. In order to achieve a transition to low-carbon mobility by 2050, a rapid move away from ICEs is necessary.

2015-2025: Developing a fascination for electric mobility

During this period, BEVs experienced a significant upward swing, characterised by massive sales increases (up to 25% of households or 2 million BEVs by 2025), the rollout of charging infrastructure, increasing variety of BEV models, and declining costs of production. HEVs also continued their market penetration. This initial ‘success story’ significantly raised the status and desirability of e-mobility, hand-in-hand with deliberate strategies to destabilise the ICE, in particular a deliberate petrol phase-out policy from 2018. A 12-year phase-out of petrol cars was announced (by 2030), with corresponding measures to dramatically step up the roll out of BEVs (with a little help from HEVs).

The main market focus was set where the existing barriers to development are small or easily overcome, such as high-intensity of localised short trips (taxis, deliveries, urban car sharing, etc.), predictable mobility patterns (public transport), high ‘user willingness’ and lower cost barrier (high-performance ground-breaking vehicles, Government procurement, etc.).

The range anxiety myth associated with electric mobility was tackled through 1) the widespread rollout of conventional charging in residential, business, and public e-parking areas, 2) early investments in fast chargers and their public demonstrations in dedicated ‘e-mobility corridors’, 3) the early diffusion of battery swapping in selected strategic locations throughout the country (seen as an emergency option), and 4) the simplicity of these services greatly enhanced by tracking and geo-location apps.

A comprehensive portfolio of innovation and deployment support enabled a rapid scaling of electric mobility.

2025-2035: Can electric mobility be truly democratic?

The period up until 2025 was characterised by a decade of truly impressive industry build-up with diffusion amongst a staggering 25% of households, supported by a – until then – costly and over-dimensioned charging infrastructure. The main challenge and question for the coming period was whether electric mobility would stand the trial of mass democratisation and deployment in the lesser affluent and environmentally committed sections of society. A number of other tensions emerged, in particular related to an increasing pressure on the special status that electric mobility had enjoyed in these early years.

Lightweight electric vehicles (LWEVs), which had enjoyed impressive market penetration since 2010, had expanded beyond early niches. Two major innovations supported the mass deployment of LWEVs to make up for unaffordable larger BEVs (by 2025, the price of BEVs was almost on a par with conventional ICE equivalent vehicles): dedicated lanes and modular design.

From a cultural-cognitive perspective, BEVs fully installed themselves as the mainstream high-end driving experience.

Policy-wise, the ambitious policies laid out in 2015-2025 were continued with surprising commitment, which made it difficult to challenge them. The initial efforts were now bearing fruit. A national innovation culture had been installed, along with the commitment to the democratisation of BEVs, and the increasingly uncontested defiance of everything petrol. This generally positive climate made things much easier. Perhaps the most challenging policy project was the development of LWE-lanes throughout the country.

2035-2050: Looking back: What a journey!

By 2035, it was clear that the present was electric. Looking back to the development of BEVs and LWEVs was very impressive. By 2050, electric mobility had produced something barely recognisable from the conventional cars of 2015. New design features had generated completely new kinds of artefacts centred on high-performance BEVs and modular LWEVs with all sorts of add-ons.

BEVs had become the standard vehicle for long journeys, but LWEVs were preferred for shorter journeys involving urban centres. Though BEVs had become affordable, they were still much more expensive than LWEVs, less practical as a daily option, and increasingly BEVs were only hired on demand. This was facilitated with tremendous improvements in self-driving technology, which enabled the unmanned delivery of BEVs (and LWEVs) at point of use, when needed.

The electrification of the car had been pioneered by a number of Dutch, Norwegian and North American companies, who were benefitting from expanding markets globally. LWEVs, a Dutch invention, were proving extremely successful in all sorts of applications worldwide, opening up a massive market for exports.

User acceptance was no longer an issue. Electric mobility was firmly established as the new societal norm, showing no more demographic disparities between, for instance, urban and rural users or different age groups. ICEs were regarded as immoral relicts of the past.

Policy measures that were hitherto regarded as ‘radical’ became accepted across the political spectrum and soon went unquestioned.

Scenario 2 (Pathway B1): Public transport

In Pathway B1, increased environmental awareness is combined with a move away from individualised transport, causing competition between car share and public transport.

Through the high number of slow mode trips in the NL, further investment in public transport eventually enables an even better combination of slow modes and public transport, leading to a relatively infrequent use of mechanised individual vehicles.

2015-2030: Who needs to own a car?

This period saw a rapid reduction in privately owned petrol cars, which were replaced by carsharing and public transport. Whilst the development of carsharing was largely due to the emergence of market opportunities and new models of consumption, the decline of the ICE and the further rise of public transport use were the outcome of deliberate planning at both national and local levels of Government.

Increasing awareness of climatic problems and air pollution fuelled a democratic movement to step up efforts to dramatically reduce emissions from transport. A 12-year phase-out of petrol cars (by 2030) was announced, and corresponding measures taken to roll out public transport. This movement, threatening to bring the Government down, led to the development of a deliberate petrol phase-out policy from 2018.

Conventional ICE cars were experiencing increasing pressure, in large part due to their poor environmental performance, and deliberate petrol phase-out policy from 2018. Rising emissions standards for new cars, tough anti-congestion zoning, and prohibitive petrol taxes meant that new ICE vehicles became increasingly costly and there were now clear signals that they would start to become unaffordable in the foreseeable future.

From a user perspective, following an emerging trend, the younger generation with less disposable income as well as urban professionals with shifting priorities quite naturally did not engage with private car ownership, and welcomed the rapid development of alternatives.

By 2025, the number of cars in circulation had shrunk by a third of its 2015 levels, and so had the average usage rate.

Strategies were devised to further raise the profile and use of public transport. Given the existence of an extensive train network for medium and long distances and of metros, trams and busses for shorter and more local trips, the main challenges to grow markets consisted in encouraging customers, extending coverage, and maximising the use of existing infrastructure.

The major successes in reducing car use in the Netherlands were due to an early move towards radical new forms of mobility, involving a shift away from private ownership

(supported by the emergence of carsharing) and the development of a robust, efficient and far-reaching public transport system with numerous options for multi-modality.

2030-2050: Winning over the last sitting automobilists

After a dramatic decline of private car ownership, supported by increasingly convenient and far-reaching multi-modality, and aggressively dissuasive policies, the number of motorists stabilised at ca. 3 million. Despite the continued implementation of phase-out strategies, it proved very difficult to cut back automobility any further. The global boom of Plug-in Hybrid Electric cars had not yet taken ground in the Netherlands. However, it now provided an alternative for the last standing private motorists. In exchange for the maintaining of special permits, motorists were forced to convert from petrol to HEVs. By 2045, only 100,000 petrol cars remained in the country – largely collectible models displayed on rare occasions.

The convenience and reliability of public transportation was improved along a number of priority objectives following from the previous period: infrastructure investment, a society-wide agenda promoting flexible and local lifestyles, and further multi-modal and -modular integration.

Plans for new track investments sought the doubling of railway tracks in high-intensity corridors linking major cities, but also in and around regional commuter towns, where population movements had concentrated. The new lines greatly relieved the railways and absorbed most of the traffic.

For a larger societal perspective, the Dutch society had gradually moved towards a socio-economic model that embraced the benefits of automation, social justice, and vibrant consumer markets by seeking full employment, the harmonisation of wages, and a generalised reduction of working hours to free up more leisure time.

Having initiated talks to seek support for more flexible employment options throughout the country to further diversify mobility patterns, the railway industry managed to gather the support of bus operators, carsharing and taxi fleet operators, but more importantly had the listening ear of central Government. By 2032, a national strategy for a ‘freetime society’ had taken shape, setting out a legal framework institutionalising shorter working hours and greater flexibility in the personal management of these reduced working hours. This provided greater clarity for public transport planning, and enabled effectively more malleable and diversified commuting patterns.

The continued rise of public transportation went hand in hand with a data- and ICT-driven process of logistical optimisation. The continued collecting of massive volumes of passenger information enabled the provision of adaptive services in real-time, the dimensioning of infrastructure investments in the longer run, the coupling of multiple modes of transportation, and the planning of housing developments.

Scenario 3 (Pathway B2): Slow modes

In Pathway B2, there is an initial adoption of electric hybrids and increased use of public transport for environmental concerns. In the longer run, mobility lifestyles in the NL change so that most slow modes prevail for most local trips while most people keep hybrid cars for longer distance and use ICT for more remote communication. To a limited extent, slow modes lifestyle relies on public transport and car share for longer distances.

2015-2030: The rapid substitution of the petrol car

This period was characterised by strong environmental pressure paving the way for a staggeringly rapid decline of petrol cars, largely replaced by hybrid cars, and an expansion of public transport. Increasing awareness of climatic problems and air pollution, exacerbated by severe floods in 2017 that further exposed the vulnerability of large parts of the Netherlands, fuelled a democratic movement to dramatically reduce emissions from transport.

Building on recent success with BEVs and HEVs in car fleets and private cars, the Government decided to initiate a nation-wide substitution policy.

By 2020, no new petrol-only cars were registered in the Netherlands, by 2025, 85% of the remaining car stock had been replaced or fitted with add-on batteries, and by 2030 virtually all but a handful of collectible cars (ca. 100,000) were effectively Plug-In Hybrids.

At the same time, local strategies to reduce the need for travel were initiated in cities, reinvigorating and extending the geographical scope of the movement to free up urban cores that had led to car-free centres since the 1960s. Government decided to support some experimental actions for ‘super-local mobility’ in specific areas, by granting further devolution of powers to local Government in experimental locations, investing in the conversion of roads for innovative cycling infrastructure, and strengthening connection with public transport infrastructure.

All municipalities over 100,000 inhabitants (but also smaller towns) were implementing zero emission zones, freeing up the streets in a shift toward ‘reclaiming the city’. Following a strategy that had proved successful in nature conservation projects, reclaiming efforts focussed on reconnecting areas by designing slow mobility corridors and revitalising them by encouraging the development of local and sustainable activities.

This experiment had an influence on large mobility infrastructure. By 2022, the declining number of motorists freed up space on highways. The Ministry of Infrastructure and the Environment approved a proposal for the partial re-appropriation of roads for ‘cycling super-highways’ in order to stimulate high-speed cycling and e-cycling.

In parallel, national strategies were devised to further raise the profile and use of public transport, mainly as a preparatory step to enable further decarbonisation of mobility in the future.

Thanks to clever marketing and pricing strategies, particularly oriented at converting motorists, train users grew rapidly. Public transportation had increased substantially by 2030. A critical aspect concerned integration with cycling and other light-weight vehicles, particularly in denser areas.

2030-2050: No more long trips, we can get by locally

After the successful implementation, uptake, and diffusion of policy measures in the previous periods, mobility between 2030 and 2050 was shaped, most notably, by developments within the spatial planning domain as well as by ideological changes and new value systems within society. These focused especially on a strong revaluation of ‘the local’ and coincided with a downright boom of health awareness.

By 2030, petrol cars were had virtually been eradicated. Automobility had receded from all cities and towns over 100,000 inhabitants, due to the implementation of the zero emission zones. Plug-In Hybrids were still numerous and commonplace, but restricted to inter-city travel on increasingly fewer lanes on highways, and to local transport in more remote areas. The reclaiming of streets and roads, starting from urban areas, sprawled in a gradual but

steady pattern, first to corridors extending and linking urban areas together, then to fringe areas. In mobility terms, cycling and walking were predominant – and indeed the congestion of cycling lanes and their punctual overflow was at time overwhelming. Telecommunications and the relaxing of physical presence requirements at work was crucial for this shift towards a more decentralised society happen.

This spatial development oriented towards localism was in stark contrast with what happened beyond those village- and city-regions.

Significant improvements in public transport, particularly rail transport over long distances serviced the bulk of personal mobility needs for journeys beyond 20kms. Large city-regions had developed large networks of tramlines from 2025.

As the trend towards sustainable localism installed itself even further as dominant social and economic principle, the need to travel long distances diminished altogether. Cycling and walking became the main means of mobility, as the population lived, worked, and played at a very local level, or – where necessary – through remote practices enabled by telecommunications.

The transition to slow modes had been supported by a deep cultural shift towards sustainable localism, which had fundamentally altered urbanisation patterns, and the way the Dutch population lived. The government had been highly instrumental in supporting this shift by investing in large infrastructure experiments, which were so successful that they became the dominant model for organising space, community and living patterns.

Conclusions

Challenging pathways. The scenarios, informed primarily by modelling work in conjunction with preliminary outputs from socio-technical analysis, are constrained by very ambitious objectives. As a consequence, the transition efforts required are very substantial for all three pathways considered in terms of the speed, scale, and scope of change in individual practices and socio-technical configurations. Most striking is how rapidly the destabilisation of the petrol car has to be set in motion for these pathways to materialise. The emergence of alternatives is perhaps less challenging in the Dutch context, as there is already a relatively favourable environment for low-carbon mobility transitions at present. Nonetheless, the breakthrough of specific alternatives, while currently ‘possible’, requires significant work and to realise. Pathway B2 presents challenges not so much in terms of the speed of change, but the scope and depth of change for a society to become almost entirely reliant on slow modes (and hence much shorter distances travelled) for virtually all personal mobility requirements.

Our scenarios, because they are constrained by ambitious sustainability objectives, demand extremely challenging transition pathways – in particular, a dramatic destabilisation of ICE in all three pathways – with varying speeds and intensities. We see that with strong commitment and a certain degree of forcefulness, the right strategies and investment, as well as with necessary behaviour changes and societal trends, these pathways *are* possible. Naturally, some luck is needed also - in the sense of, for instance, investing in the right thing at the right time and place. Policymakers, in particular, play an important role in recognising and accelerating the momentum of relevant niche innovations and to overcome lock-ins – in particular ICE. Simultaneously, however, policymakers are reliant also on other actor groups and civil society for the legitimisation of action or the break-up of specific resistances. Strict policies can only be introduced successfully with the right backing and actor coalitions in place.

Forcing through socio-political dimensions. Realising these transitions pathways, shifting away from prevailing trends and in many cases fundamentally reverting them, requires a fair amount of ‘forcing’. This can be done via a number of strategies (including relying on external shocks and dramatic events, or futuristic high-technology assumptions), but we have here relied on socio-political agency. So, our storylines – for all pathways – rely on a fair amount of public pressure for environmental issues (conveyed by social movements) and consistent and deliberate policymaking strategies to support path-breaking innovation and reduce commitment to established regimes. The value of this is to highlight the role of governance in bringing about and making sense of change (as opposed to purely techno-economic rationales), but these assumptions are nonetheless very strong and may not be feasible, as in practice socio-political swings tend to be rare. In all pathways, the deliberate destabilisation of the ICE and support for alternatives appears necessary – something that we are currently not (yet) seeing in practice. In all pathways, political pressure for environmental improvement was important. In pathway A, an important underlying narrative concerns the emergence of a national emancipatory discourse around an e-mobility innovation culture in contrast to a sense of deceit with a global conventional automobile industry. In pathway B1, a particular emphasis was set on confrontation with the global conventional automobility industry, seen as obstructive to a process of environmental improvement and untrustworthy. In pathway B2, a grassroots movement favouring hyper-localism, developing enabling innovations, practices and land use models, and new forms of collaboration is a crucial driving force of change.

It is important to note that in all pathways, we have assumed that there is no major additional issue shifting attention away from that focus on decarbonisation, and that pressure for environmental change builds up over time. This is a strong assumption, as there is no assurance that interest in environmental questions would not wane over time during this century.

The role of deliberate strategies. The storylines further highlight the importance of decision-making at different levels and by different factions of society (government, industry, users, etc.), most effectively in alliances. In all pathways, specific measures are set out to deliberately destabilise the conventional car industry and users, whilst more positive measures are intended to support specific alternative mobility modes. In both Pathways B, experimentation – often at local level – plays an important role, where local coalitions of activists and policymakers become aligned to jointly deliver on community and policy goals, and eventually address the environmental challenges linked to mobility. Whichever deliberate strategy pursued, they require strong societal support or political mandates in order to be implemented. In some instances, specific governance strategies need to be crafted to alleviate resistance, such as in the case of ‘special status’ concessions for a fraction of automobilists in pathway A, or attractive rates for carsharing and public transport to support ‘modal conversions’ of specific users in pathway B1.

Instruments and interventions. In order to realise transitions objectives, besides the need for consistent and legitimate strategies discussed above, a number of governance instruments and interventions are required. These can correspond to ‘traditional’ policy instruments such as financial (dis)incentives and regulations, but also more creative interventions, e.g. phase-out (from light-bulbs and CFCs) or ‘corridors’ as a planning method to support continuous localism (borrowed from biodiversity and wildlife management). At any rate, two aspects come to the fore when attempting to complement modelling strategies with governance considerations: 1) interventions are required well beyond the ‘blanket’ macro-instruments considered by modellers (e.g. carbon tax), and 2) no single instrument is sufficient, and instead what is needed is policy instrument mixes within specific areas and a substantial

degree of integration across policy areas (e.g. energy policy, land use and infrastructure planning, innovation support, industrial stimulus, consumer incentives).

Twists, turns, and developmental patterns. Despite the importance of deliberate strategies to make big visionary change happen, we also found that a more imaginative reflexion on multiple innovation trajectories was useful to overcome potential paradoxes. For instance, the branching of electric mobility into a high-end trajectory (aligned with current technological assumptions about BEVs) and an additional trajectory (LWEVs, characterised by greater affordability and versatility) was useful to highlight potential issues related to the inconvenience of automobile congestion and ownership, the mass production of BEVs, and the important share of slow modes in the Netherlands. In another vein, the central role of the ‘journeysaver’ app in pathway B1, in conjunction with a relaxing of commuting patterns due to social and labour policies, lead to significantly improved position for railway planning that underscore the success. Of course, such hypothetical anecdotes are not meant to be accurate predictions, but to sensitise about the interactions between infrastructure dimensioning and user patterns, and the positive role that ICT can play in supporting major system adjustments.

Stepping-stones, transitional innovation and re-combinations. The role of intermediate or transitional innovations has been particularly important in these scenarios – whether the role of hybrids in Pathway A, the role of carsharing in Pathway B1 or the role of public transport and carsharing in Pathway B2. Sometimes, they may be seen as stepping-stones as in the case of hybrids that allow further electrification of mobility but in a more gradual, tempered way. In other instances, they may be seen as buffers, as was partly the case for carsharing that allowed a more gradual phase out of the automobile. In other cases, specific innovations support the re-combination of technologies such as BEVs and a culture of slow modes to produce LWEVs as an option for the mass diffusion of electric mobility. In yet other instances, we see innovation dead-ends, such as the near-abandonment of public transport in Pathway B2 as hyper-localism virtually eliminates the need for long-distance travel.

Multiple time horizons and branching points. Starting from model projections enables narrative storytelling to focus on significant prospective events that appear necessary to break the mould of established trends, ‘bending their curves’ so to speak. In practice, these have been taken to be inflection points and the crossing of significant thresholds. They have informed the temporal bounding of storylines in two or three time periods, each characterised by a few dominant techno-economic developments to be explained by socio-technical change processes. This exercise enables us to look at potential and conditional hurdles beyond the distinction of ‘now’ and ‘2050’ (or target year), e.g. in the case of the (initial lack of) democratisation of BEVs. Section 4 was crucial in allowing us to identify the main challenges to be expected. For instance, a number of specific bottlenecks cannot be overlooked when thinking about the future of personal land-based mobility, including the need for deliberate destabilisation of conventional mobility, the need to overcome cultural reticence in the case of BEVs (in Pathway A), and the need for substantial infrastructure investments (e.g. for charging in the case of BEVs in Pathway A, for public transport in Pathway B1, for cycling lanes in Pathway B2).

From an analytical standpoint, much more can be said about earlier periods, and uncertainties significantly increase the further we move away from the present. That being said, the importance of rapidly shifting away from conventional automobility in all pathways (which is a significant departure from current trends) further underlines the importance and urgency of strong policy priority shifts in the immediate future. What we have seen in our models and scenarios is that – irrespective of the specific pathway – the next five years already are absolutely fundamental for ‘bending the curve’ in the right direction for a future of low-

carbon mobility. This is further underscored by the likelihood of resistance from established actors with vested interests in the current configuration.

Technology choice. Another interesting aspect with these pathways is the extent to which the portfolio of innovations that has effectively been mobilised is much narrower than the initial selection we started with, particularly in D2.1. Interestingly, different pathways (A, B1, B2) foreground different technologies, and hence highlight the ensuing choice. This also points to the inherent paradox in innovation policy between 1) supporting variety (and so increase the chance to uncover more optimal, fitting, or desirable alternatives) and 2) making deliberate technological choices and hence accelerate the process towards standardisation and mainstreaming. Pathway A illustrates a strong early prioritisation of an electric mobility choice, excluding other mobility alternatives, while pathways B1 and B2 have a greater tendency for nurturing and supporting a plurality of alternatives.

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1 Introduction

The purpose of this document is to develop forward-looking, qualitative scenarios describing alternative socio-technical pathways for the Dutch land-based passenger mobility domain. Concretely, we use the quantitative scenarios created in Work Package 1 (WP1) as starting point and - by following the logic of Pathway A and Pathway B - develop imaginative, yet plausible storylines of what (socio-technical) changes would need to occur in order for these scenarios to happen. We hence offer *endogenous* underpinnings of the quantitative patterns and emphasise, for instance, the role of different actor groups, struggles and conflicts, or lock-ins. To do this, we build on empirical data generated in PATHWAYS D2.1, D2.2 and D2.3, mobilising the same analytical categories.

In the next section, we briefly introduce the quantitative scenarios from WP1: that is, one scenario for Pathway A and two alternative scenarios for Pathway B.

Building on earlier WP2 work, section 3 subsequently provides an overview of main developments in the Dutch mobility domain over the last 10-15 years (niche innovations, regime developments, and landscape trends).

In Section 4, we identify the main transition challenges, i.e. the degree of departure from current trends that is needed to achieve future scenario and the main related challenges.

Section 5, then, describes our first qualitative scenario (Pathway A), followed by section 6 which depicts the scenarios for Pathway B.

We conclude with some reflections on methodology and the value and limitations of such an exercise.

2 Quantitative scenarios from WP1

In this section, we briefly introduce the quantitative future scenarios, based on WP1, on which we subsequently build our qualitative future scenarios, following imaginative storylines. For Pathway A, we identified one scenario, named 'BEV'. For Pathway B, we identified two alternative scenarios: B1 ('Public transport') and B2 ('Slow modes').

2.1 Pathway A: Fuel Switch/Battery-electric vehicles (BEVs)

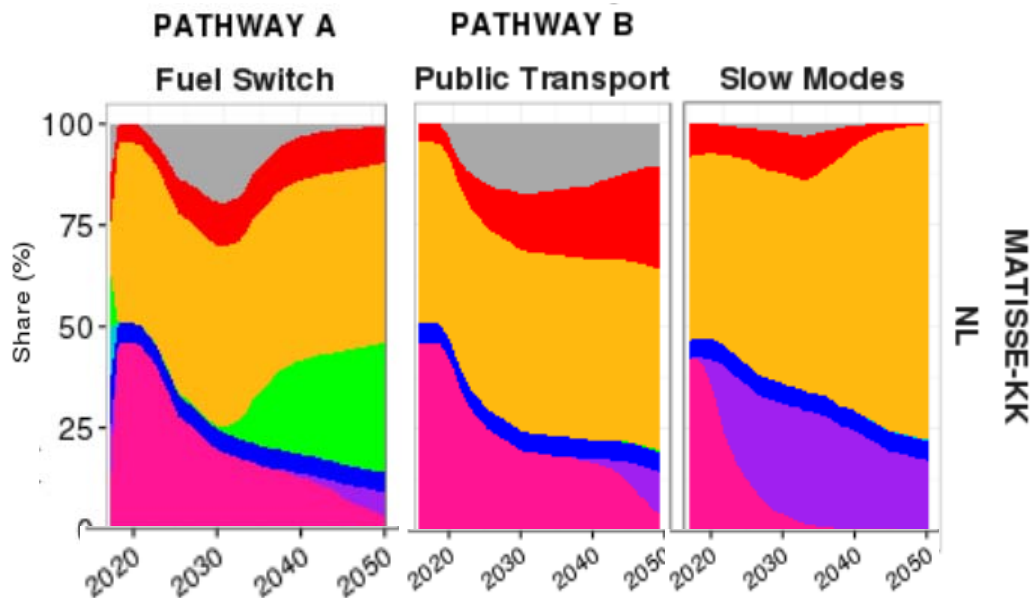
In Pathway A, increasing importance is placed on the environment, but car-based mobility prevails. BEVs initially compete with hybrids but win in the long run as BEVs' range problems are solved by more infrastructure and user familiarity leading to higher perceived convenience. For Europe, initial increased costs of BEVs through batteries are a concern, but outweighed by environmental concerns. In order to achieve a transition to low-carbon mobility by 2050, a rapid move away from ICEs is necessary.

2.2 Pathway B1: Public Transport

In Pathway B1, increased environmental awareness is combined with a move away from individualised transport, causing competition between car share and public transport. Through the high number of slow mode trips in the NL, further investment in public transport eventually enables an even better combination of slow modes and public transport, leading to a relatively infrequent use of mechanised individual vehicles.

2.3 Pathways B2: Slow modes

In Pathway B2, there is an initial adoption of electric hybrids and increased use of public transport for environmental concerns. In the longer run, mobility lifestyles in the NL change so that most slow modes prevail for most local trips while most people keep hybrid cars for longer distance and use ICT for more remote communication. To a limited extent, slow modes lifestyle relies on public transport and car share for longer distances.



3 Socio-technical developments in the recent past and present

In this section, we briefly describe the main developments – niche-innovations, regime developments, and landscape trends – over the last 10-15 years, based especially on findings from D2.1 and D2.2.

3.1 Momentum of niche-innovations

In D2.1, we have analysed the momentum of a selection of niche-innovations over the last 10-15 years, systematically reviewing dynamics in 3 dimensions (techno-economic momentum, socio-cognitive momentum, and governance and policy momentum). We present these results in Table 1. In short, there is high momentum for hybrid electric vehicles (HEVs) and carsharing, as well as significant momentum for BEVs and to a lesser extent for biofuels (for which the potential for wider expansion may be capped due to significant sustainability issues). Notably, most of these niche innovations relate to a Pathway A type development, except for carsharing. Those innovations that may be more prevalent in a Pathway B type scenario (public transport, slow modes, multi-modality) have already established themselves as subaltern regimes in the Netherlands.

Table 1: Momentum analysis of 6 niche-innovations in the mobility domain in the Netherlands

Niche	Momentum	Main drivers of momentum	Pathway
1. Hybrid electric vehicles (HEVs)	High (beyond niche)	<p>high momentum: mass commercialisation, important market share, stable design features. No longer niche?</p> <p>Stepping stone within a broader governmental vision of 'electric mobility'</p> <p>Gradual introduction of electric features within conventional cars paving the way for EVs</p> <p>Next evolutionary step: plug-in hybrids</p> <p>BUT unlikely that it will survive a mobility transition in the long-run because of technical compromise</p> <ul style="list-style-type: none"> • Techno-economic momentum: high (installed) • Socio-cognitive momentum: high (accepted) • Governance and policy momentum: stable 	A
2. Carsharing	High	<p>positive signs of increasing momentum in recent years</p> <p>urban markets developing fast. New services, new locations, etc.</p> <p>Increasingly embeddedness in existing automobility networks (e.g. manufacturers, car hire services, municipalities)</p> <p>Positive cultural and symbolic meanings (e.g. environmental, congestion)</p> <p>Linked to high innovation rate (e.g. ICT, EVs, insurance, business model)</p> <p>Policy visions as integral part of future mobility systems with a different role to play in a variety of pathways</p> <ul style="list-style-type: none"> • Techno-economic momentum: high • Socio-cognitive momentum: high (actors and acceptance) • Governance and policy momentum: high (support) 	B with elements of A

3. Battery electric vehicles (BEVs)	Moderate	<p>multiple hype/disappointment cycles Currently renewed momentum with indications that a significant threshold has been passed market deployment of commercially viable vehicles strong policy support for progress towards charging infrastructure rollout and national deployment targets enthusiastic involvement of fleet operators successful deployment of hybrids vehicles as a 'stepping stone' increasing public exposure. BUT achieving high density and interoperability of charging opportunities crucial for the stabilisation of development trajectory</p> <ul style="list-style-type: none"> • Techno-economic momentum: moderate (innovation but no dominant design) • Socio-cognitive momentum: high (expectations and visions) • Governance and policy momentum: moderate (support for rollout) 	A with elements of B
4. Biofuels	Moderate	<p>Path creation initiated in the 1990s with hype/disappointments Developments driven by EU policy since the early 2000s: market creation for biofuels <i>blending</i> Flexifuel niche is small and stagnant (in Europe) Technological diversity: 1G and 2G biofuels, in reaction to sustainability controversy Progress on 1G commercialisation Remaining doubts about commercial viability of 2G Recent deployment of pilot & commercial plants indicates stabilisation BUT concerns about traceability & scope for sustainably scaling up</p> <ul style="list-style-type: none"> • Techno-economic momentum: high (innovative sector) • Socio-cognitive momentum: low (controversies) • Governance and policy momentum: moderate (obligations) 	A with elements of B
5. Compact cities	Moderate (past)	<ul style="list-style-type: none"> - past innovation. Substantial momentum and instalment (1960s-1990s), then abandoned in NL, in favour of network model - transportation and land-use regimes interaction - spatial planning innovation rather than technological focus - strongest driver was political will (national govt support) for change and policy implementation process (local planning regulations and practices) - agreements with developers (powerful private regime actor) - unexpected and often counterproductive results on sustainable mobility: no lasting improvement, but halting more negative development <ul style="list-style-type: none"> • Techno-economic momentum: low • Socio-cognitive momentum: moderate (consensus – at the time) • Governance and policy momentum: high (strong political will –at the time) 	A but could enable B
6. Hydrogen fuel cell vehicles	Very low	<p>Technologically at an experimentation (demonstration) stage Precursor market experiments just emerging High costs considered as option for the medium and long term (2030 and beyond) BUT doubts because of repeated hype cycles to date</p> <ul style="list-style-type: none"> • Techno-economic momentum: low (early days) • Socio-cognitive momentum: low (not much exposure) • Governance and policy momentum: low 	A with elements of B

3.2 Tensions in the prevailing automobility regime

In previous work (D2.2), we have analysed the sources of stability and tensions in the automobility regime and subaltern regimes (see Table 2). We summarise these findings in the paragraphs below.

Table 2: Summary findings from D2.2 of regime lock-in and tensions in the Dutch automobility regime

	Lock-in, stabilising forces	Cracks, tensions, problems
External landscape pressures	Culture of the age (individualism, private ownership, etc.) Precedence of economic rationale Infrastructure: Sunk costs; planning patterns that favour commuting Ageing society (more older citizens with reduced autonomous mobility capacity) Globally ever-growing automobility	Environmental awareness (especially, pressures to reduce GHG emissions) Revitalisation of sustainable alternatives Rising fuel prices; debates on Peak oil; Congestion, leading to inconvenience and air pollution Information society New forms of mobility services as growing alternative to conventional car ownership Ageing society (new, specialised demand pockets)
Technology and market developments	STRONG Market segmentation: greater diversification of models; greater price ranges; more efficient vehicles (incremental changes) Incremental innovations to improve ICE performance: improved engine performance; greater in-car ICT; and safety devices Better environmental performance of new vehicles ICT: improved performance (e.g. ABS); user interface and convenience; entertainment. Safety and comfort improvements	WEAK/MODERATE Indications of a 'saturation' of the car market in the Netherlands Signs of changing mobility patterns in urban cores
Actors and Institutions	STRONG Powerful (global) automobile industry that ensures continued attractiveness of car and creates barriers for introduction of new technologies; some leading Dutch companies involved in global supply chains Petrol suppliers and distributors (especially Shell) are crucial actors in the Netherlands Turbulence in the automobile industry could lead to 'greening of cars', hence incremental changes	WEAK/MODERATE Turbulence in the automobile industry could lead to radical transformation (new engines, infrastructures, forms of ownership and organisation, etc.) either through new fringe players or absorption by automobile industry
Users	STRONG Socio-cultural preference for the car; normalcy of ways of life based on the car (reinforced by advertising, policy objectives, and future scenarios)	MODERATE Potential disinterest or unaffordability among younger people
Policy-makers	MODERATE Recent policy developments—in difficult economic times—have been reinforcing the automobility regime, e.g.: more and wider roads to tackle congestion problem; 'commuter compensation' which encourages commuting Environmental policies—especially to tackle air	POTENTIALLY STRONG Ambitious decarbonisation objectives (currently met, however, predominantly through incremental changes, e.g. transport efficiency and energy efficiency in vehicles) CO ₂ labelling scheme for cars (implemented at EU level in 2011), making carbon-efficiency

	pollution—introduced successful ‘end-of-pipe’ or ‘incremental add-on’ solutions (e.g. catalytic converters), but do not address climate change challenges frontally	explicit to consumers High fuel taxes Parking and driving restrictions in urban areas
Public debate and opinion	STRONG Society is still highly dependent on the car (or partly perceived to be); Individualism, private ownership, a strive for independence, and other ‘modern-day’ societal trends and norms are reinforcing this perception	STRONG Environmental awareness, health concerns, urban lifestyles, etc.—especially among young people—are showing moves away from automobility, supporting in particular cycling
Social movements, NGOs, scientists		STRONG (but highly localised in city centres) From the 1970s onwards, activists have been challenging pro-car urban planning (in city centres), reclaiming urban cores and seeking benefits in terms of urban life, health and environment, which influenced e.g. the development cycling infrastructure
Overall assessment	STRONG	MODERATE

The existing **automobility** regime in the Netherlands is deeply entrenched and relatively stable. It is stabilised by reinforcing initiatives and institutions that contribute to existing lock-in. These include: a powerful industry, continued technical improvements and sophistication, and supporting policies. Despite strong inherent stability, the automobile regime in the Netherlands is showing some signs of change. Recent trends point to increasing recognition of external pressures and challenges by the automobile industry itself, with greater attention to environmental and safety issues, innovation strategies geared towards lesser emissions (catalytic converters), fuel efficiency improvements, the exploration strategies with different alternative fuels, and the emergence of new business models for mobility. The emission intensity of new cars is steadily decreasing.

There are signs of change ahead, as the prevailing automobile regime is increasingly being challenged on environmental, convenience, safety, economic, and technological grounds, as well as a growing disinterest in car ownership among younger people in the Netherlands. Most responses so far, however, are currently met by regime incremental responses, which points to an incremental regime change pathway, in a context of continued policy support and little urgency for radical transform.

Overall, **public transport** is an integrated and coherent affair in the Netherlands with a strong role for public planning and harmonisation. The Netherlands is striking in its ability to retain public control over public transport (from national government down to municipality), which is one main reason why lasting support and continuity can be expected. Multimodality has been successfully supported (e.g. through integration and simplification of ticketing and fares; increasing ease of connection between modes of transport). To date the emerging issues have been successfully addressed as they have emerged.

The Netherlands has the highest **cycling** rate in Europe; cycling is culturally deeply embedded and has profited from successful policy interventions. The Netherlands has a well-established extensive, safe and convenient cycling infrastructure network, all of which contributes to a strong stability of this regime. In recent years, e-cycling has been replacing some conventional bicycle journeys, particularly over longer distances and among older age groups. The cycling revival in the Netherlands over the past 4 decades can be seen as an

exemplar of mobilisation and mobility transformation driven by 1) societal concerns (a mixture of safety and environmentalism), 2) strong policy involvement, and 3) the crucial role of infrastructure. It also is a telling (and hopeful) example of how leaner and greener alternatives may become deeply embedded in society. However, it is important to recognise that cycling - however widespread - has not yet managed to substantially displace automobility although it may have contributed to the tempering of its growth.

3.3 Potential emerging transitions dynamics

Based on D2.4, we here provide an evaluation of the foreseeable fate of niche-innovations and their potential for contributing to transitions dynamics (and qualification thereof), and we reflect on transitions dynamics in mobility in the Netherlands.

The Netherlands offers an interesting context for experimentation with low-carbon mobility as it is characterised by a high degree of innovation along a ‘greening of cars’ trajectory, decades of successful (and world-leading) experience with alternative mobility modes (public transport, cycling, multi-modality), and a variety of local and national coalitions pressing for greater efficiency and sustainability of transportation. Together, these dynamic conditions and energies generate an enabling and hopeful stage for transitions towards low-carbon mobility. There is, nonetheless, a deeply engrained habit of supporting automobility in policy, which may stand in the way of or slow down these emerging trends by sending the wrong signals.

More radical pathways stepping away from automobility altogether are still difficult to envision, as there is currently no materialisation of a fundamental questioning of automobility. Automobility is not challenged in mainstream discourse, and there is a relative shyness of policy to aggressively challenge a mobility mode that is still perceived as convenient by a majority of the Dutch population. There are promising exceptions to this (e.g. urban cores and younger generations, and general saturation) but these are not strong enough to overcome a generally risk-averse policy system that is happily seen to be actively promoting hopeful alternatives (EVs, multimodality) on discursive levels, but not yet ready to deliberately accelerate the destabilisation of automobility. In this context, we are likely to see Pathway A-type developments thriving, along with an increased contribution of new mobility modes, but may have to wait before we see a serious and unavoidable challenge to automobility in the Netherlands.

Nevertheless, the Netherlands is striking as a context that has made a head start towards sustainable mobility by 1) supporting the strong development of multiple modes of mobility, 2) seeking leadership in sustainable mobility innovation, and 3) hosting a variety of local and national coalitions pressing for greater efficiency and sustainability of transportation. These crucial developments are signs of a deep reflection within Dutch society about fostering greater flexibility of options for mobility, with particular emphasis on efficiency, accessibility (territorial and social), safety, and environmental concerns. A highly stable and effective public transport system, a mature cycling infrastructure, and an inclination towards multi-modality are a deeply entrenched part of mobility practices in the Netherlands. They provide fertile ground for stepping away from unsustainable automobility.

The Netherlands is perhaps best positioned in Europe to enable and support sustainable mobility transitions in the medium to long term. Crucial requirements ahead are greater policy clarity and coherence about no longer supporting automobility-as-usual, and embracing the sustainable mobility possibilities in the making.

4 Specifying ‘transition challenges’

In this section, we identify the main transition challenges, i.e. the degree of departure from current trends (section 3) that is needed to achieve future scenario (section 2).

Innovation /Challenge	Pathway A	Pathways B: - B1: Public Transport - B2: Slow Modes	Constraints
<i>ICE:</i>	Pathway A suggests a sharp reduction in ICE journeys from 2020 and phasing out of ICE journeys by the 2040s. This requires a reversal of current trends, which have seen an increase in ICE (stabilised in recent years).	Pathway B suggests different paths: B1: involves an initial sharp decline (halving 2015-2030), substituted by carsharing and public transport. After plateauing 2030-2040, a further sharp decline to 2050. So this effort is quantitatively comparable to pathway A, with a different sequence. B2: involves an extremely rapid and continuous phase out by 2035.	Inertia / stability in automobility regime are still substantial (although they seem to be levelling off already). >> The challenge is to make ICE less attractive (than other alternatives) Dense entrenched infrastructure webs (e.g. roads, petrol stations, manufacturing facilities) Policy/ manufacturer coalitions committed to incremental efficiency improvements
<i>HEVs</i>	Pathway A envisages an increased role for HEVs, between 2020-2030 (in parallel to but slightly before BEV) then levelling off and slightly declining as it is clearly taken over by BEVs.	B1: – relatively small proportion of HEVs kicks in very late (from 2035) as a way to compensate for the last phase of ICE decline. B2: rapid increase 2015-2020, to make up for ICE decline, then levelling off and slowly declining as slow modes experience a significant increase from 2035.	Costs (largely batteries) of HEVs remain higher than comparator ICE vehicles. >> The challenge is to increase markets in order to scale up production and drive costs down Range anxiety. Although this is not really a problem, it still is a behavioural obstacle to greater adoption. >> Challenge is to increase potential user exposure
<i>BEVs</i>	Pathway A suggests a key role for BEVs in the medium and long-term, with a steady growth from the mid-2020s up to nearly 40% of lifestyles.	BEVs account for very few journeys (near imperceptible) for both B1 and B2, which means that there is no significant challenge, although it means that current momentum should be seen as a passing hype	Cost: significantly higher (batteries, early days for genuine mass production). Both can be overcome with substantial initial support (early adopters and incentives such as tax exemptions), which can then support technology learning. >> A policy problem concerns the phasing of support and its retraction. Convenience/desirability: range anxiety remains important. >> The challenge is both technical (better batteries and charging) and psychological (exposure) Batteries and raw materials. As BEVs become more desirable, the industry may face issue concerning resource availability for Li-Ion batteries requiring further alternatives. Building an industry. To support all of

			<p>the above, there needs to be an active industrial strategy away from ICE towards BEVs, with an ensuing competitive race, which we are already starting to see.</p> <p>Integration with electricity. While this seems not to be a huge challenge, it may lead to fundamental re-structuring of both industries, with opportunities for new transversal roles</p>
HFCVs:	n/a	n/a	
BIOFUELS:	Pathway A suggests a stable 5% share of biofuels 2015- 2035, with a subsequent decline to insignificance by 2050.	Both B1 and B2 suggest a stable share of biofuels at around 5% of trips.	No real transition challenge.
PUBLIC TRANSPORT:	Pathway A suggests lifestyles dominated by public transport account for around 5% of trips across the time period, without any significant change.	<p>B1: Substantial and steady growth in trips, rising from 5% to nearly 30% of trips by 2050</p> <p>B2: increase (from next to nothing) to nearly 10% by 2030 and decline thereafter</p>	<p>No challenge for Pathway A</p> <p>Infrastructural capacity stress for pathways B (public transport). Given that network is well developed, the issue is mainly due to its overexploitation, innovation in logistics, and user-oriented strategies.</p> <p>Spatially selective prioritisation of parts of the network. Need for local expansions in more remote connections (e.g. buses) and combinations with convenient slow modes (e.g. cycle hire).</p> <p>Dominance of ideology of private mobility</p>
SLOW MODES:	Pathway A suggests no change: slow modes accounts for around 45% of households across the time period	<p>B1: no change: slow modes accounts for around 45% of households across the time period</p> <p>B2: no change until 2030: slow modes accounts for around 45% of households, and then gradual increase to nearly 80% by 2050</p>	<p>No challenge for Pathways A and B (public transport)</p> <p>Shift from substantial role in mobility in terms of trips, to substantial role in terms of distance covered.</p> <p>This implies a relative shortening of distances covered, which clashes with the dominance of a culture of long-range mobility.</p> <p>Infrastructure may feel some stress, particularly in commuting strangleholds.</p>
CAR SHARING:	In Pathway A car sharing accounts for a very small share of trips	B1: significant role, rising rapidly 2015-2020 to over 15% to make up for privately-owned automobility, and then gradually reducing to under 10% by 2050, thanks to the increasing significance of public transport, and to a lesser extent HEVs.	<p>Significant re-alignment of socio-cognitive understandings of car use as access to shared care (as opposed to permanent availability of privately owned)</p> <p>Need for significant reconfiguration in conceptions of users, business model, tracking, monitoring and</p>

		B2: slight increase (peaking at nearly 5% by 2030)	payment infrastructure and a mix of new and incumbent actors Most logistically challenging in lesser dense areas, where vacant vehicles may be beyond access.
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This brief analytical summary allows us to link the quantitative CO reduction scenarios with the qualitative socio-technical scenarios developed in this document.

For our first scenario (Pathway A), we divide our storyline into three main periods (2015-2025, 2025-2035, and 2035-2050). For our second and third scenario (Pathway B1 and B2), we tell the story along two main periods (2015-2030 and 2030-2050), as presented and summarised below. The difference in periodisation is justified by the fact that the lesser uncertainties around pathway A, which allows a more detailed exploration, and hence a finer decomposition of the time horizon. Pathways B1 and B2 are comparatively more speculative and related to higher uncertainties, because they rely on much deeper cultural shifts.

Our methodical approach is to ‘tell the history of the future’, meaning that our detailed scenario descriptions are written in past tense.

5 Scenario 1 (Pathway A): the rise of electric automobility

5.1 2015-2025: Developing a fascination for electric mobility

During this period, BEVs experienced a significant upward swing, characterised by massive sales increases (up to 25% of households or 2 million BEVs by 2025), the rollout of charging infrastructure, increasing variety of BEV models, and declining costs of production. HEVs also continued their market penetration. This initial ‘success story’ significantly raised the status and desirability of e-mobility, hand-in-hand with deliberate strategies to destabilise the ICE.

Techno-economic. Conventional ICE manufacturers and vehicles were experiencing increasing pressure, in large part due to their poor environmental performance, and deliberate petrol phase-out policy from 2018. Rising emissions standards for new cars and prohibitive petrol taxes meant that new ICE vehicles became increasingly costly and there were now clear signals that they would start to become unaffordable in the foreseeable future. Automobility was under serious threat: emissions of conventional vehicles would have to dramatic fall or electric mobility would have to be democratised. The closure of conventional production lines became a regular occurrence. The Netherlands were not as exposed to the social unrest ensuing from factory closures worldwide – in large part due to the small size of its involvement with conventional automotive manufacturing and its early move towards the new innovation avenue offered by electric mobility. The Dutch automotive sector had a head start in jumping ship from conventional cars to high-tech innovations tailored to a nascent electric mobility sector. These developments could be traced to the beginning of the century when the Netherlands had proved to be an interesting location for demonstration, and more recently for e-mobility companies to launch their European distribution and assembly, as witnessed by the implantation of ZERO Motorcycles, Nissan Motor Parts Center, and Tesla Motors European headquarters, distribution and assembly centre, but also the involvement of a much larger set of smaller companies in the connex areas of battery research, lightweight vehicle body parts, charging infrastructure, and ICT for mobility. This innovation cluster only grew bigger as the Netherlands established itself as a nation-scale lab for electric mobility.

Manufacturing. Leading automakers continued releasing a large variety of BEV models in different market segments. Following a trend established from 2010, this new market competition focussed mainly on 1) a small but lucrative market for high-end sporting vehicles with long range (300-500km) (e.g. Tesla, but soon followed by Audi, BMW, and later by other prestigious brands), 2) a larger market for compact city vehicles with a shorter range (100-200km), and 3) early steps in a potentially much larger market of middle-of-the-range family vehicles, which were initially marketed as secondary vehicles and leased to company fleets. Competition in these markets became very fierce, which contributed to driving costs down although batteries remained a significant cost. The majority of original equipment manufacturers (OEMs) became involved in the BEV market in one way or another – increasingly perceived as the most dynamic market for the future. Not being part of this innovation race was seen as an increasingly risky position for OEMs, particularly given the firm policy commitments towards full phase out of new conventional cars sales by 2030 (see below). HEVs also took up an increasing share of markets, which contributed to drive the price of batteries down. HEVs offered an intermediary solution to raise the profile of e-mobility where range anxiety still prevailed.

Users. The main market focus was set where the existing barriers to development are small or easily overcome, such as high-intensity of localised short trips (taxis, deliveries, urban car sharing, etc.), predictable mobility patterns (public transport), high ‘user willingness’ and lower cost barrier (high-performance ground-breaking vehicles, Government procurement,

etc.). The first generation of early BEV users were mostly enthusiastic motorists, affluent and urban professionals, enjoying substantial disposable income, home ownership, stable employment, and predictable journeys. However, a further proportion of society was exposed to electric driving through the use of electric company cars, notably through the full conversion of public organisation fleets to BEVs, and substantial encouragement to their suppliers. Lightweight electric vehicles (for deliveries and local tourism) also became more widespread.

The range anxiety myth associated with electric mobility was tackled through 1) the widespread rollout of conventional charging in residential, business, and public e-parking areas (in city centres but also in shopping centres, etc.), 2) early investments in fast chargers and their public demonstrations in dedicated ‘e-mobility corridors’, 3) the early diffusion of battery swapping in selected strategic locations throughout the country (seen as an emergency option), and 4) the simplicity of these services greatly enhanced by tracking and geo-location apps. This required substantial investments from local authorities (selectively starting from strategic locations), BEV manufacturers, and electricity distributors. In many cases, these entities worked in close collaboration by setting up ‘BEV clubs’ that offered e-mobility users with a range of services and advantages.

Infrastructure. Following a trend installed since 2010, the rollout of charging infrastructure grew exponentially, rapidly achieving national coverage with over 80,000 public charging points by 2017 (mainly standard). Because of the different nature of electric charging (compared to petrol charging), these figures far outweighed the 4,000 petrol stations throughout the country. This infrastructure roll-out eventually levelled off. Fast charging was developing beyond the initial ‘electric corridors’. By 2020, 5,000 fast charging stations had become operational, which required artificial support to keep running: the charging business acutely needed more customers.

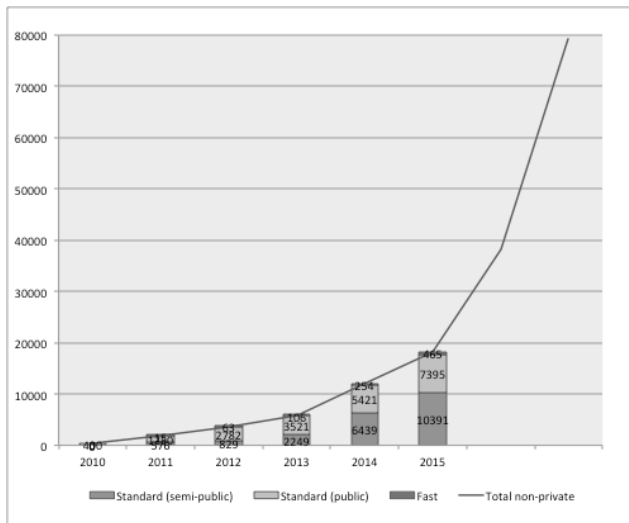


Figure 1: Growth of electric charging stations in the Netherlands (projected from 2015)¹

Nonetheless, a number of important issues remained that prevented the further diffusion of BEVs beyond the 10% market share. The main issue was cost: despite attractive advantages

¹ Data retrieved from RVO, 2016. Cijfers elektrisch vervoer tm December 2015, available at <https://bovag.nl/BovagWebsite/media/BovagMediaFiles/Cijfers/2015/Cijfers-elektrisch-vervoer-tm-december-2015.pdf?ext=.pdf>, accessed June 15 2016

and incentives, electric mobility remained a costly option not available to all. For the wide majority of users, conventional automobility remained the main option – although an increasingly costly, inconvenient, and undesirable one. Increasing numbers of users switched to plug-in hybrids.

Cultural-cognitive. BEV manufacturers developed highly educational advertising campaigns, emphasising the convenience of e-mobility, and its substantial contribution to minimising climate impacts. Stimulated by the glamorous imagery of high-performance luxury models, electric vehicles became a highly desirable object of high aspirational value.

Aware of the need to construct greater desirability and overcome range anxiety, BEV manufacturers and ‘BEV clubs’ cleverly marketed charging as a ‘package’ in combination with additional advantages such as free on-street parking, club membership, etc. Charging became highly visible in popular media, film/television, but also in public spaces. It was closely associated with high social status, elegance, constructive engagement with a greener future (proactive green consumers), and green entrepreneurship. Charging progressively became a widely understood task that, despite requiring some clever planning, was fairly benign. Product designers understood early on that charging must become a very visible task to stimulate the curiosity and desires of non-adopters, as well as elevate the pride of early adopters. Exposure to the simplicity of charging was also facilitated by widespread experience with lightweight e-mobility (e-bikes, e-scooters, etc.).

BEVs remained largely unaffordable for a wider public. Meanwhile, substantial reductions of ICE convenience and affordability were increasingly being felt, and user discontent was looming. This led to strong controversies in public opinion and a sense of victimhood, relayed by the press: “war declared on sedan”, “electric or nothing: ridding the masses of their mobility”, “green, electric, but unaffordable”. It was becoming increasingly clear that the destabilisation of conventional automobility could not be engineered in the absence of truly affordable alternatives without generating social unrest. From then on, the challenge became one of overcoming these structural issues and making dream a reality. This went hand in hand with the need to construct a vision for electric mobility that reached out beyond the elite.

Governance and policy. Supporting this initial rollout was not trivial, and costly. Early steps were a continuation of European and Dutch decarbonisation strategies, and Dutch leadership in innovation. However, from 2018, the “Taking control of our low-carbon future now” policy became an overriding priority for national and local Government alike, supported by a far-ranging portfolio of daring interventions. The main narrative combined discourses on environmental urgency, an anti-corruption purge seeking a ‘cleaner’ capitalism – in practice greater accountability and transparency of business dealings –, and national pride in leading innovation. Political determination and opportune scandals shocking public opinion were crucial in making this possible. Particular emphasis was set on low-carbon mobility and electric mobility to position the Netherlands on the leading edge of global efforts, aiming to reach 90% decarbonisation on 1990 levels by 2050 – well beyond the EC’s 60% target.

Along with an until then very gradual tightening of emission standards for conventional vehicles, BEVs had received a steadily growing set of support measures, e.g. tax exemptions, innovation tax credits and direct funding, particularly to infrastructure projects. Whilst this was generating a promising trend, there was increasing weariness from environmental activists and committed politicians that this was ‘too little, too late’.

On the ‘fossil’ side of the argument, there was an increasing distrust of car manufacturers, following a series of emissions reporting scandals, and the extent of trade deals that exposed

the extent of corruption and collusion within the industry. In 2017, amidst a rising tide of environmental and social justice protests against the endemic influence of corporate lobbyists (particularly petrol companies) in obstructing innovative efforts to decarbonise and draining immense profits and tax returns away from the Netherlands, national debates turned to the need to invent a ‘new Dutch way’, eventually leading to the “Taking control of our low-carbon future now” programme in 2018. In the mobility sector, this was translated into a direct confrontation of petrol dependence and substantial investments in electric mobility alternatives. A 12-year phase-out of petrol cars was announced (by 2030), with corresponding measures to dramatically step up the roll out of BEVs (with a little help from HEVs). The nascent Dutch BEV industry – until then on the losing side of political bargaining – was instrumental in pressing for this radical policy shift. Crucially for the success of this quite daring shift, the Dutch government had succeeded in bidding for special status within Europe as an experimental super-region for mobility transitions, which not only made substantial funding available for large-scale deployment programmes and further system innovation but also lifted regulatory constraints that enabled rapid decision-making on infrastructure. The Dutch Government invested substantially in this profitable industry, reaching majority-ownership in numerous ventures. Amsterdam, Rotterdam, and the Brabant region (South) were the initial driving poles of this innovation cluster, which eventually spread out to the entire country.

On the one hand, deliberate ICE-destabilisation interventions concentrated on a) the gradual increase of emissions standards for new vehicles (to 60gCO₂ by 2025 – literally outlawing new conventional cars), b) continued divestment from fossil fuels throughout the public sector, c) the regulation of conventional mobility with dedicated High-Occupancy and Electric Vehicle (HOEV) lanes, d) the development of a public culture that increasingly saw conventional car users as responsible for ‘destroying the future’. Various forms of compensation were trialled to curtail the anger and protest of conventional automobilists, such as monthly electric taxi allowances – in effect an income-adjusted voucher system. These measures were understood as necessary, temporary, and cost-effective in the long-run as they effectively allowed the Government to be “tough on ICE” and to further stimulate electric mobility. Aware of the potential conflicts and job losses to come, a large re-skilling campaign was initiated, targeting specific low-skilled technical jobs to offer a bright new future in the part-nationally owned industry.

On the other hand, a comprehensive portfolio of innovation and deployment support enabled a rapid scaling of electric mobility. This largely built on and improved the Norwegian model developed a few years before, but also on stepping up measures already in place since the Action Plan for electric transport 2011-2015, ‘Elektrisch Rijden in de Versnelling’. The portfolio included user measures such as tax exemptions and subsidies on new vehicles to stimulate consumption, local exemptions for parking and tolls, all-electric lanes, a nationwide procurement programme with the objective of an all-electric vehicle fleet by 2023, but also innovation support to stimulate the emergence of a leading national industry (R&D tax credits, innovation grants, re-skilling programmes to train technicians and engineers), the financing of infrastructure projects to fully deploy fast charging points, and more cross-sectoral mechanisms to encourage the exploration of integration avenues between ICT, power distribution, and other industries. Innovative new contracts were trialled to explore the feasibility of converting petrol stations into charging stations. Substantial support for conversion innovation was oriented towards developing integrated solutions such as RET and pumped storage.

5.2 2025-2035: Can electric mobility become truly democratic?

The period up until 2025 was characterised by a decade of truly impressive industry build-up with diffusion amongst a staggering 25% of households, supported by a – until then – costly and over-dimensioned charging infrastructure. The main challenge and question for the coming period was whether electric mobility would stand the trial of mass democratisation and deployment in the lesser affluent and environmentally committed sections of society. A number of other tensions emerged, in particular related to an increasing pressure on the special status that electric mobility had enjoyed in these early years.

As predicted by an expert report prepared for the Ministry of Infrastructure and the Environment (I&M) in 2022, the range of advantages offered to BEV users to support market growth could not be sustained over time, and particularly in the context of achieving the objective of phasing out petrol cars by 2030:

- Electric vehicles, despite impressive cost reductions 2010-2022 and tax exemptions, were still not affordable for lower earners. Additionally, there was a sense that fiscal advantages for BEVs could not be sustained for much longer and certainly not for a growing urban fleet.
- Electric driving was under threat of becoming less attractive as user numbers grew. This was particularly true in an urban context, where free parking had become meaningless due to the scarcity of available parking spaces.
- Improvements in battery technology and their miniaturisation was contributing to driving costs down, and offering new opportunities for frame design, yet at the same time this continuous technological change was preventing design stabilisation and standardisation.
- Electric vehicles were already putting a strain on power generation. The general assumption was that this would lead to higher demand, and predictable consumption peaks (e.g. related to night-time charging), but would also generate difficulties in terms of prediction and planning for an increasingly electric society (e.g. electrification of heating, etc.). Energy companies would need long-term visibility on demand requirements so as to better dimension their investment to match charging loads.

Techno-economic. Following a decade of impressive developments in the more affluent percentile of the population and public procurement, electric mobility faced the challenge of gearing up to a mass market. By 2025, the price of BEV vehicles was almost on a par with conventional ICE equivalent vehicles, and was considerably cheaper on an annuitized and distance-based costing: whilst vehicles themselves were more expensive, running costs made up the difference. Cheap ‘night-time charger’ electricity deals, offered by energy companies as a way to generate more predictable consumption patterns and maximise the night-time use of new installed capacity to cater for the boom in heat pumps, were also complemented by subsidised charging stations. Increasingly also, homeowners installed micro-renewable electricity technologies, and charged spare batteries whenever surplus was generated. This self-generation was seen by energy companies as a threat to the predictability of demand, as well as an uncomfortable challenge to the prevailing grid architecture. The consequence was the elaboration of stricter, more binding contracts for consumers, to ensure visibility on revenues. At any rate, for whoever could afford a BEV, running it was relatively straightforward. The BEV market continued to grow, the charging infrastructure proved very robust with fast charging reduce the length of full charge from 30 down to 7 minutes, but the idea of owning a large vehicle was becoming less attractive.

The host of measures and advantages that had enabled the success of BEVs in the first place, however, started to come under increasing pressure. Municipalities had to downscale the attribution of free parking for BEVs, replacing it instead with a point-based system with a flat rate paid by all users. Urban areas became very congested again, which meant that BEVs would have to be included in congestion charging hence losing their initial exemption. These developments contributed to reducing the attractiveness of BEVs that early adopters had enjoyed. Potential adopters initially seduced by a hassle-free motoring experience were becoming more hesitant. Of course, some privileged users (politicians, business leaders, taxi fleets) still continued to enjoy a protected status by claiming exemptions, which contributed to consolidate the image of BEVs as a class-divisive technology for the elite. Dutch BEV manufacturers, so instrumental to the deployment of BEVs nationally, but aware of these signs of saturation in urban areas, were re-orienting their strategies towards a greater influence on global markets.

At the same time, petrol had become unaffordable, due to souring relationships with oil companies, the rapid removal of subsidies, and the imposition of a carbon tax. Most ICE users restricted the amount of unnecessary driving. Trapped between high costs of BEVs, and the increasing irrelevance of owning a car, conventional car users were not tempted in renewing their vehicles – despite the toughening of emissions regulations. It became increasingly normal to drive out-dated models and risk a fine, but also to reduce car use to its bare minimum, turning to e-shopping and ride sharing where the cost of petrol could be split, walking and cycling longer distances – increasingly with the help of electric bikes and scooters.

In remote areas, where range anxiety still prevailed, HEVs still remained an option, but finding petrol was no longer as convenient as it had been in the golden age of petrol cars, and eye-wateringly expensive. Plug-in HEVs increased their battery sizes to accommodate for users increasingly generating excess renewable power at home.

Lightweight electric vehicles (LWEVs), which had enjoyed impressive market penetration since 2010, had expanded beyond early niches made up of elderly citizens and long-distance commuters. The vision was that this technology could fill the vacuum of affordable vehicles for low-income earners. The mass diffusion of LWEVs was feasible from a technical and market standpoint (they were affordable and mass-produced in Asia for nearly 2 decades now), but generated substantial challenges for policy and regulation. Most significantly, there was considerable amount of congestion on cycling lanes (where slow options were allowed, but in practice faster LWEVs were often seen riding) and increasing number of accidents conventional roads.

Infrastructure. Two major innovations supported the mass deployment of LWEVs to make up for unaffordable larger BEVs: dedicated lanes and modular design. Following the model developed for cycling lanes since the 1960s – something for which the Netherlands had been a pioneer and acquired substantial knowledge – new type of lanes was devised that would enable this medium-speed traffic to circulate safely. These lanes, successfully trialled in the Amsterdam conurbation from 2020, were well protected from conventional vehicles by bumpers, sliders and other physical barriers. With maximum speeds of 70 km/h, they allowed covering the 45km between Amsterdam and Utrecht in less than 40 minutes. LWEVs became a real alternative for commuting, one that was increasingly seen as cheap, safe, and reliable.

At the same time, manufacturers continued experimenting with modular designs. Substantial experience with tailor-made LWEVs for small businesses (deliveries, etc.) and personal vehicles had generated a number of small dedicated companies eager to take part in this booming market. Creative imagination expanded beyond e-bikes, e-mopeds and e-vans.

Companies experimented with e-tricycles and small trailers to offer LWEVs that could become real alternatives not only for single commuters, but for families, with myriad option of adding or removing (often foldable) elements according to need. LWEVs were becoming a real modular alternative to the car, which was now seen as an expensive and cumbersome good that may only be used a few times a year. Families increasingly resorted to the odd hire of a BEV for a distance vacation.

A serious issue for BEVs and LWEVs alike was the increasing scarcity of Lithium to manufacture batteries. The Dutch Government, heavily involved at the forefront of the global electric mobility revolution, had identified this problem as ‘peak Lithium’ and strongly stimulated the nanotech industry to come up with alternatives, at the same time as gradually building up impressive national reserves of Lithium for a rainy day. By 2025, carbon nanotubes battery storage had become commercially viable, and it was important to step up production capacity, and raise efficiencies in Lithium recycling. By 2035, recycling Li-Ion batteries were only used in LWEVs and BEVs were replaced by a number of different alternatives. This ‘fluid’ state of battery design was a challenge for manufacturers and generated substantial competitive tension.

Cultural-cognitive. During this period, BEVs had fully installed themselves as the mainstream of high-end driving experience, but also suffered from an increasingly toxic perception of a two-track mobility system. The democratisation of electric mobility with LWEVs was accompanied by a cultural rejection of a form of electric mobility (BEV) that still inherited a lot from its predecessor in terms of vehiculating out-dated power-relation sentiments.

LWEVs, in contrast, benefitted from much more positive connotations: they were gentle, affordable, and human-scaled. LWEVs were also decidedly and visibly more Dutch, as the quasi-entirety of supply chains were located within the country. This aspect was regularly made explicit, with strong emphasis on transparent supply chains, didactic life-cycle assessments of products, and ‘Dutch-made’ certification. Nonetheless, and in spite of long-lasting experience with cycling lanes, cycling practice, and cycling etiquette, the introduction of LWE-lanes took a little adjusting to, as it initially led to accidents and incomprehension. Manufacturers teamed up with the government to offer a compulsory but free and very practical LWE driver’s license. Simultaneously LWE-lanes were widened, to accommodate for faster and slower users without having to compromise the safety of conventional bikes or slow LWEVs (under 30km/h).

With petrol prices at a historic high, in large part due to high environmental taxes on fossil fuels and the continuation of a policy of phase out, conventional automobility became something of a nostalgic luxury – an out-dated and dirty practice that nonetheless had a certain historic value. The near-full abandonment of petrol cars fuelled discontent among remaining committed users, who had seen their convenience progressively downgraded. However, continued compensation schemes and support for alternative mobility options (e.g. electric taxis) increased acceptance. Most importantly, the narrative around the success story of Dutch electric mobility alternatives generated positive momentum, and to some extent provided a new outlet for motoring enthusiasts.

Users. Beyond mainstream models, we were now seeing the surge of highly experimental custom LWE models, built from scratch in peoples’ backyards. Motoring enthusiasts, supported by local clubs, were now engaging *en masse* with this very accessible technology. Home-grown inventors were pushing the boundaries of how various elements of LWEVs could be recombined to produce entirely new kinds of vehicles. This brand-new pastime had a very empowering and engaging feel to it as it was a very frugal kind of innovation – one

that was accessible, not increasingly costly, and involved interchangeable parts. This movement was effectively re-inventing what a vehicle looked like – fundamentally challenging taken-for-granted assumptions about vehicle design and offering much more effective alternatives. It was also tied to aspirational values associated with the environment and an ‘open-source’ kind of innovation with very little intellectual property rights. This hobbyist culture was also connected to developments in the electricity domain where a new creative space was opened up by the younger generation’s literacy in coding and enthusiasm for green and renewable energy.

Governance and policy. In this period, the ambitious policies laid out in 2015-2025 were continued with surprising commitment, which made it difficult to challenge them. The initial efforts were now bearing fruit. A national innovation culture had been installed, along with the commitment to the democratisation of BEVs, and the increasingly uncontested defiance of everything petrol. This generally positive climate made things much easier.

At the same time, the democratisation of electric vehicles was an entirely new kind of policy challenge, which was about commitment to a clear direction for innovation, and required substantial infrastructure investments to overcome deployment challenges as well as targeted incentives.

Disincentives for fossil fuels were stepped up, with a strong carbon taxation to ‘force’ a shift from conventional cars to electric vehicles. Conventional cars were restricted to a single lane on highways, and totally prevented from entering urban areas.

The range of electric mobility support measures was continued and stepped up, and a few challenging aspects for local governance had to be adjusted with care. The reallocation of free parking rights was terribly managed in the surrounding regions of Amsterdam, Rotterdam, and the Hague, leading to years of contestations against privileged parking for the elite, but Groningen and Utrecht came up with fairer systems, and invested in strategic construction of BEV garages from which users could switch to bicycles and LWEVs – electric multi-modality embracing urban spatial constraints. Most cities followed this model from 2030. Tax credits for BEVs were also gradually reduced to reflect price reductions and generate revenues for infrastructure investments.

Perhaps the most challenging policy project was the development of LWE-lanes throughout the country. This was initiated in areas identified with the largest existing pools of conventional automobilists with commuting distances under 30km, and gradually extended to achieve national coverage. Funding for such infrastructure was generated from the recycling of revenues from the carbon tax and road taxes, but also involved funding by local authorities, and entrepreneurs who were benefiting from strategically positioning their charging points. The standardisation of batteries also remained an open question, which would need to be resolved in order to further drive prices down and step up the export of the Dutch electric mobility model globally. A standardisation commission was set up in 2034 to initiate talks with most industry actors, local authorities, R&D labs, as well as representatives of LWEV clubs, with the aim to deliver a universal modular battery standard by 2036, as well as offer even easier ways for private off-grid electricity storage.

5.3 2035-2050: Looking back: what a journey!

By 2035, it was clear that the present was electric. Looking back to the development of BEVs and LWEVs was very impressive. By 2050, electric mobility had produced something barely recognisable from the conventional cars of 2015. New design features had generated completely new kinds of artefacts centred on high-performance BEVs and modular LWEVs with all sorts of add-ons.

Users. BEVs had become the standard vehicle for long journeys, but LWEVs were preferred for shorter journeys (up to 50km) involving urban centres. Though BEVs had become affordable, they were still much more expensive than LWEVs, less practical as a daily option, and increasingly BEVs were only hired on demand. This was facilitated with tremendous improvements in self-driving technology, which enabled the unmanned delivery of BEVs (and LWEVs) at point of use, when needed. This meant that individuals had adapted to the tailoring of vehicle to the specific needs of a specific journey – sometimes changing vehicles even over the course of a day.

HEVs remained used to some extent in remote areas, exceptionally long journeys, and in hiring schemes for cross-border travel (e.g. vacation rental). Conventional cars became virtually extinct.

Techno-economic. The electrification of the car had been pioneered by a number of Dutch, Norwegian and North American companies, who were benefitting from expanding markets globally. LWEVs, a Dutch invention, was proving extremely successful in all sorts of applications worldwide, opening up a massive market for exports.

Most innovation in this period concerned further standardisation of batteries around the modular add-up design, and the improvement of business models for all-integrated electric mobility.

Cultural-cognitive. User acceptance was no longer an issue. Electric mobility was firmly established as the new societal norm, showing no more demographic disparities between, for instance, urban and rural users or different age groups. ICEs were regarded as immoral relicts of the past. Early innovators of LWE models, who had originally emerged from hobbyist cultures, went “mainstream” - both in a cultural and economic sense - with LWEs conquering new, global markets.

Governance and Policy. Policy measures that were hitherto regarded as ‘radical’ became accepted across the political spectrum and soon went unquestioned. Even the somewhat contested policy project of LWE infrastructure proved a success, with the initially uncertain funding scheme based on revenues from carbon and road taxes becoming a blueprint for other countries.

The ‘cleaner and greener’ variety of capitalism that had developed in the Netherlands had become an exemplary case of overturning nationalist sentiment into a collective project for betterment through innovation. It had become a model to be followed.

6 Scenario 2 (Pathway B1): Public transport

6.1 2015-2030: Who needs to own a car?

This period saw a rapid reduction in privately owned petrol cars (halving from 2015 levels by 2030), which were replaced by carsharing and public transport. Whilst the development of carsharing was largely due to the emergence of market opportunities and new models of consumption, the decline of the ICE and the further rise of public transport use were the outcome of deliberate planning at both national and local levels of Government.

Cultural-cognitive. Increasing awareness of climatic problems and air pollution fuelled a democratic movement to step up efforts to dramatically reduce emissions from transport. There was an increasing distrust of car manufacturers, following a series of emissions reporting scandals, and trade deals that exposed the extent of corruption and collusion within the industry. In 2017, amidst a rising tide of environmental and social justice protests against the endemic influence of corporate lobbyists (particularly petrol companies) in obstructing innovative efforts to decarbonise and draining immense profits and tax returns away from the Netherlands, national debates turned to the need to invent a ‘new Dutch way’, eventually leading to the “Taking control of our low-carbon future now” programme in 2018. In the mobility sector, this was translated into a direct confrontation of petrol dependence and substantial investments in public transport. A 12-year phase-out of petrol cars (by 2030) was announced, and corresponding measures taken to roll out public transport. This movement, threatening to bring the Government down, led to the development of a deliberate petrol phase-out policy from 2018.

Techno-economic. Conventional ICE cars were experiencing increasing pressure, in large part due to their poor environmental performance, and deliberate petrol phase-out policy from 2018. Rising emissions standards for new cars, tough anti-congestion zoning, and prohibitive petrol taxes meant that new ICE vehicles became increasingly costly and there were now clear signals that they would start to become unaffordable in the foreseeable future. Automobility was under serious threat: emissions of conventional vehicles would have to dramatically fall or alternatives would have to be sought.

Whilst the global automobile industry was gradually improving emission standards for new vehicles, the Netherlands went for a deliberate transition strategy oriented towards drastically reducing car dependence. This strategy rested on aggressively discouraging private car ownership and use – apart from a few key strategic areas such as commercial distribution and other public services – supporting a massive shift to public transport. Early moves towards electric mobility were abandoned for lack of an appropriate funding mechanism. From 2020, it became prohibitively expensive to privately own a car, and increasingly inconvenient, as the number of parking spaces were reduced, their cost increased, and lanes available for single occupancy vehicles restricted.

Users. Following an emerging trend, the younger generation with less disposable income as well as urban professionals with shifting priorities quite naturally did not engage with private car ownership, and welcomed the rapid development of alternatives. On the other end of the spectrum, dedicated motorists were resistive of the ‘war on automobility’, and organised themselves to ring-fence a number of activities (sales, construction, school runs, etc.) and situations (disability, old age, large families) from automotive disincentives. This drive to claim special status opened the door to lot of excesses that the Government had difficulties curtailng.

Governance and Policy. However, a good half of motorists were more amenable to being convinced by the Government’s ‘offers’ to support conversion: attractive rates for vehicle

recycling, free car club memberships and allocated kms, support to car-pooling company fleets with home pick-up services, and attractive rates on public transport. By 2025, the number of cars in circulation had shrunk by a third of its 2015 levels, and so had the average usage rate. New sales of low-emission vehicles replaced a shrinking number of vehicles. Following this dramatic decline, the closure of conventional production lines became a regular occurrence. Fortunately, the Netherlands were not as exposed to the social unrest ensuing from factory closures as other places around the globe – in large part due to the small size of its involvement with conventional automobile manufacturing and to the conversion opportunities that were opened in public transport.

Infrastructure. Strategies were devised to further raise the profile and use of public transport. Public transport in the Netherlands had been thoroughly developed throughout the twentieth century and beyond, leaving a far-reaching and efficient infrastructure. Given the existence of an extensive train network for medium and long distances and of metros, trams and busses for shorter and more local trips, the main challenges to grow markets consisted in encouraging customers, extending coverage, and maximising the use of existing infrastructure.

For long-distance travel, the gradual rise in train use experienced since 2003 was accelerated. Thanks to clever marketing and pricing strategies, particularly oriented at converting motorists, train users grew rapidly. Despite a gradual opening to new entrants since 1999, the railway industry managed to coordinate its strategy, harmonising prices and working together by targeting of different mobility patterns in a rapidly expanding sector. The market was characterised by a collaboration and complementarity rather than cut-throat competition. It was enabled by regulatory oversight, which also provided clear strategic objectives for expansion, and the clear overriding objective of winning away former motorists. In fact, the ‘switch over now’ advertising campaign was built around making savings explicit for any journey. The ‘journeysaver’ app, allowing to calculate savings and purchase tickets in real-time reached 10 million downloads by 2022, and led to a substantial increase in daily ticket sales. The rail market expansion was so successful that the challenge was to maintain an acceptable level of service, with increasingly congested trains at peak hours. In the short run, this was solved by increasing the number of trains, doubling the number of buses including for long journeys, and altering pricing to further encourage off-peak travel. The main train company Nederlandse Spoorwegen (NS) invested in a large fleet of buses, which were freely chartered to cover emergency peaks putting extra strain on the network. In collaboration with ‘journeysaver’, public transport users were punctually offered voluntary compensation for not travelling on their preferred train in times of intense traffic. But in order to continue expansion, something more structural would have to be implemented. Plans for new track investments, literally doubling tracks in high-intensity were devised for the long term, and talks were initiated to seek support for more flexible employment options throughout the country to further diversify mobility patterns.

For more local transportation, trams, metros and slow modes prevailed in urban areas, and buses covered longer local distances and less dense areas. This regional system was already strongly integrated by 2020, with joint ticketing, coordinated strategic expansion, and ICT-supported timetabling and real-time information. These local public transport options were boosted mainly by car-destabilising measures, which comparatively raised their attractiveness. As the lanes available for single-occupancy vehicles were drastically reduced, bus journeys became up to twice as fast as car journey, and more than three times cheaper – winning over a large proportion of the population. A critical aspect concerned integration with cycling and other light-weight vehicles, particularly to win over automobilists discouraged by the loss of autonomy and the often large distance from and to public transport.

Business models. In the short term, carsharing and low-emission taxis proved an unlikely ally. Carsharing and car clubs offered an alternative to traditional automobile vehicle ownership, which supported a shift from mobility consumption based on material ownership to mobility as a service: private mobility on demand. Generalising from 2010, individuals could hire a vehicle from a range of fleet operators offering short-term access membership-based schemes. This form of mobility rapidly became a growing alternative to conventional car ownership, significantly enabled by innovations in ICT, community logistics of online platforms, new services and organisational models. Carsharing offered a transitional option to weather the discontent of car users who clung on to the notion of freedom and personal mobility. It also enabled to attend to the initial shortcomings of a public transport network that did not immediately reach out to the most remote areas of the territory, and for timetable gaps. Following the introduction of new High-Occupancy Vehicle lanes throughout the country, picking up passengers on commuter routes became an established practice, enabling more predictable journey times than on the increasingly sluggish Single-Occupancy Vehicle lanes. Furthermore, short-term vehicles for hire became increasingly integrated with public transport, as initiated by NS to boost train use in more remote areas. Building upon the model set out by Uber and similar services, it became possible to hire pooled vehicles not only in real time, but also in advance and for a predictable fixed cost. Multi-modal transport had become more convenient than the car, even in less dense areas. Interestingly, the success of carsharing and other fleets also contributed to a decline in average emissions from automobility. Indeed, car sharing allowed the emergence of new criteria for vehicle purchase, such as fuel economy and durability, as well as corporate image. Carsharing operators in practice offered lower emission vehicles and renewed their fleets much more rapidly than private motorists. This multi-modal kind of carsharing was also competing with cycling and cycle-for-hire schemes at major public transport stations.

The major successes in reducing car use in the Netherlands were due to an early move towards radical new forms of mobility, involving a shift away from private ownership (supported by the emergence of carsharing) and the development of a robust, efficient and far-reaching public transport system with numerous options for multi-modality.

6.2 2030-2050: Winning over the last sitting automobilists

Users. After a dramatic decline of private car ownership, supported by increasingly convenient and far-reaching multi-modality, and aggressively dissuasive policies, the number of motorists stabilised at ca. 3 million. This figure was in large part made up of those ring-fenced classes of individuals, who benefited from less stringent rules, and hard-core automobilists who would not easily be convinced to switch to low-carbon options. Despite the continued implementation of phase-out strategies, it proved very difficult to cut back automobility any further. The last standing car-committed households represented around a third of the population – mostly special-permit holders. As the Ministry of Infrastructure and Environment tried to cut back on permit holders, motoring clubs supported their members in their legal recourses to appeal status changes. By 2040, the number of registered cars had only diminished slightly. The only way to avoid this confrontation and win over motoring fans was to allow these special statuses to remain untouched and instead push for higher emission standards. The global boom of Plug-in Hybrid Electric cars (2020-2040) had not yet taken ground in the Netherlands because of the country's aggressive road policies, and favouring of alternative transportation modes. However, it now provided an alternative for the last standing private motorists. In exchange for the maintaining of special permits, motorists were forced to convert from petrol to HEVs. By 2045, only 100,000 petrol cars remained in the country – largely collectible models displayed on rare occasions.

Infrastructure. The convenience and reliability of public transportation was improved along a number of priority objectives following from the previous period: infrastructure investment, a society-wide agenda promoting flexible and local lifestyles, and further multi-modal and -modular integration.

Plans for new track investments, initiated in 2028, sought the doubling of railway tracks in high-intensity corridors linking major cities (Amsterdam, The Hague, Rotterdam, Utrecht, and Groningen), but also in and around regional commuter towns, where population movements had concentrated. The new lines, coming on stream from 2035, greatly relieved the railways and absorbed most of the traffic. Critically, innovation in noise reduction enabled the generalisation of high-speed train around major axes without generating resistance, which meant superior convenience of rail over any other mobility means in an age where time had become the most valued commodity. Indeed, the Dutch society had gradually moved towards a socio-economic model that embraced the benefits of automation, social justice, and vibrant consumer markets by seeking full employment, the harmonisation of wages, and a generalised reduction of working hours to free up more leisure time.

Governance and Policy. Having initiated talks to seek support for more flexible employment options throughout the country to further diversify mobility patterns in 2027, the railway industry managed to gather the support of bus operators, carsharing and taxi fleet operators, but more importantly had the listening ear of central Government. The proposals picked up ideas developed in Scandinavia that linked time management and non-work time to higher levels of satisfaction and overall economic productivity, and translated them into an agenda that would enable spreading out journeys over time and space. For public transport, this provided opportunities to completely restructure the scheduling of work, leisure, and other activities impacting mobility patterns. By 2032, a national strategy for a ‘freetime society’ had taken shape, setting out a legal framework institutionalising shorter working hours and greater flexibility in the personal management of these reduced working hours. This provided greater clarity for public transport planning, and enabled effectively more malleable and diversified commuting patterns: by 2035, the taken-for-granted two daily peaks that had shaped mobility patterns for centuries were unrecognisable – to a large extent shaved and spread out over the day. Furthermore, ‘journeysaver’ had acquired a central role in enabling adaptive timetabling and journey pricing to support this shift.

The continued rise of public transportation went hand in hand with a data- and ICT-driven process of logistical optimisation. The continued collecting of massive volumes of passenger information enabled the provision of adaptive services in real-time, the dimensioning of infrastructure investments in the longer run, the coupling of multiple modes of transportation, and the planning of housing developments.

7 Scenario 3 (Pathway B2): Slow modes

7.1 2015-2030: The rapid substitution of the petrol car

This period was characterised by strong environmental pressure paving the way for a staggeringly rapid decline of petrol cars, largely replaced by hybrid cars, and an expansion of public transport.

Cultural-cognitive. Increasing awareness of climatic problems and air pollution, exacerbated by severe floods in 2017 that further exposed the vulnerability of large parts of the Netherlands, fuelled a democratic movement to dramatically reduce emissions from transport. Despite an increasing distrust of car manufacturers, following a series of emissions reporting scandals, and revelations about the extent of corruption and collusion within the industry, the Ministry for Infrastructure and the Environment was convinced that working with manufacturers was a better solution than a direct confrontation.

Governance and Policy. Building on recent success with BEVs and HEVs in car fleets and private cars, the Government decided to initiate a nation-wide substitution policy. Proactive politicians resisted lobbying pressure for leniency. The example of CFC substitution and the more recent light-bulb phase-out were recurrently mobilised to make the case for change. It was argued that under such strong support for environmental improvement and in the presence of a technical alternative – even at a price premium – there was a political and legal mandate for a drastic substitution policy. Discussions were initiated around the feasibility of a full substitution to BEVs, but lagging manufacturers managed to drown discussions and argue for HEVs as a much cheaper, yet still effective option to achieve targets. The nascent BEV industry, arguing from their recently established Nissan Motor Parts Center and Tesla Motors European headquarters, furiously rejected the proposals that they saw as undermining their frontrunner advantage and potentially draining them from crucial infrastructure development support. This campaigning was in vain. The Dutch Prime Minister announced a 12-year substitution of petrol cars (by 2030) by HEVs. This policy relied on three main components: 1) drastic regulation banning the sale of new petrol cars by 2020, with priority to the lowest emission vehicles, 2) financial compensation for switching over based on a vehicle recycling payment and continued tax credits for HEVs, and 3) financial incentives to support the conversion of HEVs into Plug-In Hybrids and for battery range extensions. The nascent Dutch battery and charging industry was instrumental in pressing for this radical policy shift. Crucially for the success of this quite daring shift, the Dutch government had succeeded in bidding for special status within Europe as an experimental super-region for rapid HEV support, which not only made substantial funding available for this large-scale deployment programme and further system innovation but also lifted regulatory constraints that enabled rapid decision-making on infrastructure and recycling options. The Dutch Government was strongly committed in this scheme, and oversaw the instalment of production lines from all major global OEMs, which generated further support in a time where the South of the Netherlands (Brabant and Limburg) was in dire need for a reinvigoration of industrial employment. By 2020, no new petrol-only cars were registered in the Netherlands, by 2025, 85% of the remaining car stock had been replaced or fitted with add-on batteries, and by 2030 virtually all but a handful of collectible cars (ca. 100,000) were effectively Plug-In Hybrids.

Infrastructure. At the same time, local strategies to reduce the need for travel were initiated in cities, reinvigorating and extending the geographical scope of the movement to free up urban cores that had led to car-free centres since the 1960s. Starting with Amsterdam, Utrecht, Eindhoven and Delft, various schemes were put in place to trial possibilities for the extension of pedestrian and cycling zones and corridors. This was strongly supported by ‘super-local’ –

a radical grassroots sustainability movement that had become popular especially amongst younger people, but was backed also by proactive mayors. It advocated for a society based on increasingly local activities that tended towards self-sufficiency and full decarbonisation. In mobility terms, this meant the eradication of the car, and reducing the need to travel altogether. The management principles focussed on the possibility to experiment with new forms of production and consumption that sought to retain added value locally and invest in self-sustaining communities. This movement saw opportunities for experimentation with fundamentally new and carbon-free lifestyles, the re-invigoration of declining areas on urban fringes, their connection to large cities through corridors. In sympathy with this movement, the national Government decided to support some experimental actions for ‘super-local mobility’ in specific areas, by granting further devolution of powers to local Government in experimental locations, investing in the conversion of roads for innovative cycling infrastructure, and strengthening connection with public transport infrastructure.

All municipalities over 100,000 inhabitants (but also smaller towns) were implementing zero emission zones, freeing up the streets in a shift toward ‘reclaiming the city’. Since cars (increasingly Hybrids) were still used for long-distance travel, the removal of inner-town parking space had to be compensated by parking *ex muris*. Local transport (deliveries, taxis, etc.) was largely replaced by cycles and tricycles, supported by crafty innovation in modular trailers and other increments. Beyond obvious environmental and wellbeing benefits, it reclaiming streets from car traffic was seen as opening up an untapped potential for re-invigorating local commerce, small-scale manufacturing, and community activities. This reclaiming extended beyond cities and towns, in a move to physically re-connect neighbouring communities via infrastructure. Following a strategy that had proved successful in nature conservation projects, reclaiming efforts focussed on reconnecting areas by designing slow mobility corridors and revitalising them by encouraging the development of local and sustainable activities.

This experiment had an influence on large mobility infrastructure. By 2022, the declining number of motorists freed up space on highways. It was important for the decarbonisation agenda that motoring trends would not be inverted even if these had been Plug-in Hybrids with lower emissions. The Ministry of Infrastructure and the Environment approved a proposal for the partial re-appropriation of roads for ‘cycling super-highways’ in order to stimulate high-speed cycling and e-cycling. Following large-scale experiments led by the universities of Eindhoven and Delft, a multiple lanes road design model was selected, focussing on safety and speed. In 2025, construction started around and between major conurbations, aiming for nationwide coverage by 2035.

Users. In parallel, national strategies were devised to further raise the profile and use of public transport, mainly as a preparatory step to enable further decarbonisation of mobility in the future. Public transport in the Netherlands had been thoroughly developed throughout the twentieth century and beyond, leaving a far-reaching and efficient infrastructure. Given the existence of an extensive train network for medium and long distances and of metros, trams and busses for shorter and more local trips, the main challenges to grow markets lay in encouraging customers, extending coverage, and making fullest use of existing infrastructure. For long-distance travel, the gradual rise in train use experienced since 2003 was accelerated. Thanks to clever marketing and pricing strategies, particularly oriented at converting motorists, train users grew rapidly. Despite a gradual opening to new entrants since 1999, the railway industry managed to coordinate its strategy, harmonising prices and working together by targeting different mobility patterns in a rapidly expanding sector. The market was characterised by a collaboration and complementarity rather than cut-throat competition. It was enabled by regulatory oversight, which also provided clear strategic objectives for

expansion and for winning over former motorists. A ‘switch over now’ advertising campaign was built around making savings explicit for any journey. The ‘journeysaver’ app, allowing to calculate savings and purchase tickets in real-time reached 3 million downloads by 2022, and led to a substantial increase in daily ticket sales. For more local journeys, trams, metros and slow modes prevailed in urban areas, and buses covered less dense areas. This regional system was already strongly integrated by 2020, with joint ticketing, coordinated strategic expansion, and ICT-supported timetabling and real-time information. Public transportation had increased substantially by 2030. A critical aspect concerned integration with cycling and other light-weight vehicles, particularly in denser areas.

7.2 2030-2050: No more long trips, we can get by locally

After the successful implementation, uptake, and diffusion of policy measures in the previous periods, mobility between 2030 and 2050 was shaped, most notably, by developments within the spatial planning domain as well as by ideological changes and new value systems within society. These focused especially on a strong revaluation of ‘the local’ and coincided with a downright boom of health awareness. The latter was linked to the government’s proactive – if not aggressive – fight against obesity, which had reached alarming levels across the country. People choosing to walk or cycle was one side-effect.

Cultural-economic. By 2030, petrol cars were had virtually been eradicated. Automobility had receded from all cities and towns over 100,000 inhabitants, due to the implementation of the zero emission zones. Plug-In Hybrids were still numerous and commonplace, but restricted to inter-city travel on increasingly fewer lanes on highways, and to local transport in more remote areas. The reclaiming of streets and roads, starting from urban areas, sprawled in a gradual but steady pattern, first to corridors extending and linking urban areas together, then to fringe areas. This was fundamentally transforming the landscape in a highly organic way. Observers started comparing this new continuous Dutch landscape to the high-density rural areas of South East Asia at the beginning of the century: highly visible activity on the street, a blurring of the distinction of private and public space as streets and roads became extensions of private homes and dwellings, vibrant use of this communal space for work and leisure. In mobility terms, cycling and walking were predominant – and indeed the congestion of cycling lanes and their punctual overflow was at time overwhelming. This was a highly localised society, but also a very affluent one, where time and productive activity seemed to have taken on another meaning. Telecommunications and the relaxing of physical presence requirements at work was crucial for this shift towards a more decentralised society happen.

This spatial development oriented towards localism was in stark contrast with what happened beyond those village- and city-regions. The dream of the local economy was unfolding; yet, it was riddled with contradictions. While the Dutch agri-food and energy systems were tending towards self-sufficiency (e.g. with a massive deployment of decentralised renewable energy, and a less energy-intensive society as a whole), people were still heavily reliant on the circulation of goods and people from other regions and beyond. This required maintaining a certain minimum of automotive transportation means for Hybrid vehicles, preserved in dedicated corridors connecting city-regions. Logistical dispatch centres were constructed at the periphery of city-regions, adjoining such corridors. These dispatch centres served to manage the inflow of people and goods from interregional travel, from where transport would be taken up by a variety of non-motorised vehicles of all shapes and sizes. Conversely, those dwellers absolutely reliant on motorised transport would cycle to their nearest dispatch centres to pick up their hybrid car with which they could reach locations less disserved by public transport. Whilst this was very efficient for the transport and dispatch of goods, it never really became a viable alternative for more predictable journeys such as commuting.

Infrastructure. Significant improvements in public transport, particularly rail transport over long distances serviced the bulk of personal mobility needs for journeys beyond 20kms. Large city-regions had developed large networks of tramlines from 2025. They differed from the tramlines seen in the twentieth century in that there was an extensive but not very dense coverage, i.e. there were many stations but the distance between them was long. This meant that for most rail transport (conventional and light), people needed to travel from and to stations, which happened increasingly by foot and bicycle (with an expansion of cycle parking and in-train cycle space), and for less able individuals by electric or non-motorised light-weight vehicles such as tricycles and tuk-tuk-type taxis.

However, as the trend towards sustainable localism installed itself even further as dominant social and economic principle, the need to travel long distances diminished altogether. Cycling and walking became the main means of mobility, as the population lived, worked, and played at a very local level, or – where necessary – through remote practices enabled by telecommunications. Long-distance rail travel receded in importance, and was mainly used for leisure and cultural activities.

Cultural-cognitive. The transition to slow modes had been supported by a deep cultural shift towards sustainable localism which had fundamentally altered urbanisation patterns and the way the Dutch population lived. This had been supported by the recognition of the need for more gentle mobility technologies and strong reliance on non-motorised travel by walking and cycling. The government had been highly instrumental in supporting this shift by investing in large infrastructure experiments, which were so successful that they became the dominant model for organising space, community and living patterns.

Conclusions

We here make a few concluding comments about future-oriented transitions pathways storylines.

Challenging pathways. The scenarios, informed primarily by modelling work in conjunction with preliminary outputs from socio-technical analysis, are constrained by very ambitious objectives. As a consequence, the transition efforts required are very substantial for all three pathways considered in terms of the speed, scale, and scope of change in individual practices and socio-technical configurations. Most striking is how rapidly the destabilisation of the petrol car has to be set in motion for these pathways to materialise. The emergence of alternatives is perhaps less challenging in the Dutch context, as there is already a relatively favourable environment for low-carbon mobility transitions at present. Nonetheless, the breakthrough of specific alternatives, while currently ‘possible’, requires significant work and to realise. Pathway B2 presents challenges not so much in terms of the speed of change, but the scope and depth of change for a society to become almost entirely reliant on slow modes (and hence much shorter distances travelled) for virtually all personal mobility requirements.

Our scenarios, because they are constrained by ambitious sustainability objectives, demand extremely challenging transition pathways – in particular, a dramatic destabilisation of ICE in all three pathways – with varying speeds and intensities. We see that with strong commitment and a certain degree of forcefulness, the right strategies and investment, as well as with necessary behaviour changes and societal trends, these pathways *are* possible. Naturally, some luck is needed also - in the sense of, for instance, investing in the right thing at the right time and place. Policymakers, in particular, play an important role in recognising and accelerating the momentum of relevant niche innovations and to overcome lock-ins – in particular ICE. Simultaneously, however, policymakers are reliant also on other actor groups and civil society for the legitimisation of action or the break-up of specific resistances. Strict policies can only be introduced successfully with the right backing and actor coalitions in place.

Forcing through socio-political dimensions. Realising these transitions pathways, shifting away from prevailing trends and in many cases fundamentally reverting them, requires a fair amount of ‘forcing’. This can be done via a number of strategies (including relying on external shocks and dramatic events, or futuristic high-technology assumptions), but we have here relied on socio-political agency. So, our storylines – for all pathways – rely on a fair amount of public pressure for environmental issues (conveyed by social movements) and consistent and deliberate policymaking strategies to support path-breaking innovation and reduce commitment to established regimes. The value of this is to highlight the role of governance in bringing about and making sense of change (as opposed to purely techno-economic rationales), but these assumptions are nonetheless very strong and may not be feasible, as in practice socio-political swings tend to be rare. In all pathways, the deliberate destabilisation of the ICE and support for alternatives appears necessary – something that we are currently not (yet) seeing in practice. In all pathways, political pressure for environmental improvement was important. In pathway A, an important underlying narrative concerns the emergence of a national emancipatory discourse around an e-mobility innovation culture in contrast to a sense of deceit with a global conventional automobile industry. In pathway B1, a particular emphasis was set on confrontation with the global conventional automobility industry, seen as obstructive to a process of environmental improvement and untrustworthy. In pathway B2, a grassroots movement favouring hyper-localism, developing enabling

innovations, practices and land use models, and new forms of collaboration is a crucial driving force of change.

It is important to note that in all pathways, we have assumed that there is no major additional issue shifting attention away from that focus on decarbonisation, and that pressure for environmental change builds up over time. This is a strong assumption, as there is no assurance that interest in environmental questions would not wear over time during this century.

The role of deliberate strategies. The storylines further highlight the importance of decision-making at different levels and by different factions of society (government, industry, users, etc.), most effectively in alliances. In all pathways, specific measures are set out to deliberately destabilise the conventional car industry and users, whilst more positive measures are intended to support specific alternative mobility modes. In both Pathways B, experimentation – often at local level – plays an important role, where local coalitions of activists and policymakers become aligned to jointly deliver on community and policy goals, and eventually address the environmental challenges linked to mobility. Whichever deliberate strategy pursued, they require strong societal support or political mandates in order to be implemented. In some instances, specific governance strategies need to be crafted to alleviate resistance, such as in the case of ‘special status’ concessions for a fraction of automobilists in pathway A, or attractive rates for carsharing and public transport to support ‘modal conversions’ of specific users in pathway B1.

Instruments and interventions. In order to realise transition objectives, besides the need for consistent and legitimate strategies discussed above, a number of governance instruments and interventions are required. These can correspond to ‘traditional’ policy instruments such as financial (dis)incentives and regulations, but also more creative interventions, e.g. phase-out (from light-bulbs and CFCs) or ‘corridors’ as a planning method to support continuous localism (borrowed from biodiversity and wildlife management). At any rate, two aspects come to the fore when attempting to complement modelling strategies with governance considerations: 1) interventions are required well beyond the ‘blanket’ macro-instruments considered by modellers (e.g. carbon tax), and 2) no single instrument is sufficient, and instead what is needed is policy instrument mixes within specific areas and a substantial degree of integration across policy areas (e.g. energy policy, land use and infrastructure planning, innovation support, industrial stimulus, consumer incentives).

Twists, turns, and developmental patterns. Despite the importance of deliberate strategies to make big visionary change happen, we also found that a more imaginative reflexion on multiple innovation trajectories was useful to overcome potential paradoxes. For instance, the branching of electric mobility into a high-end trajectory (aligned with current technological assumptions about BEVs) and an additional trajectory (LWEVs, characterised by greater affordability and versatility) was useful to highlight potential issues related to the inconvenience of automobile congestion and ownership, the mass production of BEVs, and the important share of slow modes in the Netherlands. In another vein, the central role of the ‘journeysaver’ app in pathway B1, in conjunction with a relaxing of commuting patterns due to social and labour policies, lead to significantly improved position for railway planning that underscore the success. Of course, such hypothetical anecdotes are not meant to be accurate predictions, but to sensitise about the interactions between infrastructure dimensioning and user patterns, and the positive role that ICT can play in supporting major system adjustments.

Stepping-stones, transitional innovation and re-combinations. The role of intermediate or transitional innovations has been particularly important in these scenarios – whether the role of hybrids in Pathway A, the role of carsharing in Pathway B1 or the role of public transport

and carsharing in Pathway B2. Sometimes, they may be seen as stepping-stones as in the case of hybrids that allow further electrification of mobility but in a more gradual, tempered way. In other instances, they may be seen as buffers, as was partly the case for carsharing that allowed a more gradual phase out of the automobile. In other cases, specific innovations support the re-combination of technologies such as BEVs and a culture of slow modes to produce LWEVs as an option for the mass diffusion of electric mobility. In yet other instances, we see innovation dead-ends, such as the near-abandonment of public transport in Pathway B2 as hyper-localism virtually eliminates the need for long-distance travel.

Methodological issues. This exercise entails some methodological issues, which we briefly want to reflect upon. Quantitative models, like the ones we used as basis for our analysis here, often neglect important (socio-technical) developments related to, for example, different actor groups and their interactions; policies; beliefs, decisions, struggles and conflicts; or lock-ins. Moreover, they lack a degree of imagination and hence do not show how prospective pathways may unfold. These shortcomings were our main motivation for this exercise of developing qualitative socio-technical scenarios. In performing this exercise, we were constrained by the model outputs as a guide to conform to. However, the models do provide us with alternative views of futures that might be possible – for us to further elaborate. This is a formative exercise that can shed light on specific tensions and incoherencies, enables us to look at potential and conditional hurdles, and go beyond a simple distinction between ‘now’ and, say, 2050 by offering a number of hypothetical branching points to focus our socio-technical narratives. Importantly, however, the stories we tell are speculative and must not be taken literally. Rather, they provide socio-technical texture to future pathways and so offer further opportunities to evaluate transitions challenges within reasonable expectations.

Multiple time horizons and branching points. Starting from model projections enables narrative storytelling to focus on significant prospective events that appear necessary to break the mould of established trends, ‘bending their curves’ so to speak. In practice, these have been taken to be inflection points and the crossing of significant thresholds. They have informed the temporal bounding of storylines in two or three time periods, each characterised by a few dominant techno-economic developments to be explained by socio-technical change processes. This exercise enables us to look at potential and conditional hurdles beyond the distinction of ‘now’ and ‘2050’ (or target year), e.g. in the case of the (initial lack of) democratisation of BEVs. Section 4 was crucial in allowing us to identify the main challenges to be expected. For instance, a number of specific bottlenecks cannot be overlooked when thinking about the future of personal land-based mobility, including the need for deliberate destabilisation of conventional mobility, the need to overcome cultural reticence in the case of BEVs (in Pathway A), and the need for substantial infrastructure investments (e.g. for charging in the case of BEVs in Pathway A, for public transport in Pathway B1, for cycling lanes in Pathway B2).

From an analytical standpoint, much more can be said about earlier periods, and uncertainties significantly increase the further we move away from the present. That being said, the importance of rapidly shifting away from conventional automobility in all pathways (which is a significant departure from current trends) further underlines the importance and urgency of strong policy priority shifts in the immediate future. What we have seen in our models and scenarios is that – irrespective of the specific pathway – the next five years already are absolutely fundamental for ‘bending the curve’ in the right direction for a future of low-carbon mobility. This is further underscored by the likelihood of resistance from established actors with vested interests in the current configuration.

Technology choice. Another interesting aspect with these pathways is the extent to which the portfolio of innovations that has effectively been mobilised is much narrower than the initial selection we started with, particularly in D2.1. Interestingly, different pathways (A, B1, B2) foreground different technologies, and hence highlight the ensuing choice. This also points to the inherent paradox in innovation policy between 1) supporting variety (and so increase the chance to uncover more optimal, fitting, or desirable alternatives) and 2) making deliberate technological choices and hence accelerate the process towards standardisation and mainstreaming. Pathway A illustrates a strong early prioritisation of an electric mobility choice, excluding other mobility alternatives, while pathways B1 and B2 have a greater tendency for nurturing and supporting a plurality of alternatives.