THE ROLE OF ELECTRIFICATION IN THE URBAN ENVIRONMENT IN A 1.5° C SCENARIO

REFORM GROUP MEETING 2019

17 OCTOBER 2019

NAVIGANT

DISCLAIMER

Notice Regarding Presentation

This presentation was prepared by Navigant Consulting, Inc. (Navigant) for informational purposes only. Navigant makes no claim to any government data and other data obtained from public sources found in this publication (whether or not the owners of such data are noted in this publication).

Navigant does not make any express or implied warranty or representation concerning the information contained in this presentation, or as to merchantability or fitness for a particular purpose or function. This presentation is incomplete without reference to, and should be viewed in conjunction with the oral briefing provided by Navigant. No part of it may be circulated, quoted, or reproduced for distribution without prior written approval from Navigant.

NAVIGANT COMPANY OVERVIEW

NAVIGANT AT A GLANCE

NAVIGANT AT A GLANCE

TOTAL REVENUES:
2018 $743M

SERVED CLIENTS IN 37 COUNTRIES (2018)

AWARDS AND ACCOLADES

=10 CONSECUTIVE PERFECT SCORES ON THE HUMAN RIGHTS CAMPAIGN FOUNDATION'S CORPORATE EQUALITY INDEX (CEI)

2019 VAULT AWARDS BEST CONSULTING FIRM FOR:
#10 Energy Consulting
#12 Healthcare Consulting
#20 Financial Consulting

AMERICA'S BEST EMPLOYERS 2018, 2017 & 2016
TOP 250 MID-SIZE FIRMS – FORBES

CLIENTS THREE KEY BUSINESS SEGMENTS

- HEALTHCARE 58%
- ENERGY 21%
- FINANCIAL SERVICES ADVISORY AND COMPLIANCE 21%

PEOPLE
5,950 EMPLOYEES
1,400 EXPERT CONSULTANTS
3,300 TECHNOLOGY, DATA, AND PROCESS PROFESSIONALS

SIGNIFICANT CLIENT RELATIONSHIPS**

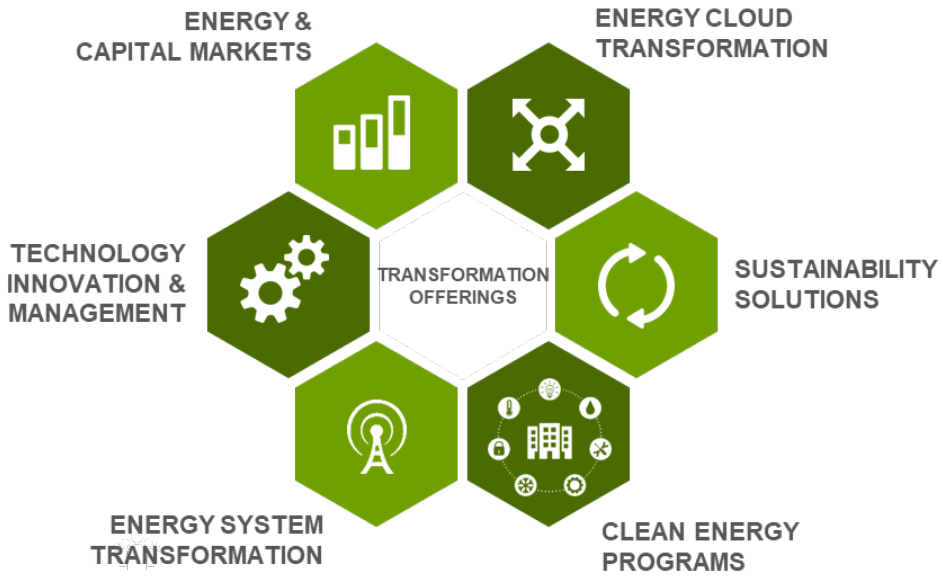
5+ YEARS = 67%

92%

92% OF OUR LARGEST 100 CLIENTS WERE REPEAT CUSTOMERS IN 2018

* EBITDA is earnings from continuing operations before interest, taxes, depreciation, and amortization. Adjusted EBITDA excludes the impact of severance expense and other operating costs (benefit).
** Revenues over $500K in 2018

WHAT WE OFFER



- ✓ Industry's largest energy management consulting team
- ✓ Consultants average 15v years of experience
- ✓ 60% have an advanced degree
- ✓ Among Top 10 in Vault's 2017 Best Consulting Firms for Energy
- ✓ Named "Best Advisory – Renewable Energy" in 9th and 10th Annual Environmental Finance and Carbon Finance Market Surveys

WHO WE WORK WITH

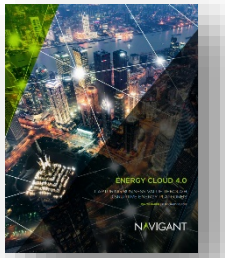
Ministerie van Infrastructuur en Milieu · UK Power Networks · enel x · Schneider Electric · TAQATI · Shell · dewa · GE · ENGIE · DUKE ENERGY · STEDIN · BMW · LA DWP Los Angeles Department of Water & Power · TenneT · MRDH METROPOOLREGIO ROTTERDAM DEN HAAG · SAMSUNG · Gemeente Utrecht · Madison · RWE · alliander · Bundesministerium für Wirtschaft und Energie · Cu European Copper Institute · Danfoss · EDF

About Navigant

With over 600 consultants, Navigant's global Energy practice is the largest energy and sustainability consulting team in the industry. We collaborate with utilities and energy companies, government and NGOs, large corporations, product manufacturers, tech vendors, and investors to help them thrive in a rapidly changing energy environment. Our clients include the world's 60 largest electric, water, and gas utilities; the 20 largest independent power generators; and the 20 largest gas distribution and pipeline companies. Navigant's seasoned professionals and highly skilled specialists form exceptional teams to help clients transform their businesses, manage complexity and accelerate operational performance, meet compliance requirements, and transform organizations and systems to address upcoming changes as the energy transition accelerates.

SUMMARY OF NAVIGANT THOUGHT LEADERSHIP

1

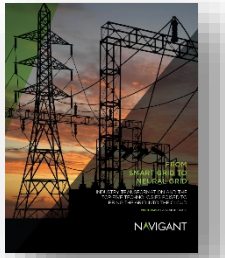


Navigant
Energy Cloud 4.0

The Energy Cloud is Navigant's description for our future energy system that will support two-way energy flows in which customer choice (optionality), clean energy, innovation, and agility command a premium.

Navigant's white paper, Energy Cloud 4.0: Capturing Value through Disruptive Energy Platforms, is the next instalment in Navigant's Energy Cloud series. The paper examines the impacts of an Energy Cloud future, profiles the emergence of dynamic, high-growth platforms, and finally, provides a framework for capturing value.

2



Navigant
From Smart Grid to Neural Grid

Today, the smart grid implies the legacy mechanical T&D networks enhanced by pockets of automation, connectivity, and centralized IT systems. The Neural Grid implies a vastly more powerful platform of hard and soft assets leveraging ubiquitous connectivity, the cloud, robotics, AI, edge computing, and pervasive sensing to perform energy and non-energy applications.

The paper identifies the critical components of this Neural Grid ecosystem, describes the conditions necessary for accelerated market expansion, and finally, identifies the top five growth markets that stand to benefit from this Neural Grid transformation.

3

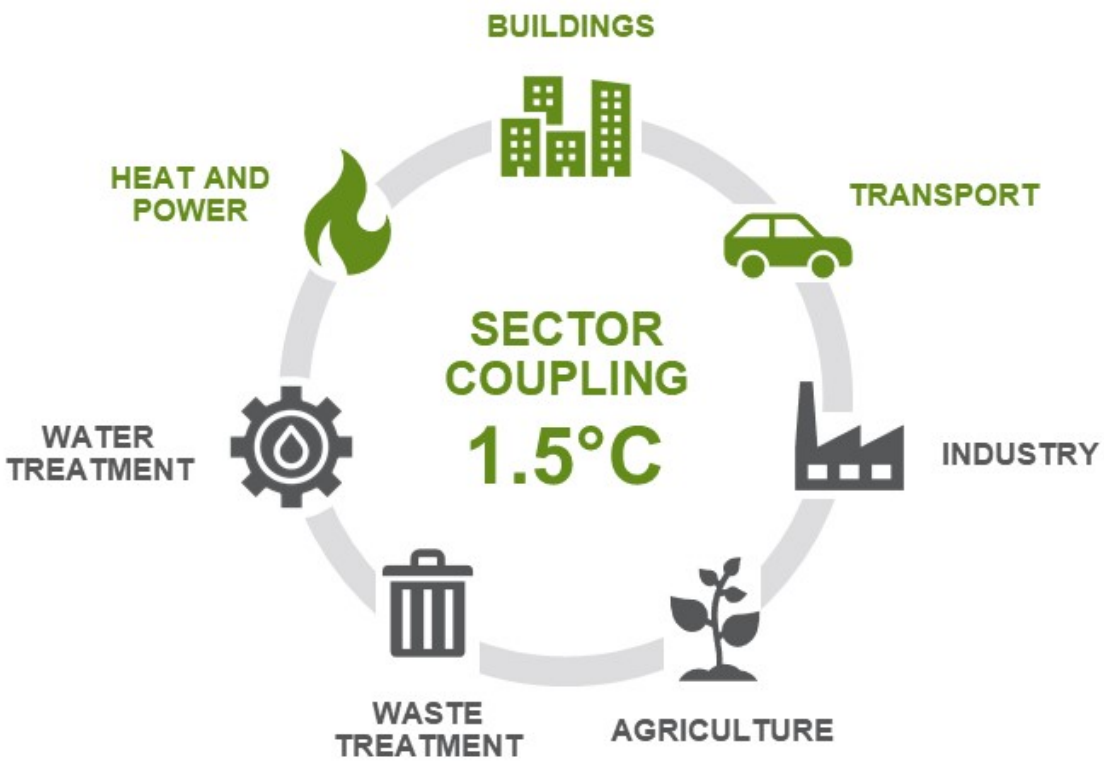
Navigant
Navigating the Urban Energy Transformation

The importance of cities to the development of a sustainable, global economy that can address the need to increase prosperity, address climate change, and ensure the well-being of all populations is widely recognized. Key to the advancing these ambitions is the future energy landscape of cities and communities.

This paper looks at the critical elements of the emerging city energy landscape – including the spread of distributed renewable energy, building energy programs, and the rethinking of city transportation – outlining the opportunities and challenges that digital technologies and the new platforms and business models offer to diverse stakeholders in the future urban energy market.

ABOUT THIS PROJECT

- Most advanced urban action plans aim at a 2°C pathway
- Recent science indicates cities should strive for a 1.5 °C pathway
- Lack of understanding for what the 1.5°C track would mean
- Navigant quantified technology uptake on a 1.5°C pathway
- High-level recommendations for cities leadership



EXAMPLE CITIES INCLUDED IN THIS STUDY

Selection criteria

- ✓ C40 member
- ✓ Port city
- ✓ Pilot city within EV 30@30 campaign
- ✓ Strategies for decarbonisation

London

New York

Rotterdam

Shanghai

IMPORTANCE OF CITIES – AGENTS OF CHANGE FOR CLIMATE ACTION

Urbanization

- 55% of world population living in urban areas
- Increase to 70% expected by 2050

Force for good

- Majority of GDP generated in urban areas
- Catalyst for upward social mobility
- Innovation hub

Challenges

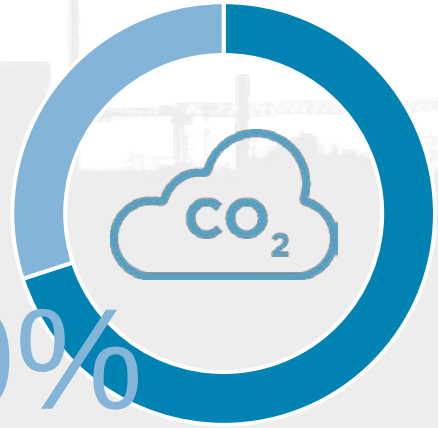
- Reduction in GHG emissions
- Reduction in air pollution

City Leadership

- Shift in power to where economic growth and welfare are created
- Mayors more powerful

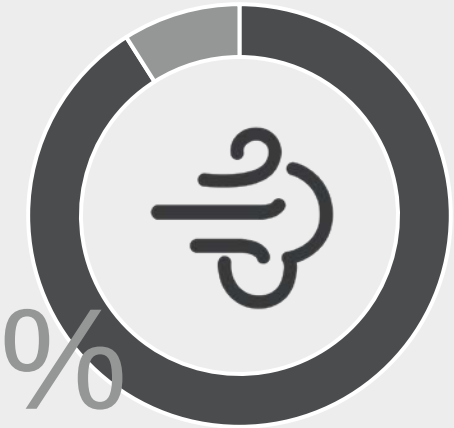
3%

Land mass



70%

CO_2 emissions



91%

Population in polluted air

NAVIGANT

DEVELOPING 1.5°C PATHWAYS

NAVIGANT

APPROACH – THERE ARE VARIOUS WAYS TO GET TO THE END GOAL OF 1.5°C

Define Indicators

Per sector, based on insights from Navigant's sector experts and data availability.

Create a pathway per indicator

Adjust and refine the various IEA pathways using input from the IPCC 1.5°C report to create indicator-specific pathways.

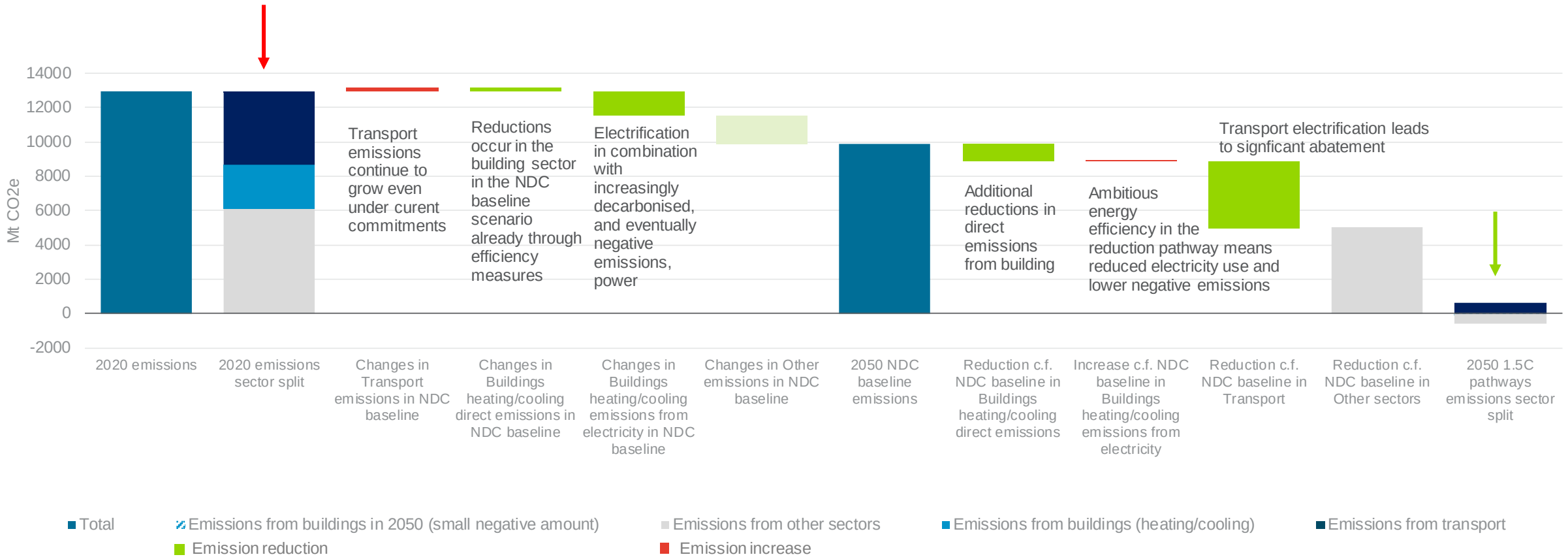
Downscale pathways to city level

Downscale the indicator pathways to city level for the selected cities up to 2050, using historical data and city targets.

Based on our expertise, we see the reasonable 1.5°C scenarios are those which:

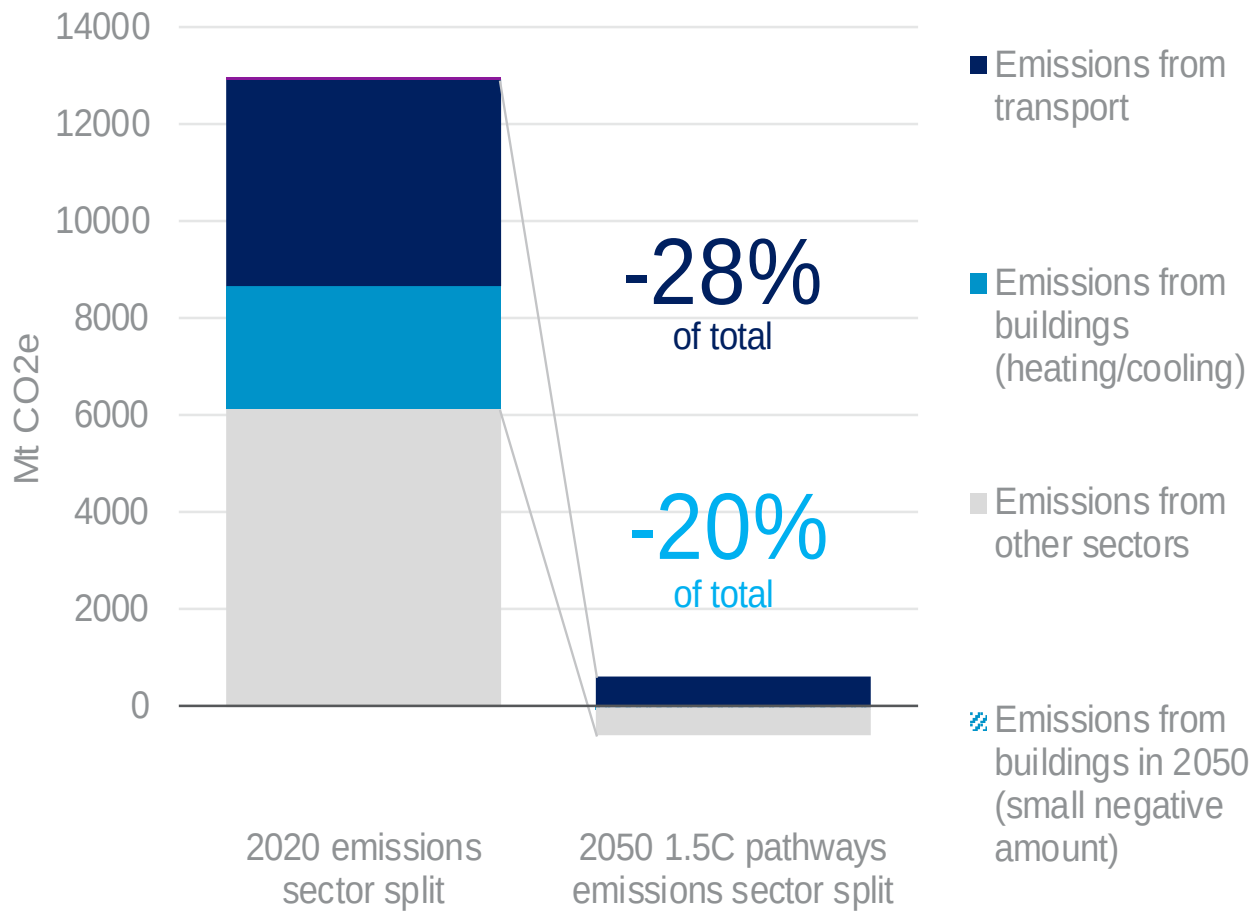
- Aim for 1.5°C or 1.5°C low overshoot warming by 2100
- Do not rely heavily on Bioenergy with Carbon Capture and Storage (BECCS)
- Do not rely heavily on afforestation

OUTCOMES



NAVIGANT

OUTCOMES



NAVIGANT

KEY INDICATORS TO DESCRIBE THE 1.5°C WORLD

	TRANSPORT	BUILDINGS	POWER
Quantitative Indicators	• Number of electric private passenger vehicles registered in the city • Number of electric busses registered in the city • Number of electric trucks for last mile and commercial delivery (< 15t) • Number of public charging stations in the city	• Final energy consumption of electricity for space heating • Final energy consumption of electricity for space cooling • Number of heat pumps for heating and cooling	• Energy produced by renewable energy technologies for the city's electricity consumption • Total kWh of battery storage required to optimise the use of renewable energy
Qualitative assessment	• Electric ships and shore side electricity		• Flexible demand • Energy and thermal storage

BUILDINGS

NAVIGANT

HIGHLY ENERGY EFFICIENT BUILDINGS CREATE BENEFITS AT THREE LEVELS

- Reduction in CO_2 emissions through reduced energy use (both heating and cooling)
- Decarbonisation of energy supply through electrification

➢ **Energy efficient buildings account for 20% of total emissions reduction**

- Reduction in energy system investments: 60GW capacity, €89-153 billion of CAPEX reduction in 2050
- Reduction of urban heat island effect (by 3°C-4°C)
- Reduction of air pollution

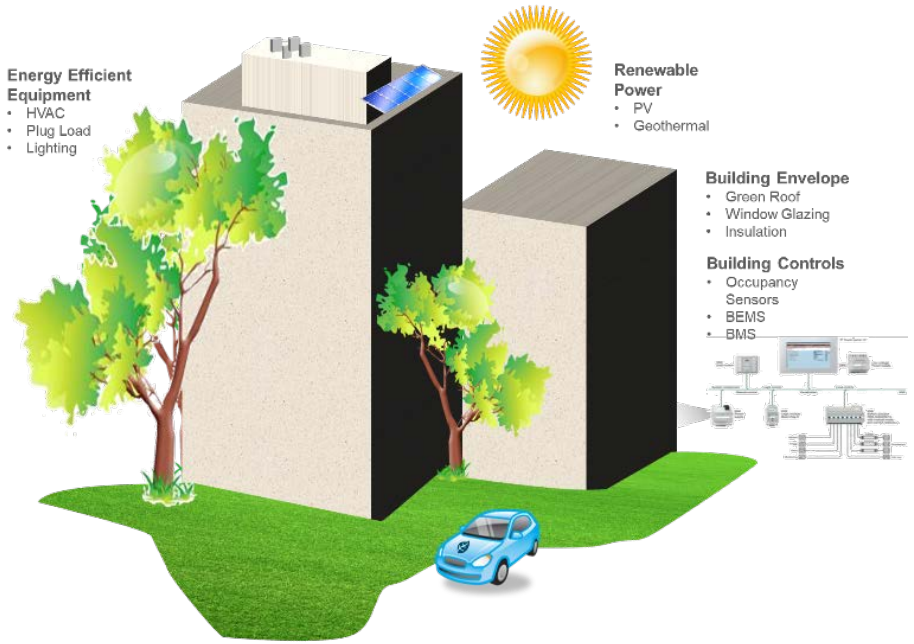
➢**Energy efficient buildings free up capital to decarbonize transport**

- Improvement of indoor air quality and thermal comfort

➢**Energy efficient buildings improve health.**

CREATING HIGHLY ENERGY EFFICIENT BUILDINGS

50% Building Envelope & Shading



50% Technical Building Systems & Renewable Energy

- **Energy efficiency first**
  - Climate change is about cumulated GHG emissions
  - Negawatt trumps Megawatt
  - Demand reduction enables electrification with heat pumps
- **Renovate as deep as you can**
  - Step-by-step, seize quick wins first
  - Very deep renovation to (nearly) zero energy building level
  - 1.5°C means going to technical limits
- **Boost energy renovation rates**
  - 50%-60% reductions of urban buildings' energy use needed
  - Tailored district-by-district approach based on building stock, ownership, heat sources, infrastructure

➢ **Monumental challenge!**

RECOMMENDATIONS FOR CITY LEADERSHIP

Act now

- Only small carbon budget left to stay within 1.5°
- Moving early lowers costs, avoids damages, enhances attractiveness and leaves you in control
- Start with quick wins that do not compromise next steps

Lead by example

- City leadership decisions directly cover ~50% of savings potential
- Use own assets to set an example and inspire
- Forge alliances and orchestrate the urban energy transition

Ambitious and actionable plan

- Rely on Science Based Targets
- Design and enforce mandatory building codes
- Continuous improvement through feedback and monitoring
- Engage in PPPs to standardize, industrialize and implement solutions at scale
- Connect short-term benefits to long term goals

TRANSPORT

NAVIGANT

ELECTRIFICATION OF URBAN TRANSPORT CREATES BENEFITS AT THREE LEVELS

- Reduction in CO_2 emissions through reduced energy use (30% increase in well-to-wheel efficiency for EVs)
- Decarbonisation of energy supply through electrification

➢ **Electrification of transport accounts for 28% of total emissions reduction**

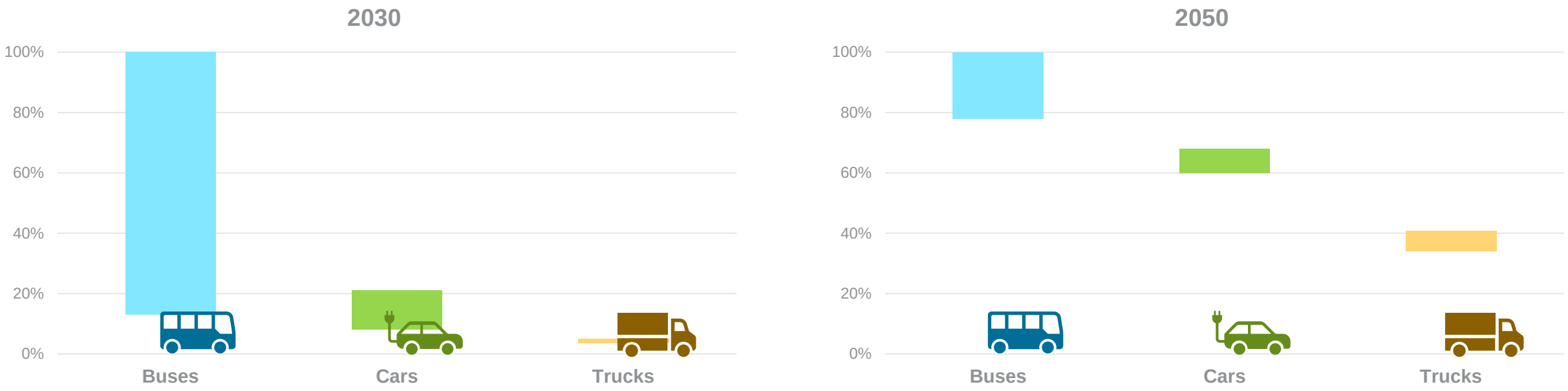
- Reduction of air pollution
- NO_x reduction of up to 90% per passenger kilometer by 2050
- Reduction of noise pollution

➢ **Electrification of transport improves livability of cities**

- Reduction of Total Cost of Ownership of ~10% (€1250/year) for car owners

➢ **Electrified transport saves money**

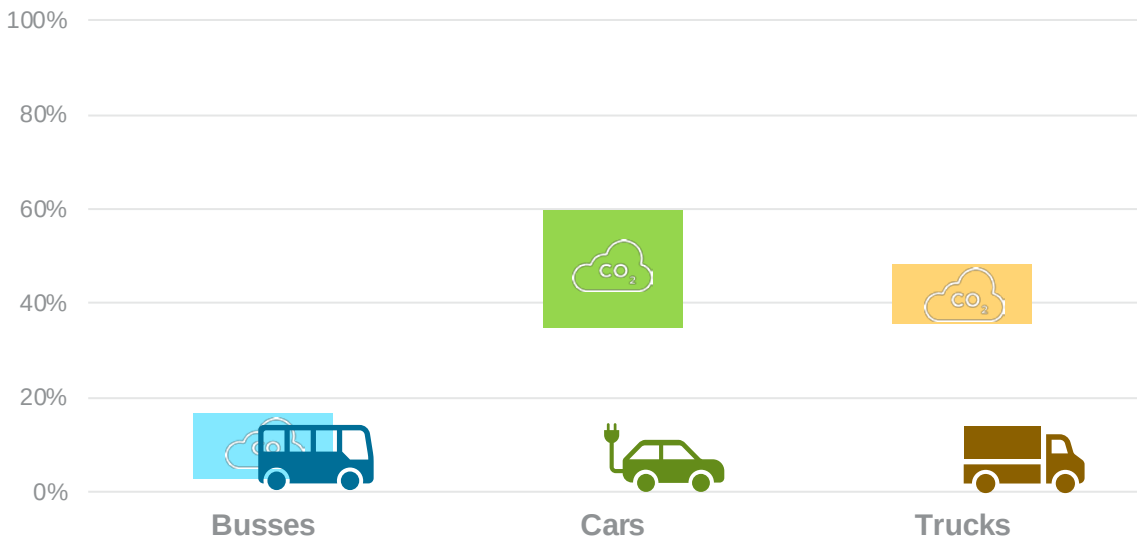
ELECTRIFICATION LEVELS FOR DIFFERENT TRANSPORT MODES



Estimated range of electrification for different modes of urban transport in 2030 and 2050 for the example cities.

NAVIGANT

ELECTRIFICATION LEVELS FOR DIFFERENT TRANSPORT MODES



Estimated relative range of contribution to CO_2 reduction for different modes of urban transport in a 1.5°C pathway scenario for the example cities.

- **Cars can contribute most significantly**
  - Uncertainties around carsharing, ridesharing, and autonomous vehicles
- **Substantial infrastructure investments are required**
  - EVs will be the single largest addition of energy demand
  - The total charging energy demand could reach 280 billion kWh by 2030 in EU, USA and China
  - Smart charging reduces the need for grid expansion to 2030 by 40% to 50%
  - An estimated US$ 47 billion of investment is required for 42 million chargers until 2030 in EU, USA and China
- **Electrification of shipping is lagging**
  - Two application areas for electrification: power trains and the shore-side electricity
  - Power trains only for domestic shipping

➢ **Challenging but feasible!**

RECOMMENDATIONS FOR CITY LEADERSHIP

Orchestrate

- Information sharing
- Transparent planning
- Facilitation of concurrent infrastructure build-out

Create clear, actionable plans

- Develop a holistic strategy that recognizes impact of societal changes on mobility
- Connect long-term climate goals with short-term air pollution and congestion management benefits
- Celebrate success

Enable an environment that promotes flexibility and adaptability in electrifying transport

- Create platforms for collaboration and procurement
- Recognize the utilize the value technology leaders and knowledge partners can bring
- Create incentives that can kickstart the transition (e.g. preferred parking, congestion charge, environmental zones)
- Invest in stakeholder management

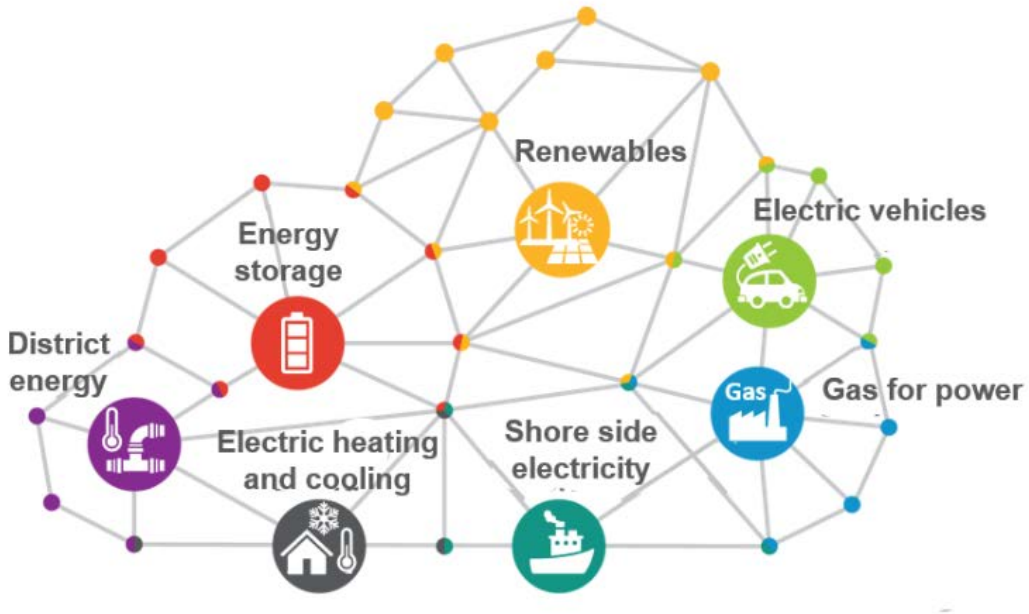
SECTOR COUPLING

NAVIGANT

SECTOR COUPLING

- **Most cost-effective 1.5° path requires cross-sector integration**
  - Connection between electricity, heat and fuel reduces investments in generation capacities and energy infrastructure
- **Storage and system flexibility**
  - Storage capacity and system flexibility are needed at different time scales and require different technologies
  - Flexible end-use facilitates renewables integration
- **Example: District Heating Systems**
  - Operated in different modes, depending on renewable energy availability, to cost-effectively provide sustainable heat.

➢ **Cities are well-suited for sector coupling – high density and diversity of energy infrastructures, loads and demands**



Interconnected urban energy system: the Urban Energy Cloud

NAVIGANT

FLEXIBILITY OPTIONS

	Short-Term Flexibility	Medium-Term Flexibility	Large-Term Flexibility
Challenge	• Short-term variability of demand and RES • **Timescale:** Fractions of a second to minutes	• Daily fluctuation of demand and RES • **Timescale:** Hours	• Over or undersupply • **Timescale:** Days to weeks
Technology Solution	• Battery storage • Flywheels • Flexible demand from EVs and heat pumps	• Battery storage • Flexible demand from EVs and heat pumps	• Long-term storage (pumped-hydro, compressed-air) • Power-to-heat with thermal storage • Power-to-gas

CASE STUDIES

- LONDON
- NEW YORK
- ROTTERDAM
- SHANGHAI

NAVIGANT

NAVIGANT

ROTTERDAM@1.5

In 2016 Metropole Region, Rotterdam, The Hague, aimed to transition into a fully sustainable economy by 2050.

What does it mean for the Greater Rotterdam Area in terms of technological change?

Navigant translated IEA and IPCC projections, focusing on key solutions: electrification of transport, energy efficient buildings, transformation of the power sector and coupling sectors to an optimised system.

Population

GREENHOUSE GAS EMISSIONS

[$MtCO_{2e}$]

	Today	2050
City	7	~0

*Assuming similar reduction pathways in other sectors

Energy efficiency, a larger share of renewable energy, sector coupling and affordability are prerequisites for GHG reduction and to be in line with a 1.5°C scenario.

1.2 ~0

- Urban logistics and mobility is fully fossil free by using hydrogen and electricity
- Zero emissions for all new buses in 2025

0.9 ~0

- Large scale energy efficiency retrofitting for existing buildings
- District heating and electrification of supply

Net-zero is required for both transport and buildings to be in line with 1.5°C

- Transformation to decentralised renewable energy
- Share of renewable energy will increase 3-fold
- Linking sectors makes transition affordable

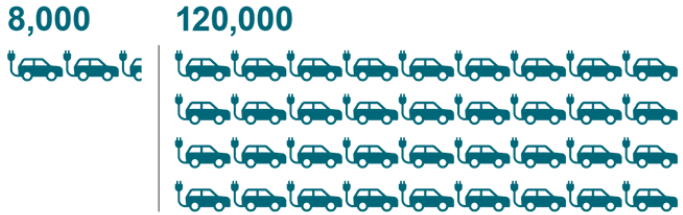
NAVIGANT

TRANSPORT ELECTRIFIES

Rotterdam's population will witness a massive uptake of battery electric vehicles.

Mobility cost will decrease due to lower fuel costs and shared use.

NO. OF BATTERY ELECTRIC CARS



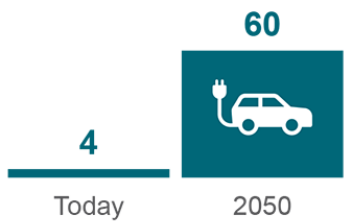
NO. OF BATTERY ELECTRIC BUSES

A 15-fold increase of electric vehicles will be complemented by modal shift and high vehicle efficiency.

A fleet of zero carbon cars and buses will significantly contribute to better quality of air and life.

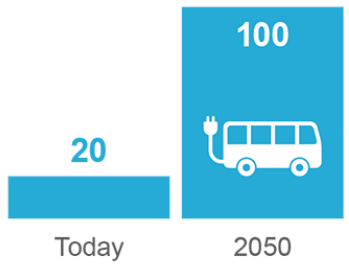
SHARE OF BATTERY ELECTRIC CARS

% of fleet



SHARE OF BATTERY ELECTRIC BUSES

% of fleet



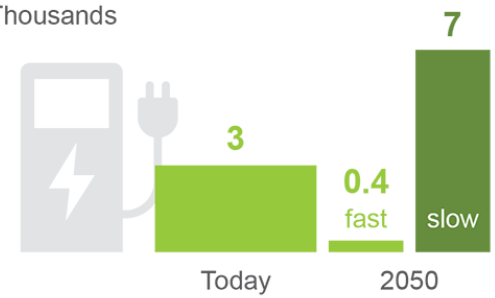
In 2030 a level of saturation for slow chargers will be reached.

Trend to fast charging at mobility hubs with access to medium voltage to limit impacts on the grid.

Charging at home and at work will still play a significant role.

NO. OF PUBLIC CHARGERS

Thousands



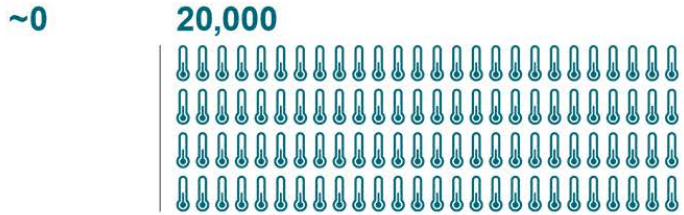
Share of transport in total GHG reduction till 2050

BUILDINGS GO GREEN

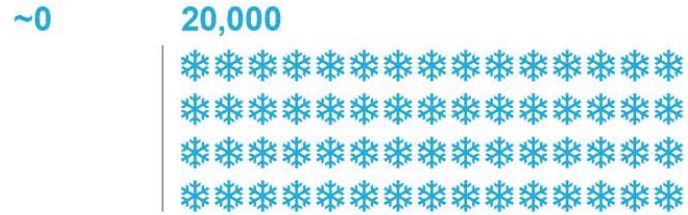
Fossil gas boilers and electric radiators are phased out on the heat market.

Much more efficient buildings catalyze the massive uptake of high efficient electric heat pumps till 2050.

NO. OF HEAT PUMPS
For space heating



NO. OF HEAT PUMPS
For space cooling

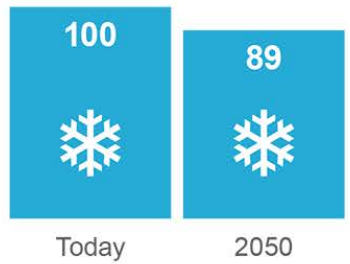


Smart, reversible heat pumps and building controls will help shift loads and improve occupant comfort and health.

Energy efficient HVAC systems and nearly-zero energy buildings are key towards sustainable heating and cooling.

SHARE OF ELECTRICITY
%, for heating

SHARE OF ELECTRICITY
%, for cooling



District heating develops into a key pillar of decarbonised heat for Rotterdam.

Large heat pumps running on renewable electricity will be crucial.

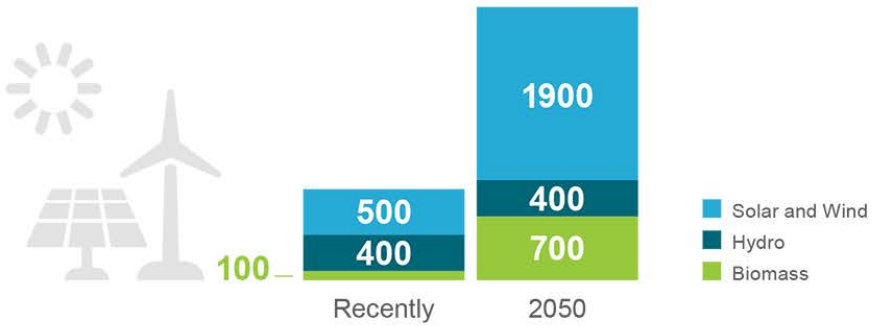
LARGE HEAT PUMPS
MW (electric), for district heating

Share of heating & cooling in total GHG reduction till 2050

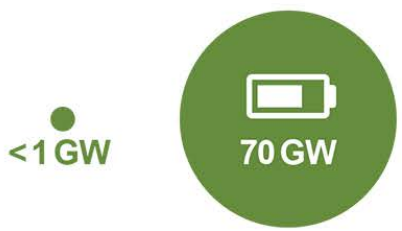
NAVIGANT

SECTOR COUPLING

RENEWABLE ELECTRICITY GENERATION (EU)



Annual **renewable electricity**: increases 3-fold until 2050.
Share of **solar and wind** increases to 60% in total power.
Battery capacity supports solar & wind, > 100-fold increase:



FLEXIBLE LOADS

Rotterdam will provide system flexibility through flexible loads:

- 10 MW of installed capacity of heat pumps connected with thermal storage
- 120.000 electric vehicles: plugged in at home/ work, will respond to the needs of the power system.

CLEAN AIR@1.5

FULL POWER. ZERO EMISSIONS.

Heerema Marine Contractors is willing to go to the ambitious end of Paris Agreement with a plan to build the biggest shore power connection in the offshore industry. A shore power connection of approximately 20 MW is required to fully electrify the vessels of Heerema Marine Contractors in the Calandkanaal.

An Ambitious Shore power project in Calandkanaal, Port of Rotterdam.

- Nearly all emissions – CO_{2e}, NO_x, SO_x and PM – will be eliminated by Heerema in the channel by completion of the project.

Rotterdam inhabitants will be unburdened by annual air pollution of:

CONCLUSIONS AND RECOMMENDATIONS

NAVIGANT

CONCLUSIONS AND RECOMMENDATIONS

The challenge is huge – start acting now	Set up ambitious and actionable master planning that is sufficiently embedded backed regulation and supported by civil society to transcend political cycles
Demonstrate leadership	Move early to have advantages in terms of lower costs, avoided damage and being in control. Use your own assets to set examples and communicate to motivate citizens and industry
Don’t go it alone – It is a team effort	All but the largest cities lack the expertise and budget to create and execute a climate action plan. Aim for PPPs with industry and knowledge partners
Prepare the infrastructure	Infrastructures energy, data communication, transport have a long life time. Leverage natural trigger points (modernization, maintenance) to make them ready for a 1.5°C pathway.
Rigorously pursue deep renovation	30 years left to achieve zero GHG emissions from buildings; this means an annual 3.3% linear decrease, far more than what’s achieved now. Seizing of quick wins at scale needed.

CONTACTS

MARCEL VOLKERTS, PHD
Associate Director
+ 31 (0) 6 29119963
Marcel.Volkerts@navigant.com
Location: Utrecht, Netherlands

NAVIGANT