Towards a carbon-free urban energy system in 2050

TU Delft’s urban-energy research agenda

Challenges ahead and expertise available at TU Delft

A research agenda in cooperation with AMS Institute and The Green Village
The Dutch government aims for a 49% reduction in greenhouse gas emissions in 2030 (compared to 1990). During the current government term, each year 30,000-50,000 existing homes need to be converted to make them gas-free, and the market should be ready to make 200,000 houses per year sustainable beyond 2021. The large-scale energy transition of the urban energy system faces multiple challenges, which calls for the active involvement of house owners and stakeholders across many sectors.

In this leaflet, we present the major research challenges that need to be addressed to achieve the energy transition. In nearly all faculties of TU Delft relevant research of high quality is being carried out, from in-depth technical research via integrated approaches connecting all expertise to assessment methods needed for decision making. The social innovation aspect is part of the research portfolio as well.

The research challenges are categorised along six intertwined themes, covering the building, neighbourhood, district and city scales, and involving multiple disciplines. Examples of ongoing projects at TU Delft demonstrate our track record in this research field.
We need:
- New buildings that go beyond energy neutrality, consider circularity, and are comfortable and healthy.
- Existing buildings that are equipped with affordable future-proof solutions enabling connection to (centralised) sustainable energy supply.

Research challenges
- Buildings designed for the local climate, providing thermal, visual and acoustical comfort (bioclimatic design)
- High-performance materials and components taking into account embodied energy and circular use
- Technologies for feasible renovation solutions that enable sustainable energy supply and a fast renovation process
- New approaches for assessing and integrating the ambitions in different aspects of the energy transition

Examples of TU Delft projects

Prêt-à-Loger: house with a skin
This project developed an ambitious renovation solution for a very common type of house in the Netherlands: the post-war row house. By putting an extra layer over the existing house, it becomes energy neutral and more space is added, while its living quality remains untouched. The project was executed by team consisting of 53 TU Delft students from all corners of the world, and won top honours at the Solar Decathlon Europe 2014. See: PretaLoger.eu

Smart Urban Isle
This project explores the possibilities of neighbourhoods to become ‘Smart Urban Isles’: areas – possibly around a public building – where energy is generated, exchanged and stored to locally balance supply and demand as much as possible. Research also focusses on finding an optimum between building renovation and collective neighbourhood energy solutions. TU Delft provides expertise on bioclimatic design for existing buildings and smart energy networks at the neighbourhood scale. Nine case studies are developed, two of which are in the Netherlands (Haarlem and Amsterdam). See: SmartUrbanIsle.eu
Theme 2: Fast transition of the existing building stock

Delivering 200,000 high-performance renovations per year

We need:
• Building owners commissioning the renovation of their buildings themselves.
• A construction sector that has the capacity (in size and quality) to deliver renovations on a large scale.
• Affordable renovations.
• Guaranteed performance of renovation solutions in terms of energy, comfort and operations.

Research challenges
• Nudging and incentivising building owners to create demand
• Building process innovation: industrialisation and standardisation
• Continuous monitoring of building performance
• Evidence-based policies to incentivise innovations
• Development and supply of innovative business and financing models

Examples of TU Delft projects

Green and Convenience
The Green and Convenience (Groen en Gemak) project investigates if residents can be encouraged to think ‘greener’ in and around their houses by reducing (psychological) barriers. For example, by offering combined attic insulation and attic cleaning. In this project, TU Delft researchers with a background in environmental psychology work in a technical environment, applying quantitative research methods.

Progress and performance in the social housing sector
This ongoing research collaboration with Aedes and the Dutch social housing associations gives detailed insight into the characteristics of 2.3 million dwellings and their occupants. Renovation measures taken and their impact on the energy use are analysed, showing the challenges involved in realising high performance and comfort and in dealing with the variations in occupants’ behaviour.
Theme 3: Thermal urban energy systems

Deliver heat, in the right place, at the right time and at the right temperature

We need:
• Technology in place to deliver heat efficiently to all parties in the urban environment.
• Reliable and predictable thermal heating systems, enabled by robust business models.
• Integrated solutions connecting distributed and centralised sources, and on-demand storage facilities.

Research challenges
• Better predictions of geothermal source and storage performance
• Development of high-efficiency, low-noise and low-cost heat pumps
• Governance of heat and electricity infrastructure, such as underground management and optimisation
• Balancing heat demand and supply over the year
• Integration of renewable sources of different scales into district heating networks

Examples of TU Delft projects

Energy piles
Energy piles are building foundations that also provide heating and cooling. The use of geothermal heat can reduce energy consumption considerably. A full-scale energy-pile demonstrator will be complemented with lab-scale experiments at The Green Village on the TU Delft campus. Parameters such as efficiency, design methods and energy saving potential are investigated for short-term (seasonal) and long-term (years) periods.

Smart thermal grid at TU Delft
TU Delft’s campus heating network is connected to 23 buildings and used as a ‘living lab’ to demonstrate the transition of a conventional district heating grid towards a renewables-driven fourth-generation district-heating network. The first step involves an anticipative and peak-shaving control strategy to minimise the supply temperature, which is necessary to integrate a future geothermal source into the network. This first step already showed a 20% reduction of natural gas consumption without having to make any large-scale modifications to buildings or heat sources.
Theme 4: Urban solar

Utilisation of solar energy everywhere

We need:
- Electricity production from all available surfaces (photons to electrons).
- Multifunctional solar cells integrated in building elements, urban surfaces and the landscape.
- Smart combination of custom shapes, bendability, colour, transparency, shading tolerance and heat usage.
- Circular and efficient materials and components.

Research challenges
- Photovoltaic (PV) solar energy fully integrated in building elements such as walls, bricks, pavements, coatings, roofing and acoustic screens
- Modelling of design and energy yield of urban/architectural integrated PV systems
- PV solutions for architectural heritage, domotics, e-mobility and heat management

Examples of TU Delft projects

Floating solar panels on indoor waterways
Floating solar panels are an example on how solar cells can be integrated into the landscape. Together with Blue 21, Dutch Water Authority Rivierenland and Hakkers, TU Delft develops cost-competitive PV systems with bifacial modules and sustainable, lightweight materials. TU Delft provides high-accuracy DC-to-AC electricity yield prediction modelling as well as the implementation of power output monitoring.

E-bike charging station
Integrated in the TU Delft campus, the e-bike charging station combines a modern design with a highly efficient PV system. TU Delft’s innovative DC electric system including batteries is placed inside the station. Here, cyclists can recharge their bikes and researchers can gather data for studies on solar energy and e-mobility.
Theme 5: Smart monitoring, management & control

Give brains to urban energy systems

We need:
• Energy systems with maximum efficiency under all circumstances.
• Consumers participating in the energy transition through smart home appliances and smart grids.
• Smart and ethical use of data for demand/supply match and system optimisation.

Examples of TU Delft projects

Smart-meter data for automated energy and comfort diagnosis in homes
Smart-meter data at several aggregation levels (place and time) support the development of better prediction models for energy consumption in dwellings. With these models, based on actual energy use and behaviour, much more accurate energy savings potentials can be determined at the house, block or neighbourhood levels. Thermal sensation data and diverse physical parameters are gathered in real time in order to learn about the occupant’s wishes and behaviour. TU Delft explores this topic in various projects with multiple industry partners.

An energy-neutral office through the Internet of Things
An office building in Rijswijk is used as a test environment to demonstrate how an energy-neutral office can be achieved through using the Internet of Things (IoT) and smart controls. TU Delft has been working on how to use the data collected by the IoT platform to design self-learning controls that reduce energy consumption and increase comfort. The Dutch Government Real Estate Agency (Rijksvastgoedbedrijf) has established the test environment in Rijswijk as one of the initiatives in the Green Technologies 3.0 programme.
Theme 6: Transforming the cities

Robust, integrated local energy-transition plans

We need:
• Design and engineering solutions for the energy transition.
• Decision support for integrated energy solutions on the city, district and neighbourhood levels.
• Local authorities to direct and facilitate the energy transition.
• Empowerment of energy communities.

Research challenges
• Approaches, methods and tools for the energy transition of cities
• Integrated modelling of sustainable energy systems for neighbourhoods, districts and cities
• Development of new governance models for the energy transition in cities
• Interactive co-creative workshops to set energy visions and action agendas across Europe

Examples of TU Delft projects

Energy Transition Roadmaps
For the EU project City-zen, TU Delft developed an energy transition roadmap for Amsterdam, showing how the city can become energy neutral by 2040. TU Delft realised the energy master planning approach as well as methods and tools to help guide the city to an envisioned sustainable future. City-zen Roadshows across Europe help cities start their own energy transition. See: cityzen-smartcity.eu

Engaging citizens
Energy Cooperatives are an important means to engage citizens in the energy transition. The European project REScoop Plus explores ways and analyses best practices to stimulate engagement of energy saving tools by energy cooperatives, and lower energy use by cooperative members. TU Delft provides expertise on the behavioural impact of the best practices on the cooperative members, and on behavioural changes due to the cooperative engagement with the energy cooperatives themselves. See: REScoop-ee.eu
Expertise at TU Delft

Faculty of Architecture and the Built Environment
Circular/carbon-neutral design and planning, building product innovation, architectural engineering, housing quality and process innovation, housing governance, housing systems.

Faculty of Technology Policy and Management
Governance, policy, energy systems, behaviour, social innovation.

Faculty of Civil Engineering and Geosciences
Shallow and deep geothermal energy systems, aquifer thermal energy storage.

Faculty of Electrical Engineering, Mathematics and Computer Science
Solar cells and PV module manufacturing, smart module design, modelling of energy yield of PV systems.

Faculty of Mechanical, Maritime and Materials Engineering
Systems and control, smart building and smart cities.

Faculty of Industrial Design Engineering
Design conceptualisation and communication.

The Green Village
Living-lab environment where universities and businesses can develop, test and demonstrate innovations with close involvement of the public and government.

TU Delft is academic partner of the Amsterdam Institute for Advanced Metropolitan Solutions (AMS Institute).
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