

# Weather and daily mobility in international perspective

## A cross comparison of Dutch, Norwegian and Swedish city regions

### Findings from ClimaMob work package 1



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*transport*



*climate*





# Contents

- International literature
- Study areas and data
- Paper I: Weather and travel behaviour
- Paper II: Weather and transport energy use
- Conclusions and discussion

# International literature

- Seasonality and weather on travel behaviour, mainly transport mode
- Often assumed linear relationships

- Weather and outdoor physical activity
- Urban microclimates, biometeorology, thermal comfort and outdoor physical activity

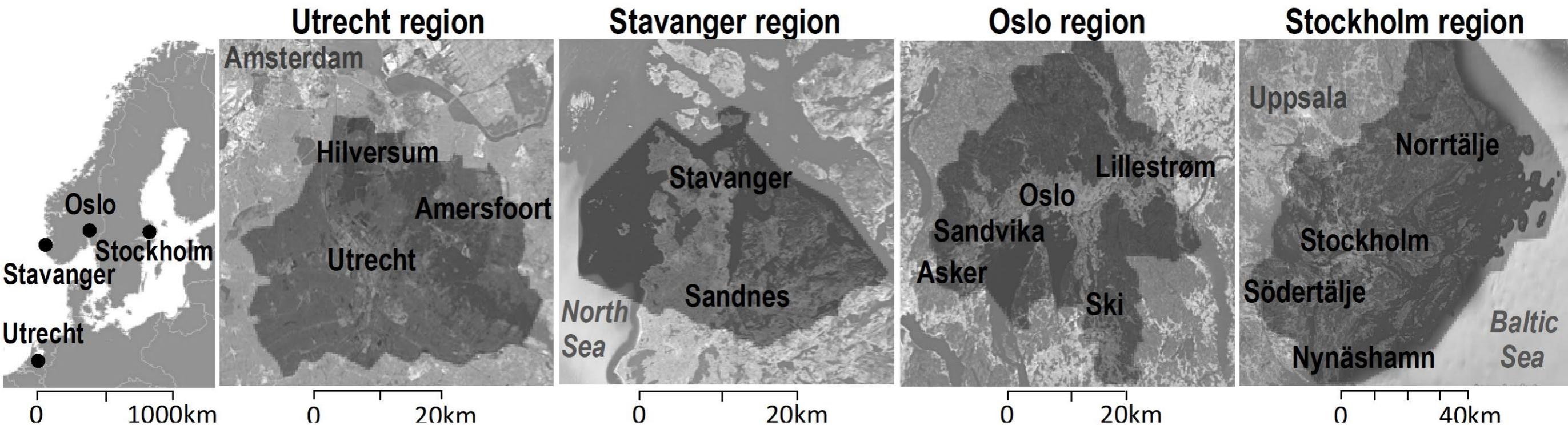
- Nonlinearity of weather effects
- Thermal optimum for walking, cycling and outdoor attendances
- Thresholds and tipping points

- A couple of systematic literature reviews point out that...
- Knowledge is highly fragmented over different disciplines
- Weather effects differ geographically by climate and transport regime

# Knowledge needs

- Need for international comparison studies
- Need for integrated examinations of how weather affects a wider range of travel behaviours simultaneously
- To address the complex relation between weather and climate, and between adaptation and mitigation, there is a need to explore direct linkages between weather and energy for transport

# Study areas



maritime climate

warm summers:  
(highs 23°C; lows 13°C),

mild winters:  
(highs 6°C; lows 0°C)

833 mm of precipitation

inland, totally flat terrain  
±50km from sea

maritime climate

mild summers:  
(highs 19°C; lows 12°C)

mild winters:  
(highs 3°C; lows -1°C)

1,180mm precipitation

coastal flat/hilly terrain

humid continental

warm humid summers:  
(highs 22°C; lows 12°C)

cold winters:  
(highs -2°C; lows, -7°C)

763mm precipitation

hilly terrain at inland  
end of sea inlet

humid continental

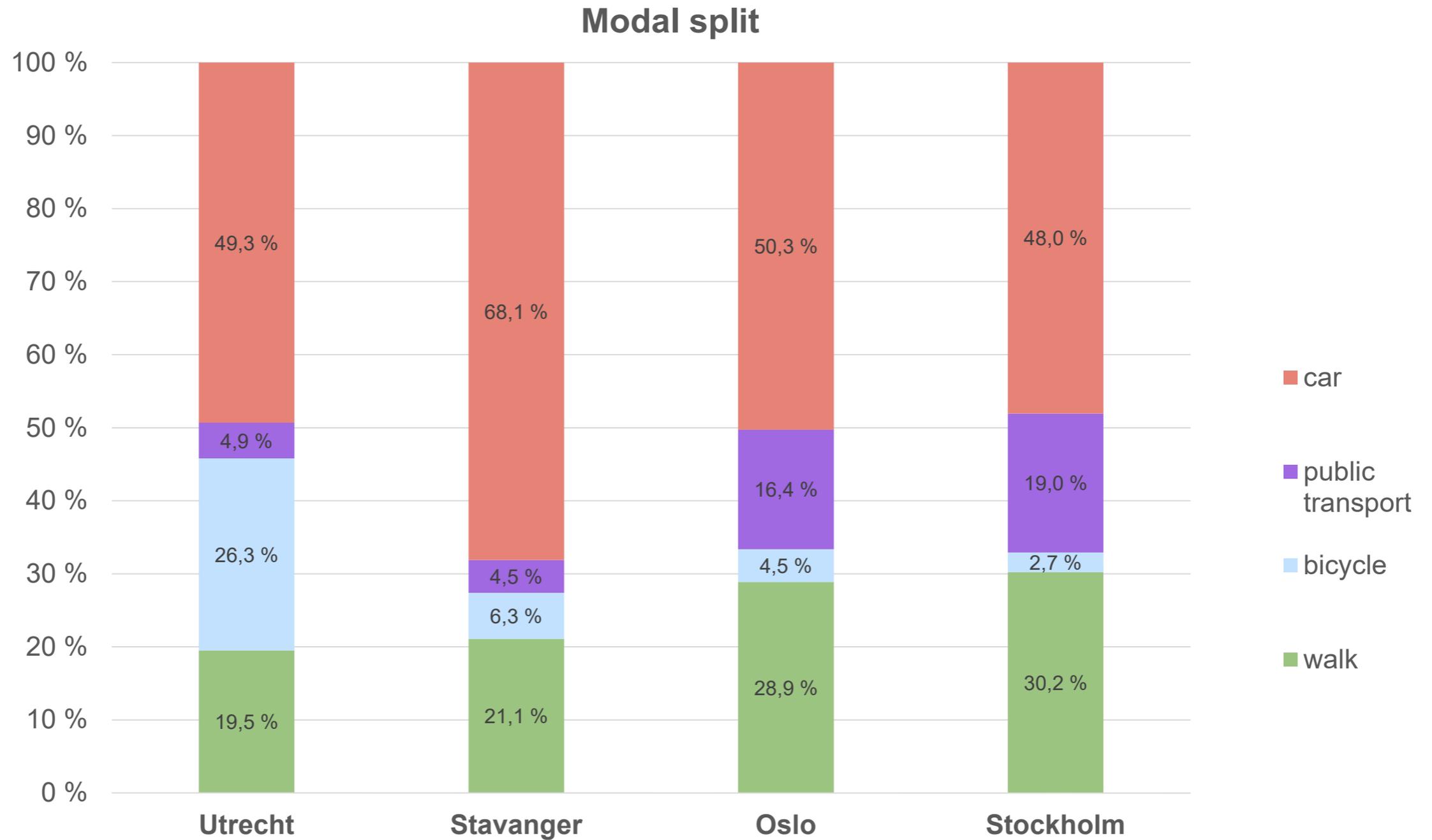
warm humid summers:  
(highs 22°C; lows 13°C)

cold winters:  
(highs -1°C; lows, -5°C)

539mm precipitation

near-coastal flat/hilly  
island-rich terrain

# Study areas



# Data

## Regional subsamples of **national travel survey data**

- Utrecht: 4413 respondents / 8972 trips (source: OViN 2010-2012)
- Stavanger: 1981 respondents / 5454 trips (source: RVU-Norway 2013-2014)
- Oslo: 6454 respondents / 14601 trips (source: RVU-Norway 2013-2014)
- Stockholm: 2087 respondents / 4650 trips (source: RVU-Sweden, 2011)

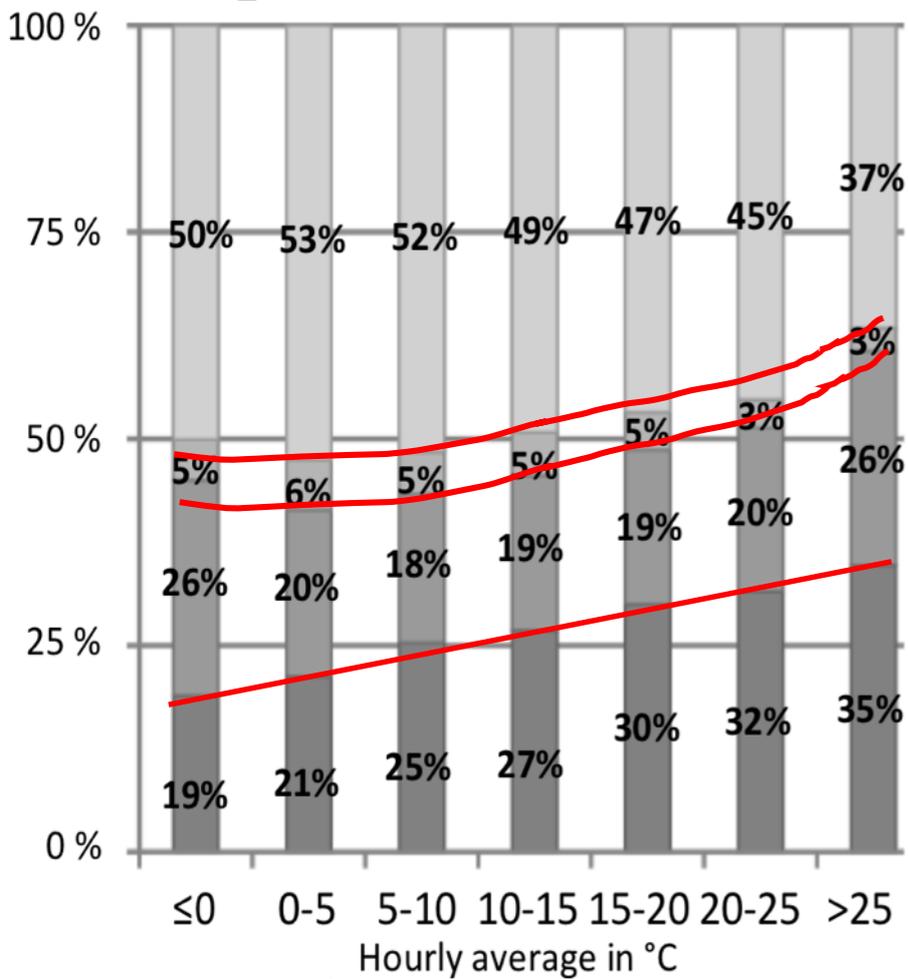
## **Daily and hourly data on air temperature, wind speed, rainfall, snowfall**

- Norwegian Meteorological Institute (MET, 2015)
- Swedish Meteorological and Hydrological Institute (SMHI, 2012)
- Royal Dutch Meteorological Institute (KNMI, 2015)

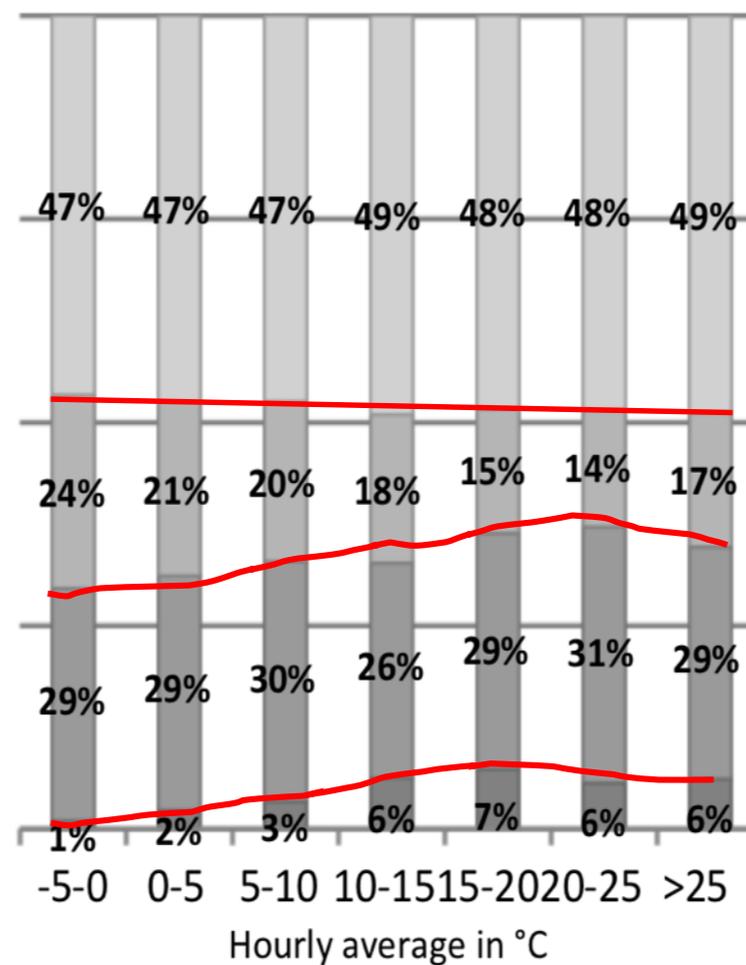
**Matched in GIS** via residential postal code to **nearest weather station** (max 20km)

# I Weather and travel behaviour

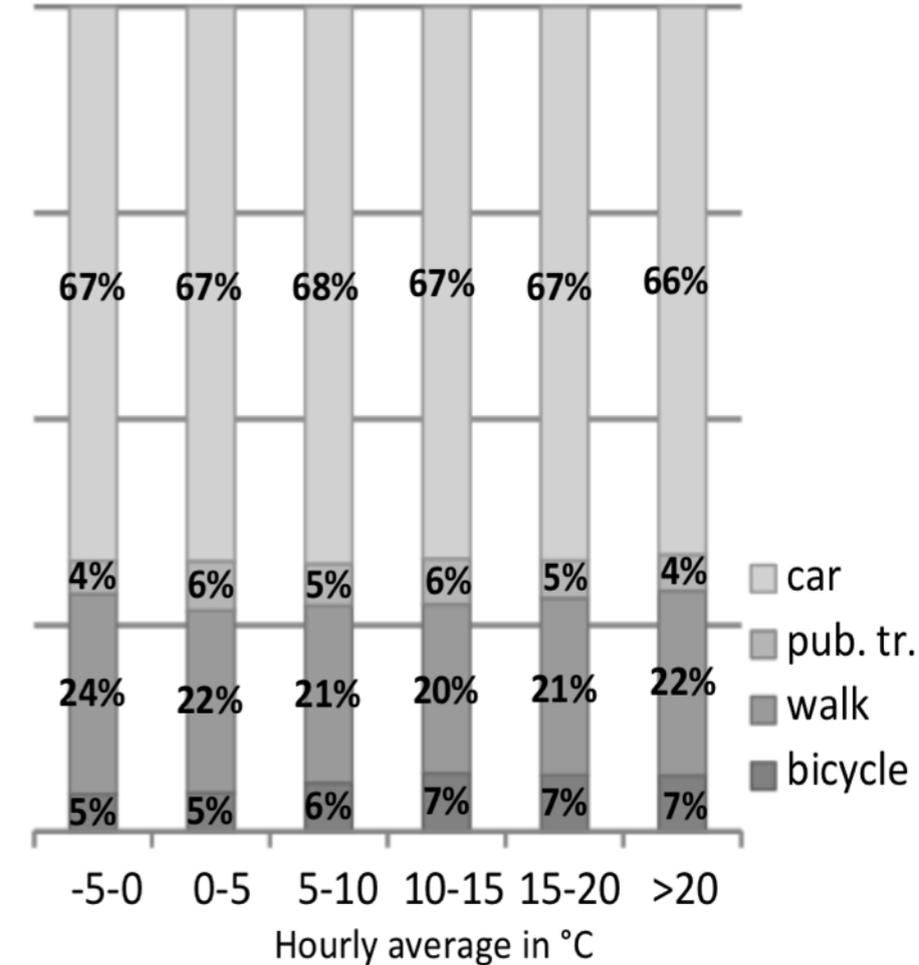
## Air temperature



Utrecht region



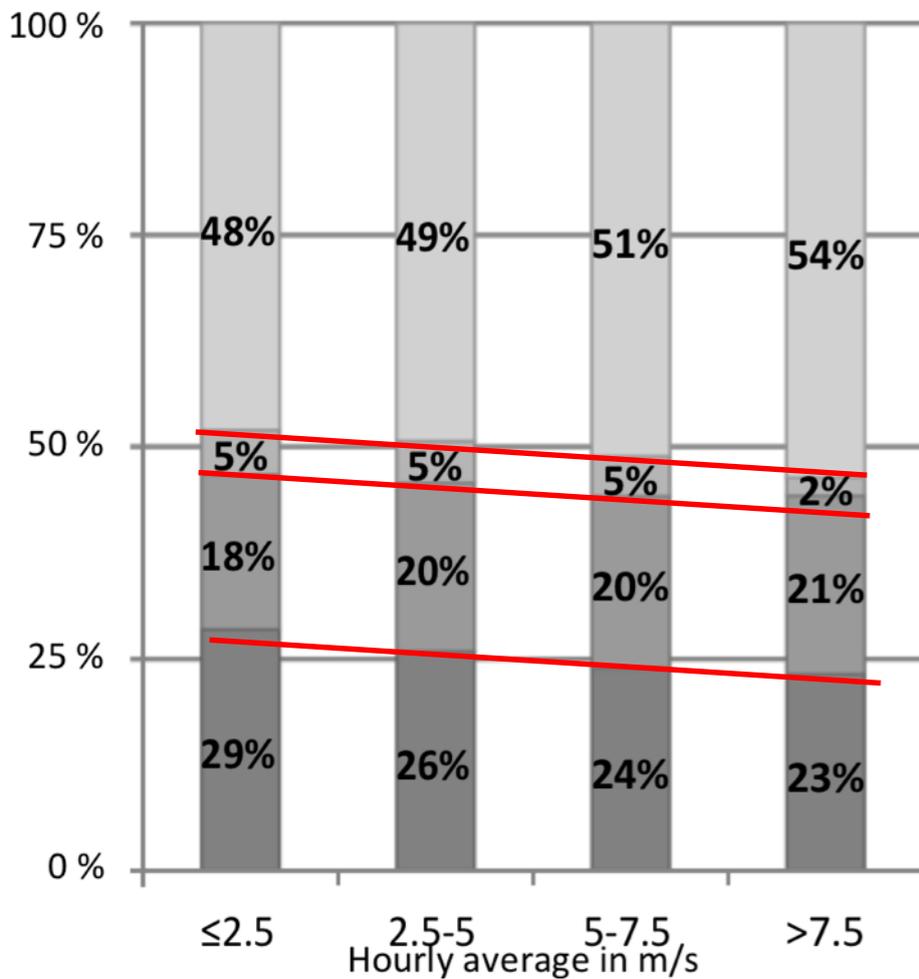
Oslo region



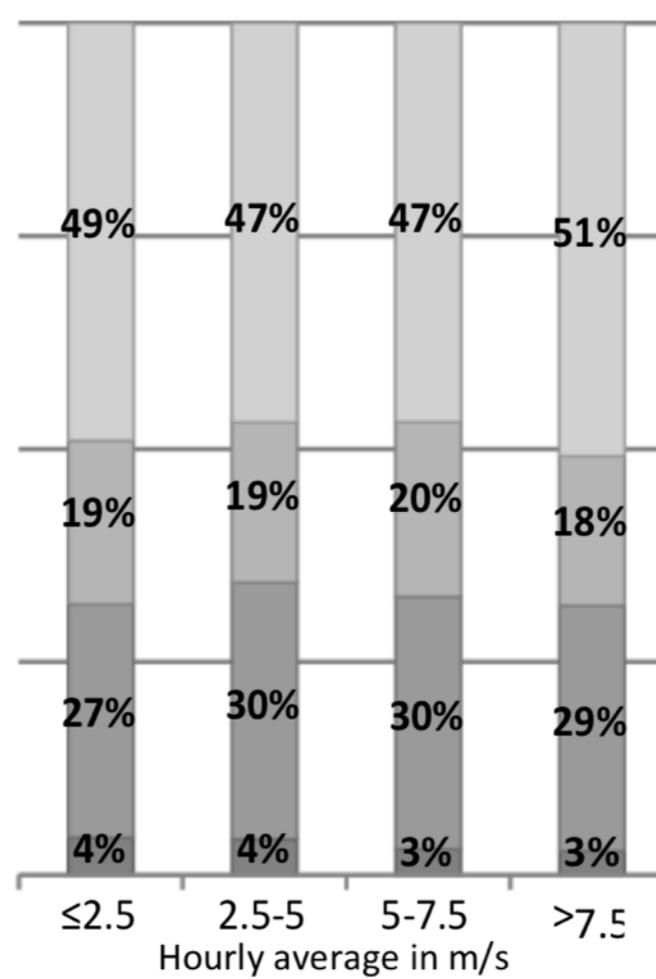
Stavanger region

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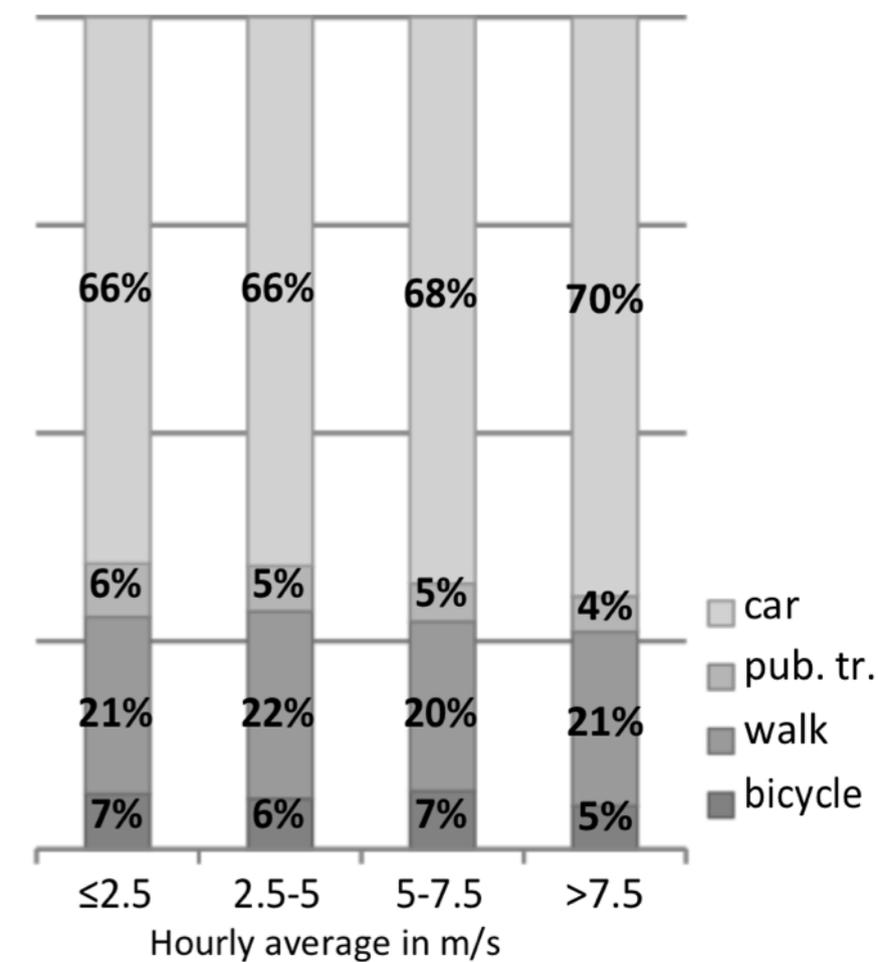
## Wind speed



Utrecht region



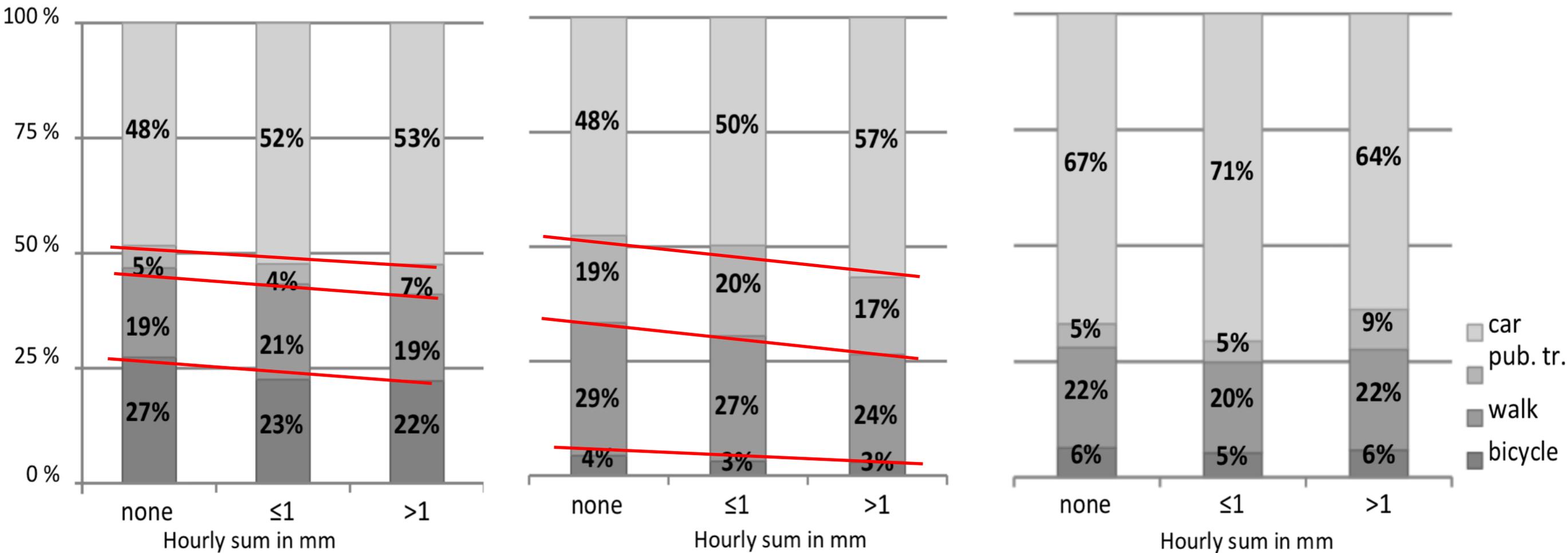
Oslo region



Stavanger region

# I Weather and travel behaviour

## Precipitation



Utrecht region

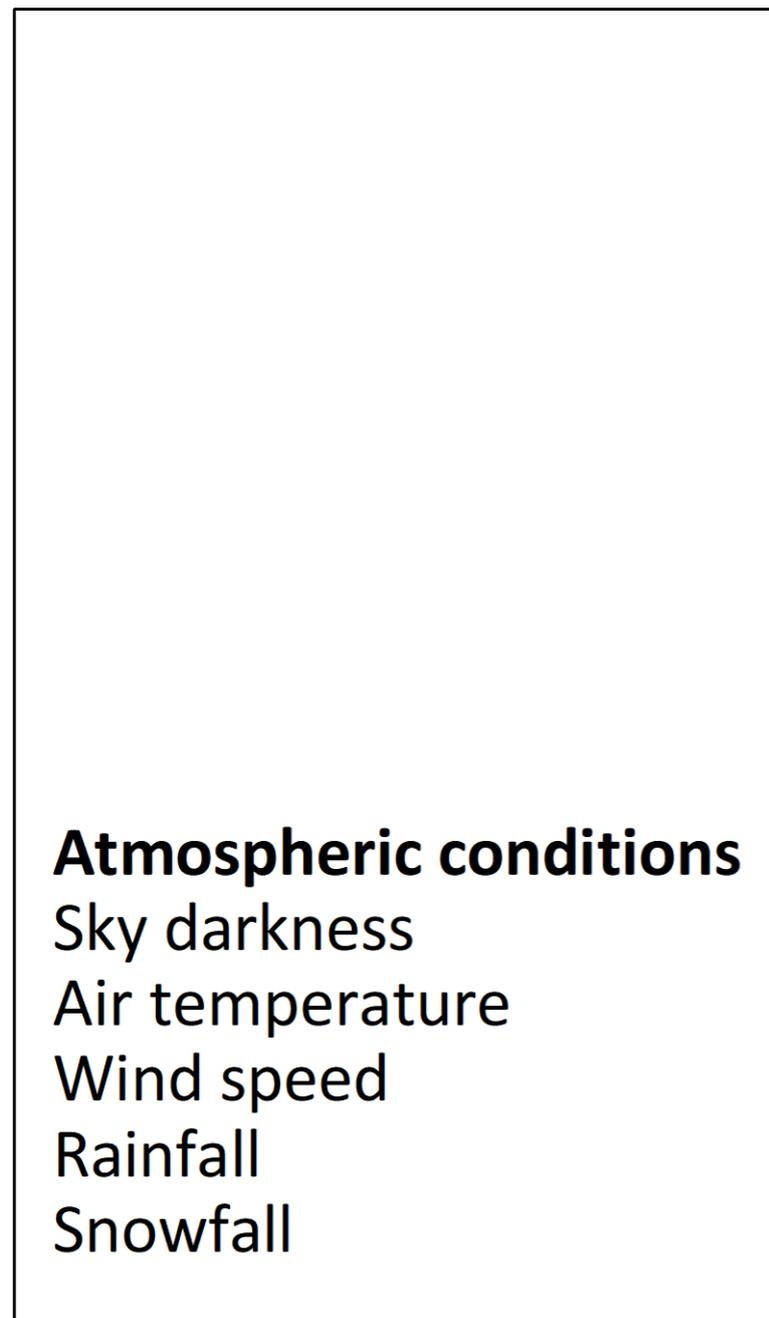
Oslo region

Stavanger region

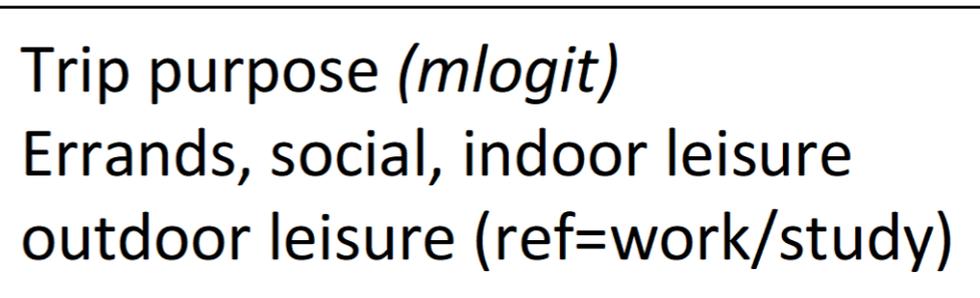
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- We analyse the simultaneous effects of **hourly weather** on four dependent variables
- Hereto we use structural equation modelling (SEM)

## Independent variables

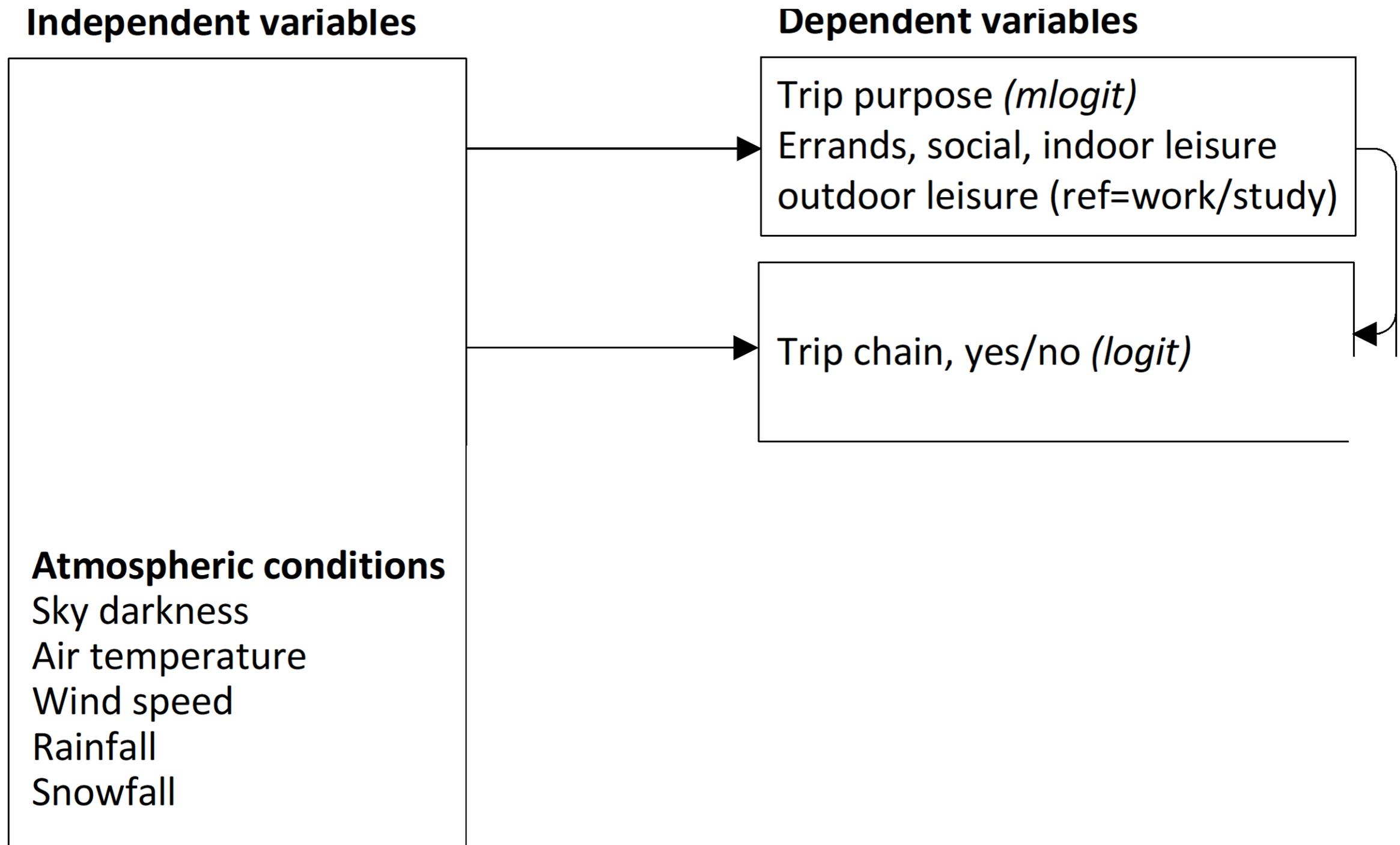


## Dependent variables



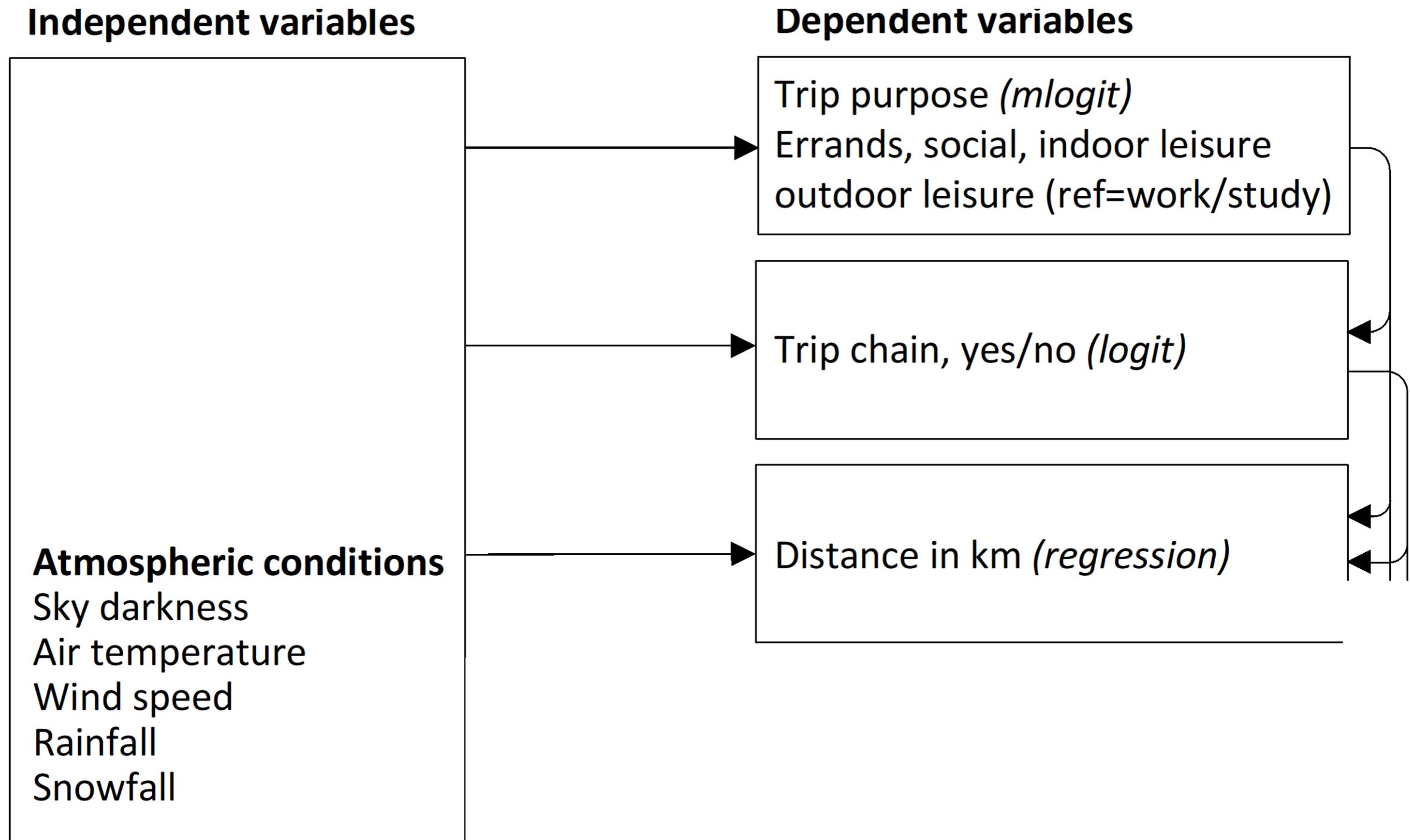
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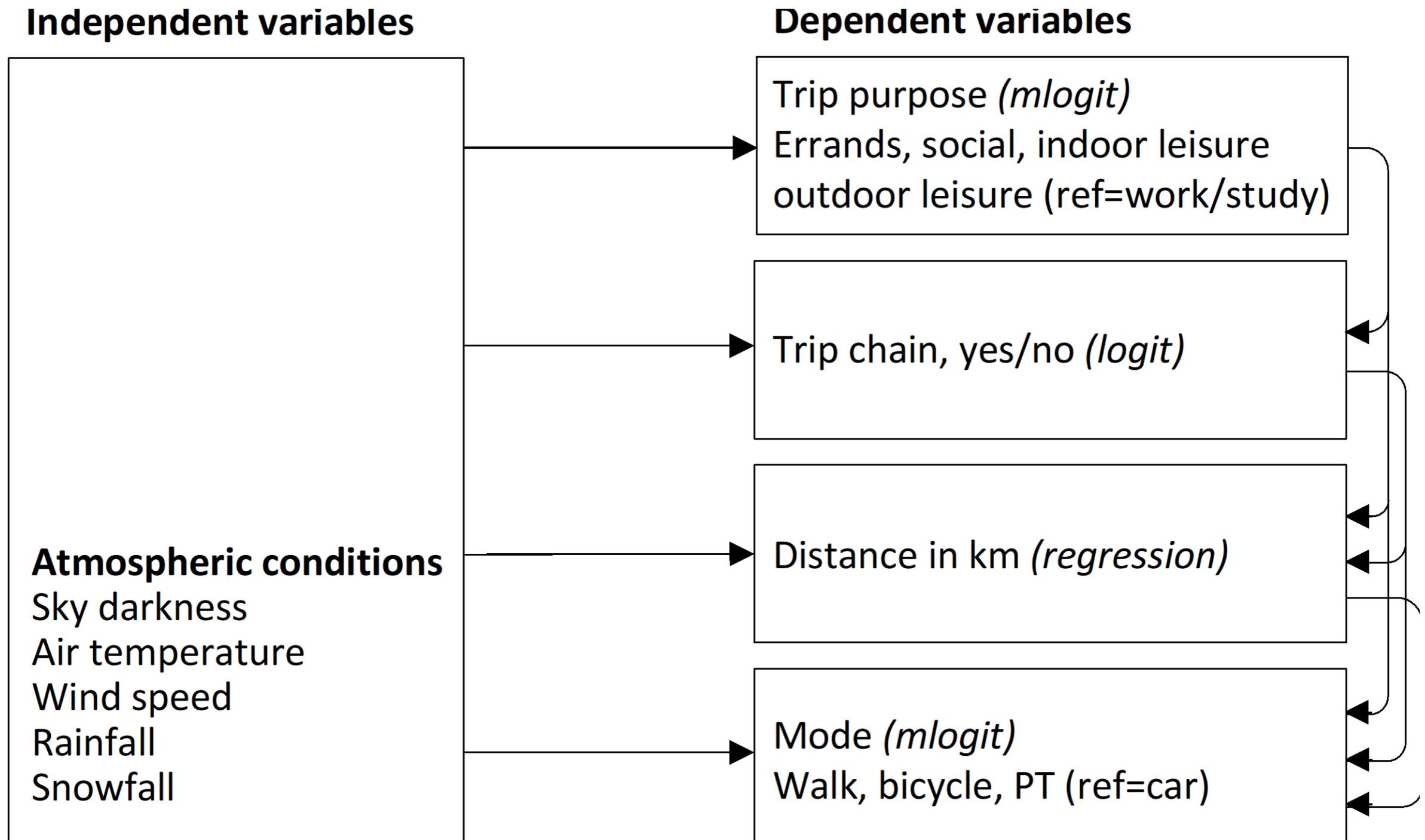
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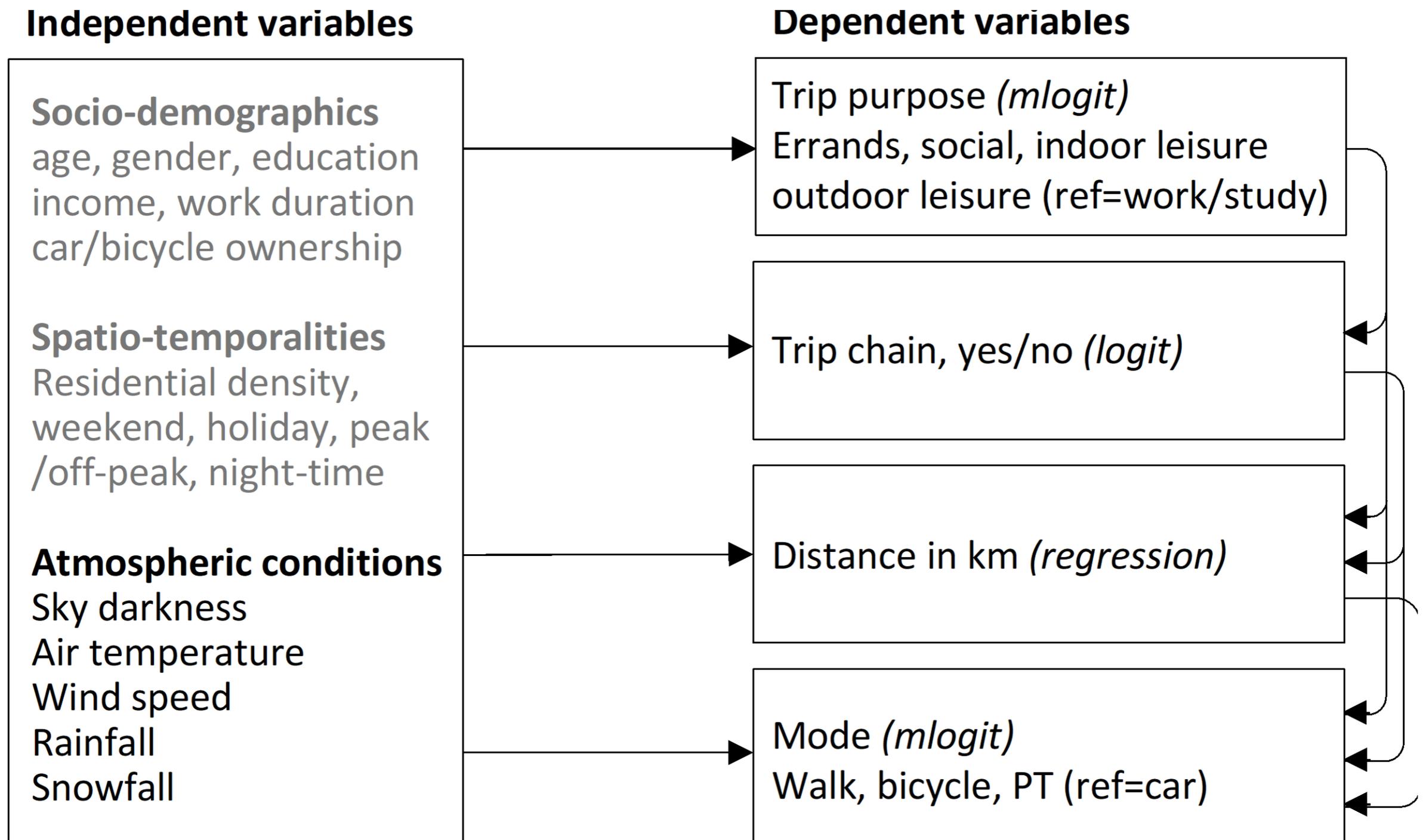
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# Multivariate results Stockholm

	trip purpose (compared to work/study trips)				trip chain	trip length	transport mode choice (compared to car trips)		
	errands	social	leisure outdoor	leisure other	(yes/no)	(yes/no)	walk	cycle	public transport
sky darkness (yes/no)	.456	.890	.730	.387	-.376	-.404	-.327	.103	-.197
air temperature (in °C)	.014	.023	-.005	-.007	-.006	-.010	-.006	.165	-.020
air temperature (squared)	.000	.000	.001	.000	.001	.002	-.001	-.005	.000
wind speed (avg) in m/s	.023	-.059	.066	.038	-.018	.011	.002	.072	.048
rainfall (yes/no)	-.108	.266	-.253	-.038	.117	-.385	-.147	-.339	.174
snowfall (yes/no)	-.161	-.482	-.461	-.264	.064	-.386	.037	-.970	-.077

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sky darkness (yes/no)	.176	.876	.640	.461	-.208	-1.655	-.137	-.365	.028
air temperature (in °C)	.021	.029	.053	.026	-.005	-.023	.003	.167	-.001
air temperature (squared)	-.001	-.001	-.001	.000	.000	.004	-.001	-.004	.000
wind speed (avg) in m/s	-.010	.014	-.041	-.005	.029	-.031	.009	-.024	.020
rainfall (yes/no)	-.147	-.113	-.393	.008	-.009	1.103	-.083	.005	.077
snowfall (yes/no)	-.014	-.022	.140	-.042	.078	-.328	-.083	.109	-.200

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air temperature (in °C)	.000	.022	.019	.034	-.021	-.058	-.068	.025	-.001
air temperature (squared)	.000	.000	.000	.000	.001	.004	.003	.000	.000
wind speed (avg) in m/s	-.018	-.035	-.020	-.028	.020	.307	-.005	-.061	-.060
rainfall (yes/no)	.014	-.022	-.063	.033	-.011	.016	-.035	-.259	.082
snowfall (yes/no)	.149	-.409	.433	-.179	-.256	-3.788	-.014	.273	-1.168

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sky darkness (yes/no)	.011	.544	.334	.282	-.461	-.991	-.056	-.292	-.030
air temperature (in °C)	.046	.048	.043	.009	-.003	-.159	-.013	.077	.011
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rainfall (yes/no)	-.015	-.135	-.523	-.293	-.119	.631	.075	-.099	.152
snowfall (yes/no)	-.310	-.064	-.866	.184	.146	-3.606	.263	1.529	-11.304

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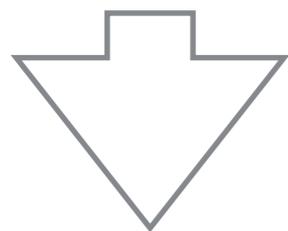
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# II Weather and transport energy

Conversion of mobility data to energy use and physical activity

Trip distance /respondent/day

- By petrol car
- By diesel car
- By electric car
- By local/regional train
- By tram
- By metro
- By bus

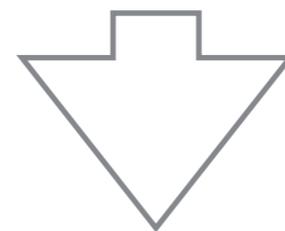


via local emission factors  
& vehicle occupancy data

Energy use: petrol, diesel, and  
electricity-based  
(*MJ/respondent/day*)

Trip duration /respondent/day

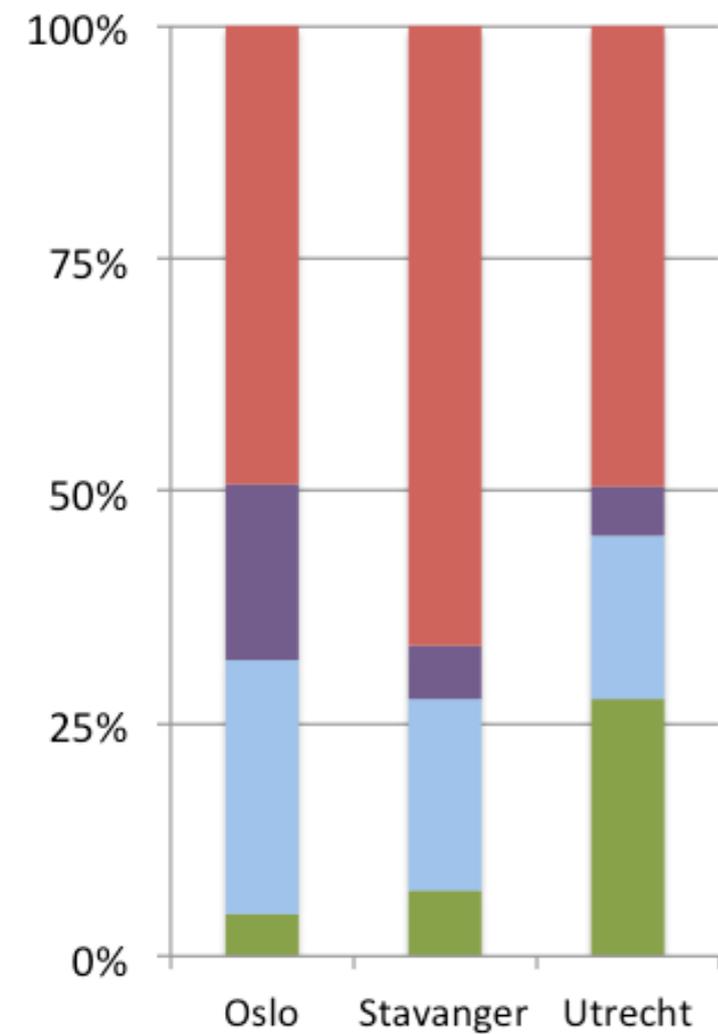
- By foot
- By foot to/from public transport
- By bicycle
- By bicycle to/from public transport



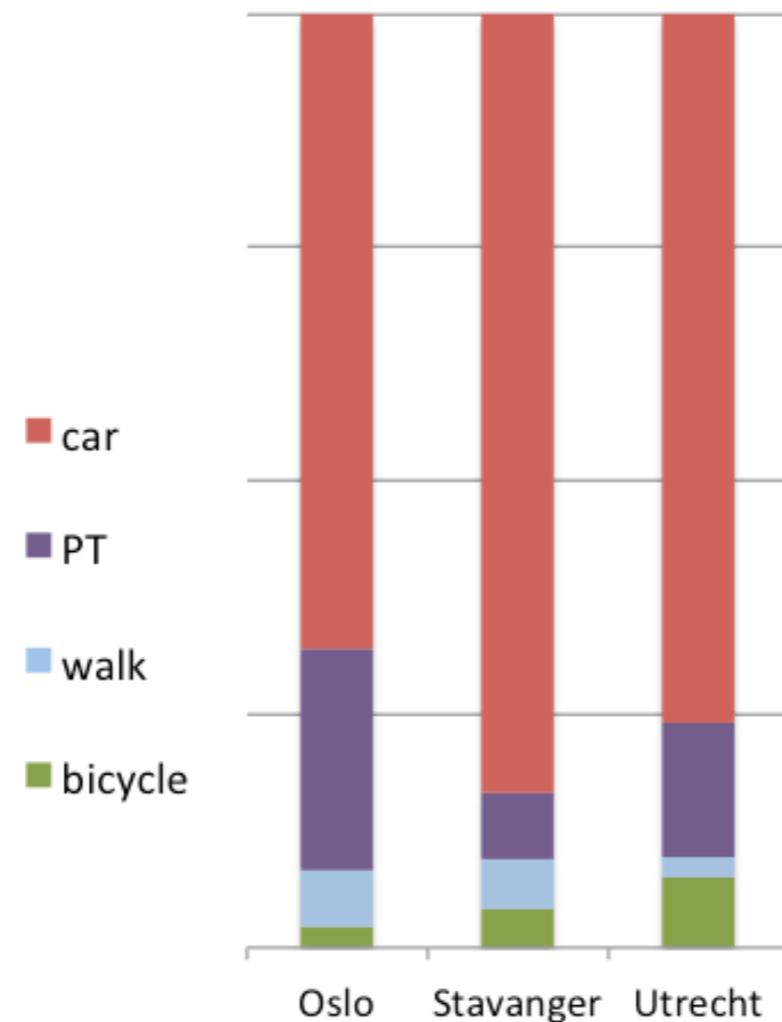
via Metabolic Equivalent of Task (MET)  
Fishman et al 2015; Ainsworth et al 2011

Physical activity from daily mobility  
(*MET-hours/respondent/day*)

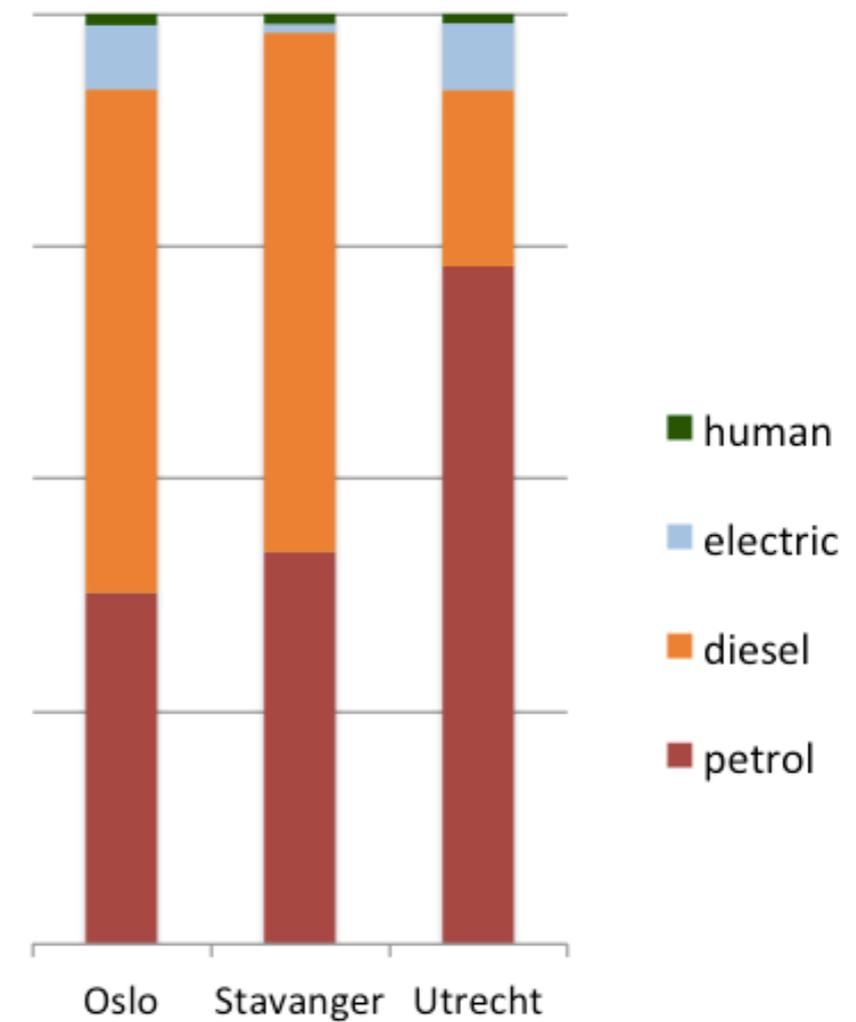
# Modal split → Energy modal split



Trip based mode shares

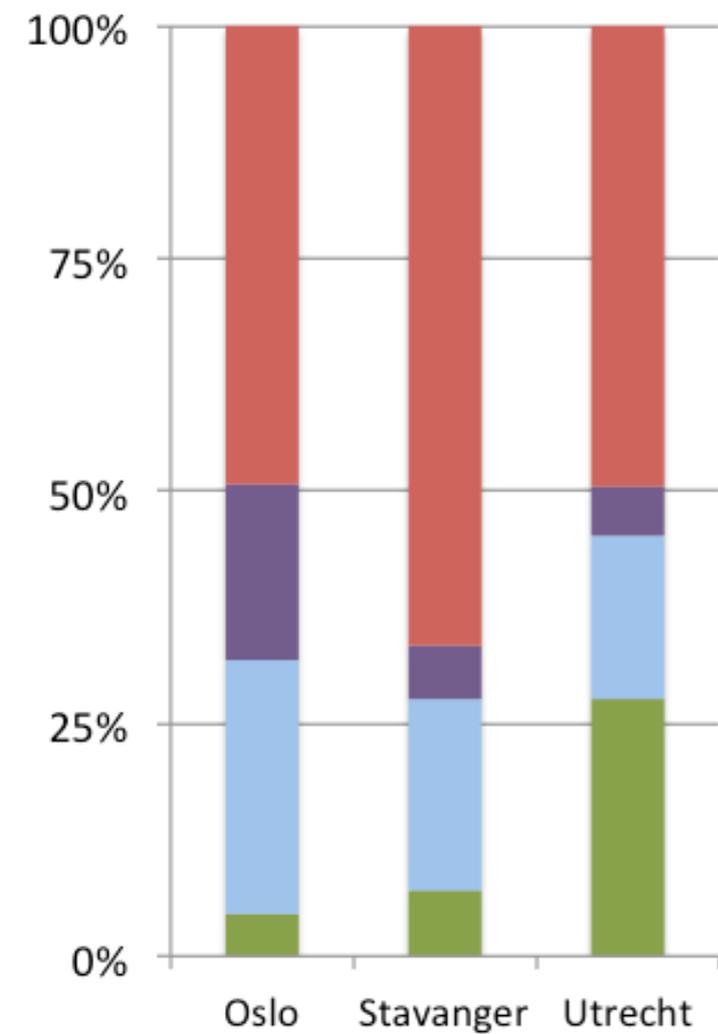


Distance based mode shares

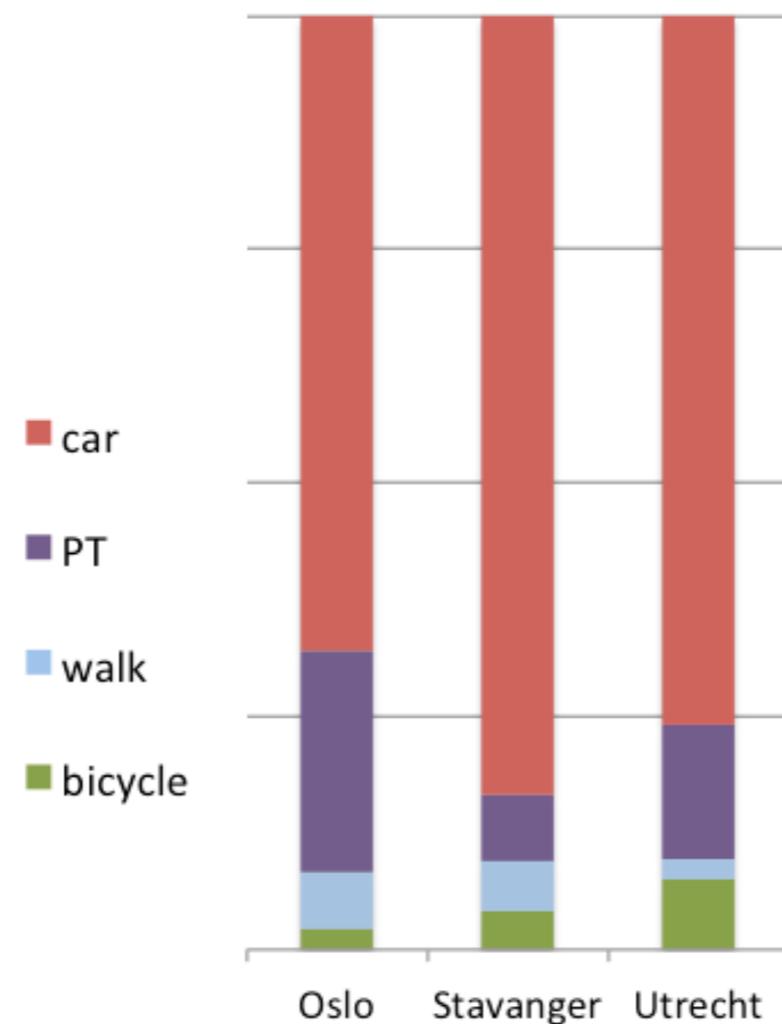


Distance based energy (MJ) shares

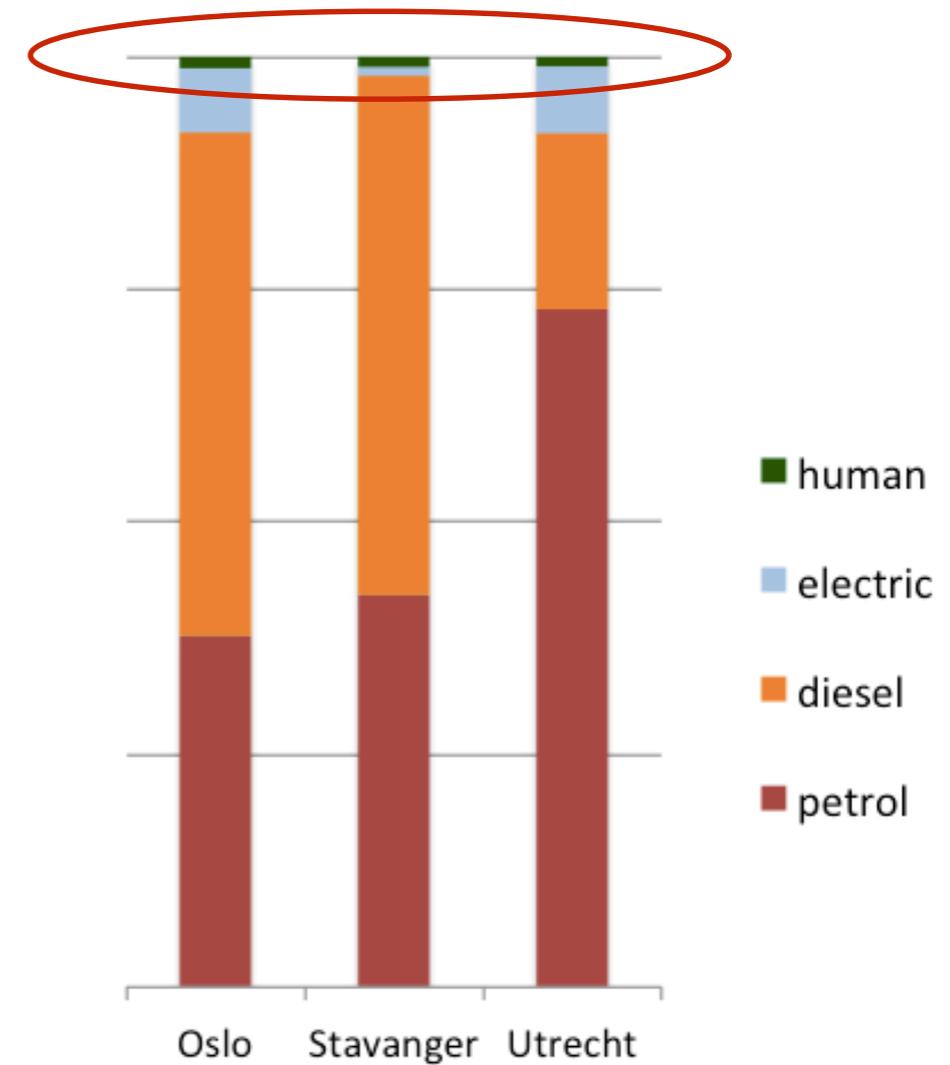
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Trip based mode shares

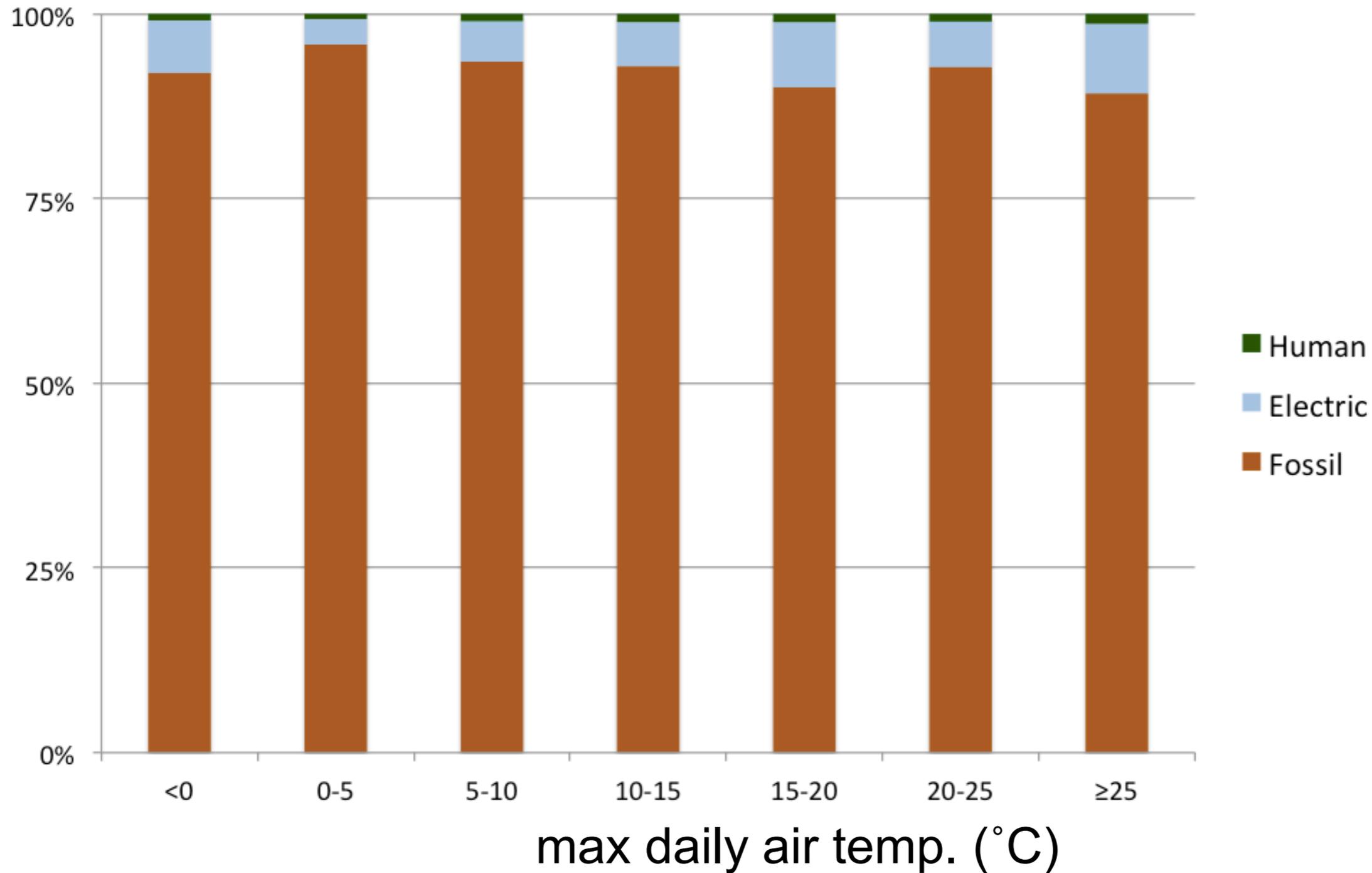


Distance based mode shares



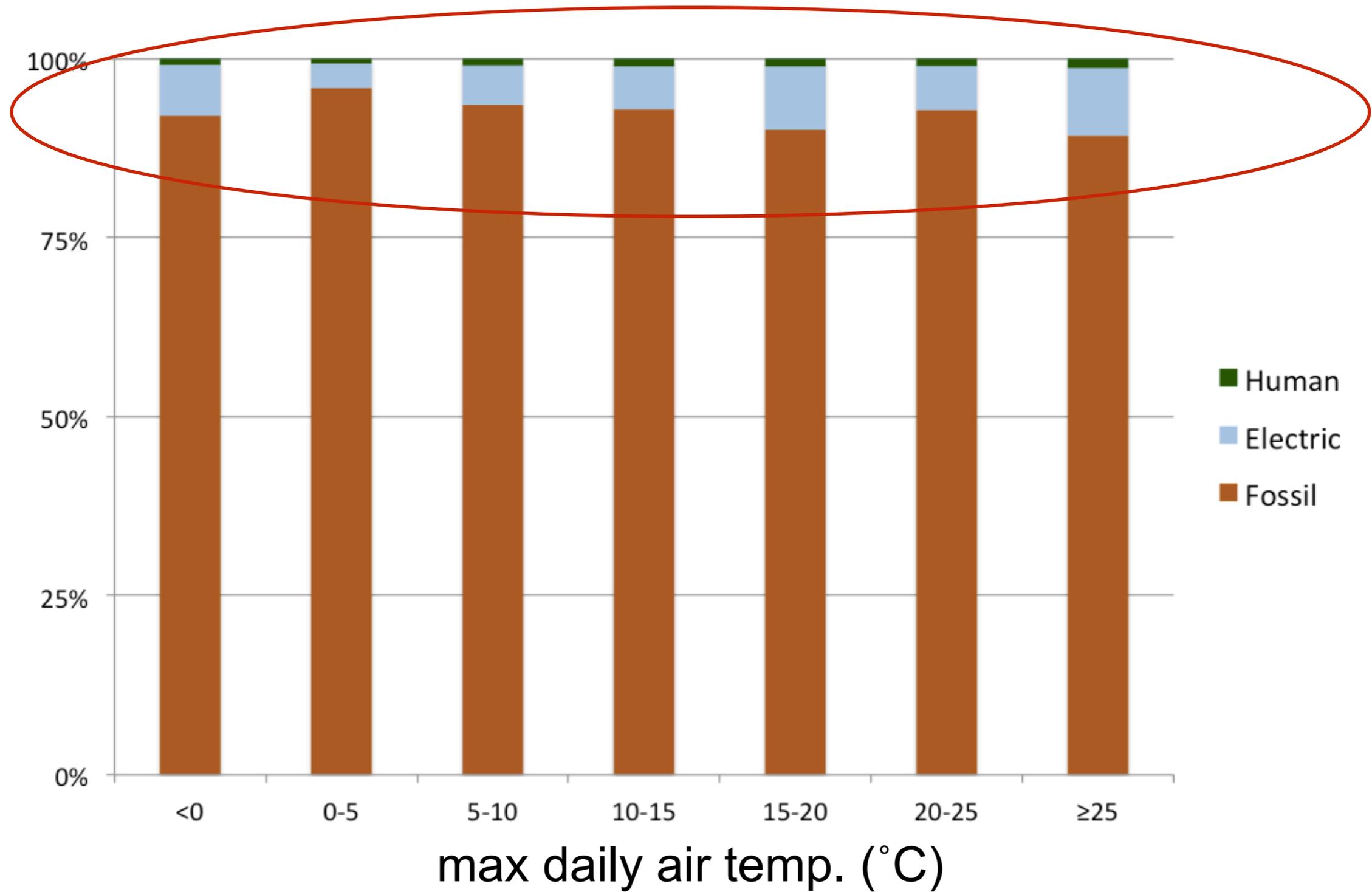
Distance based energy (MJ) shares

# Weather and energy modal split



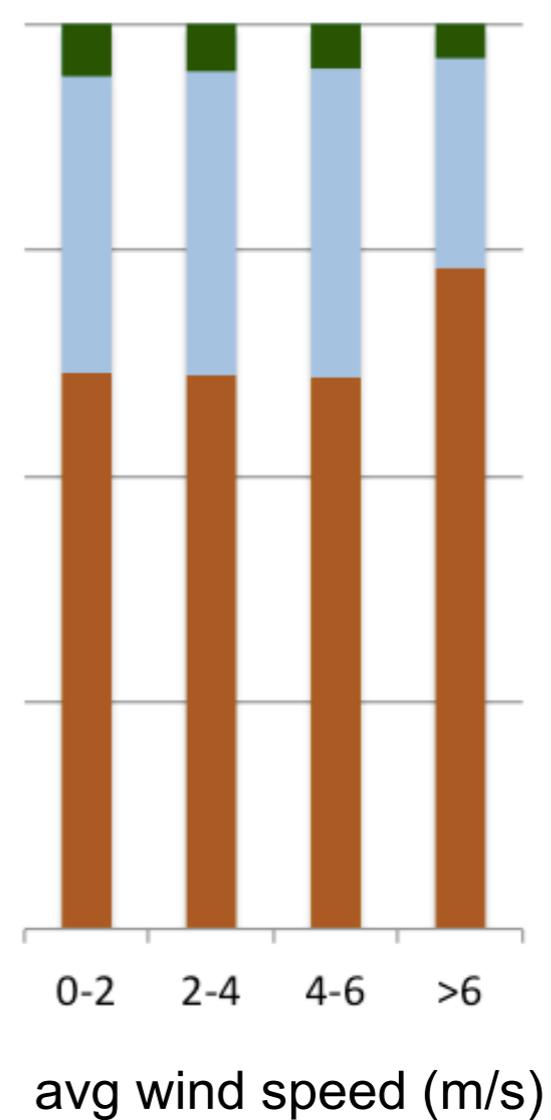
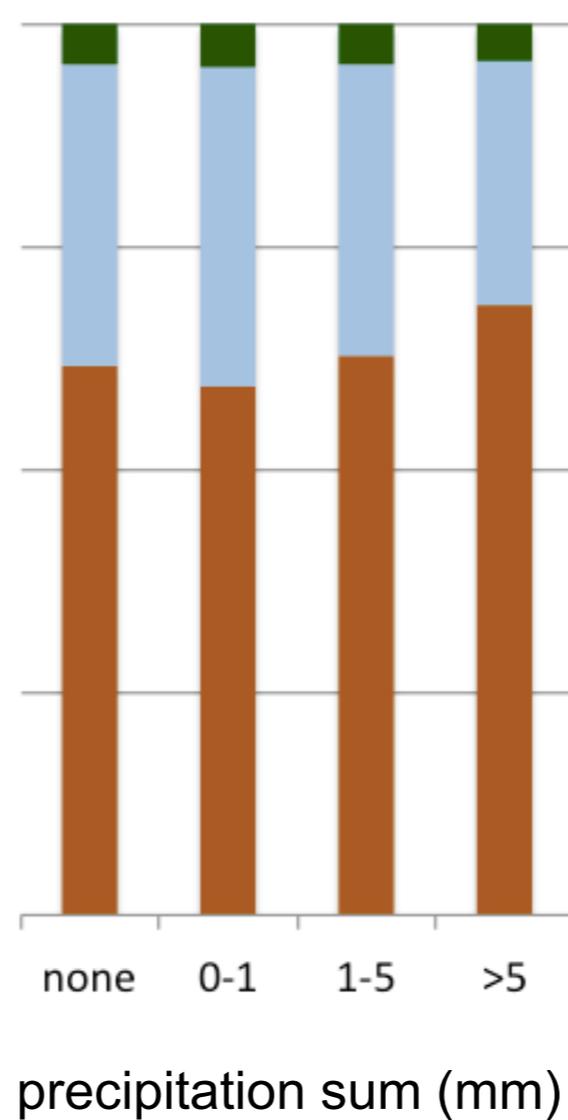
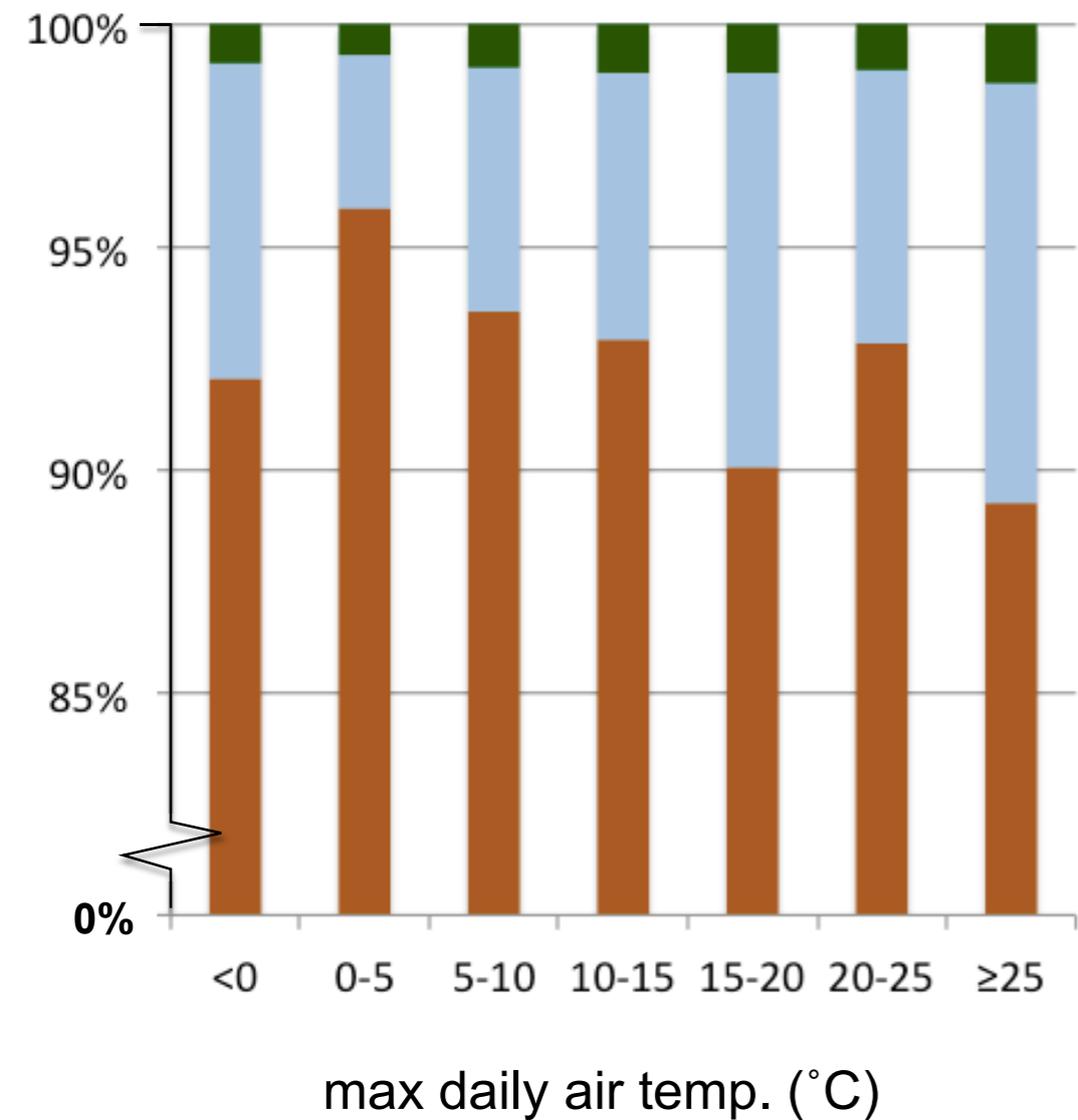
Utrecht

# Weather and energy modal split



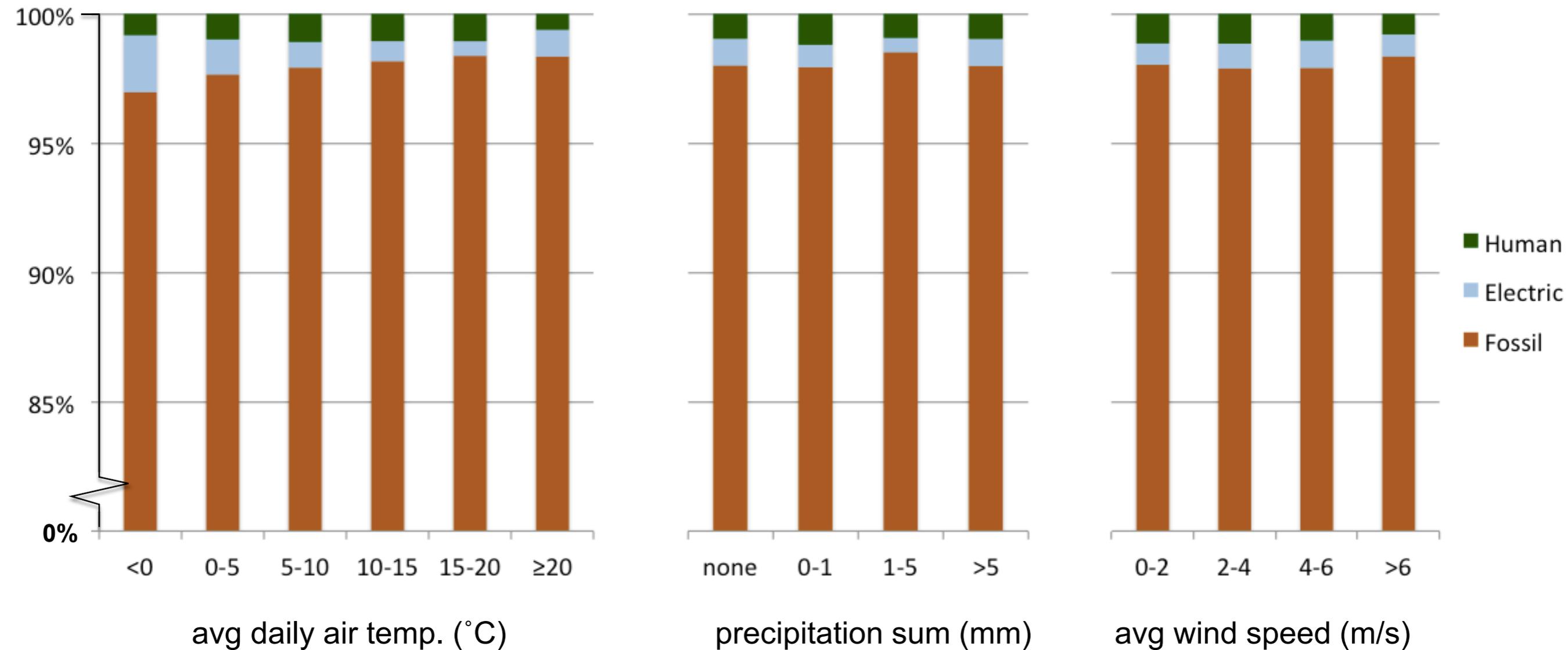
Utrecht

# Weather and energy modal split



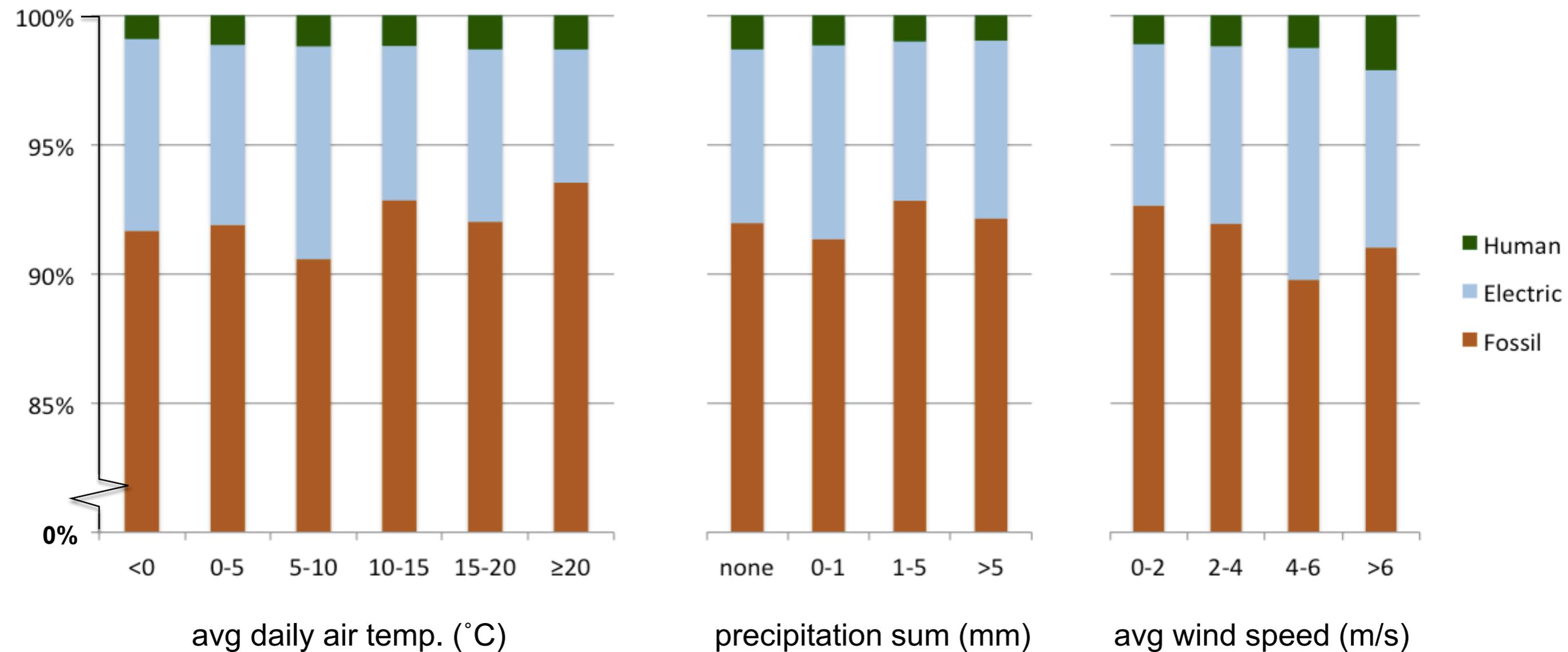
Utrecht

# Weather and energy modal split



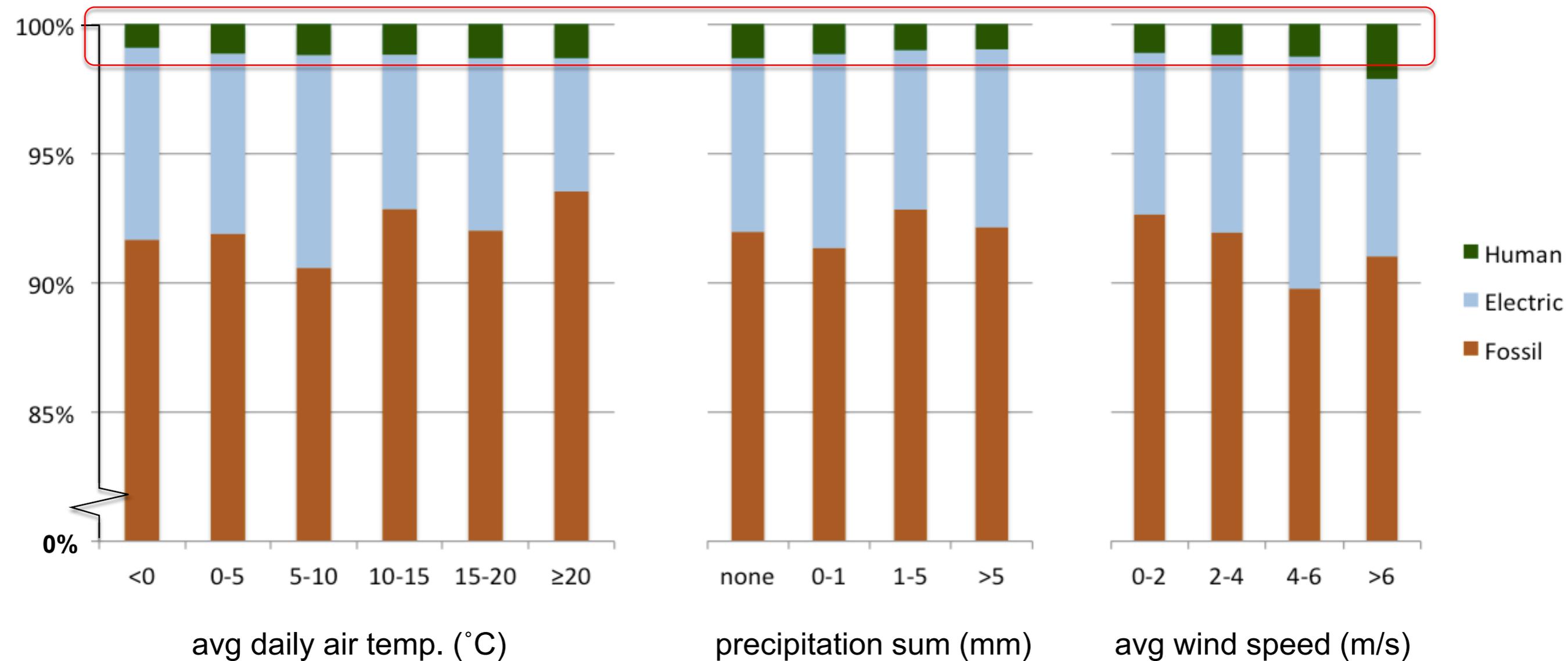
## Stavanger

# Weather and energy modal split



Oslo

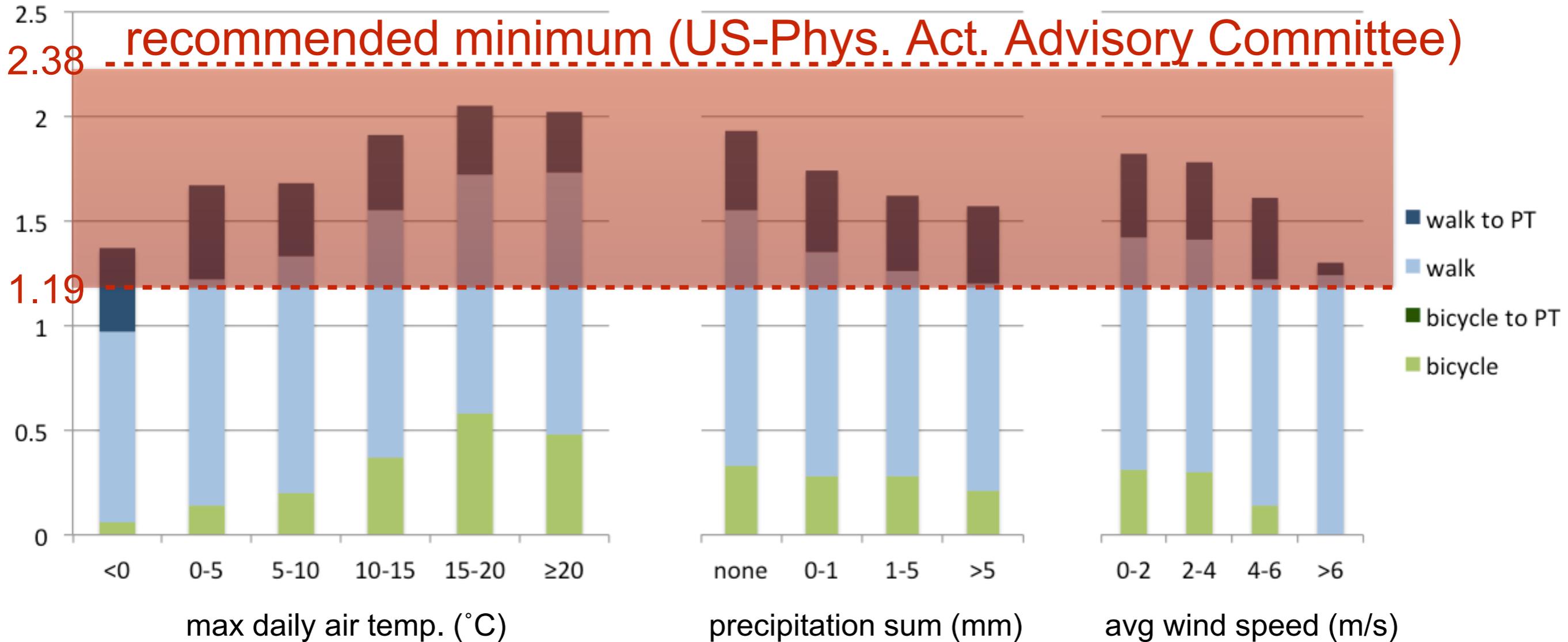
# Weather and energy modal split



Oslo

# Weather and physical activity

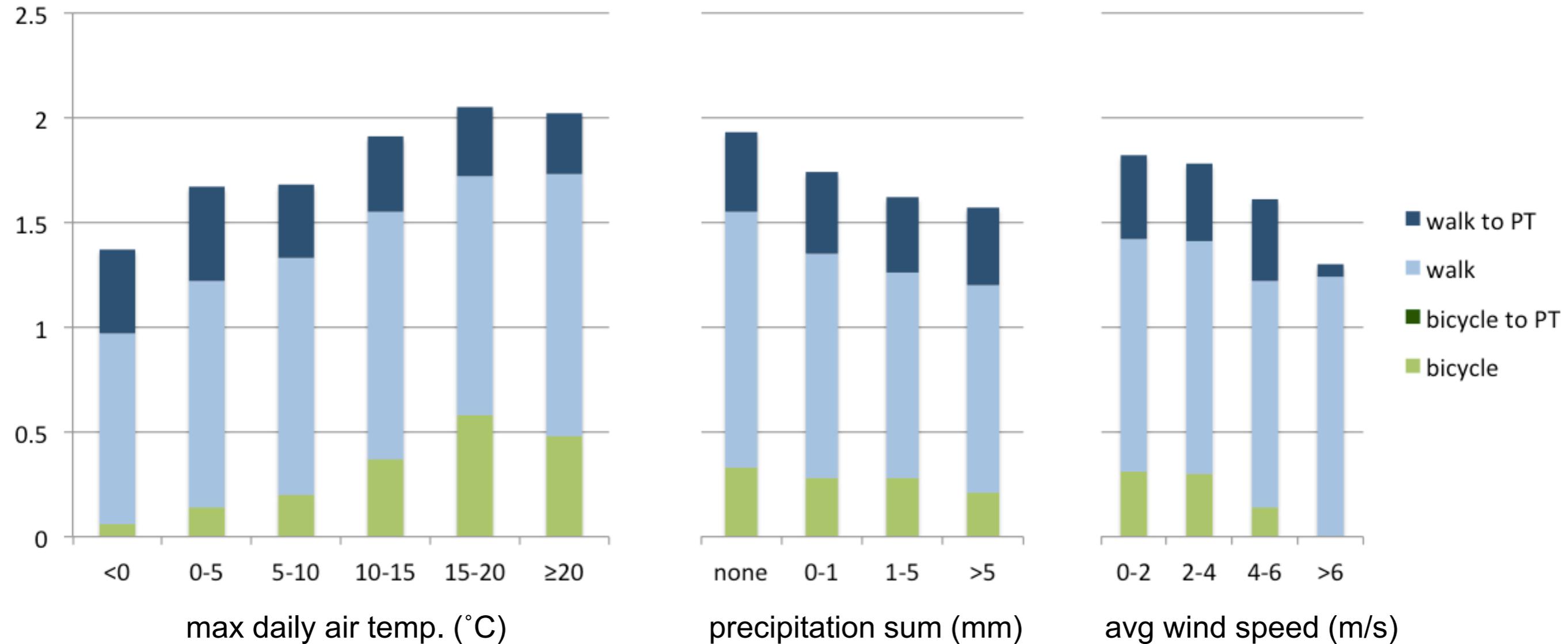
MET-hours/person/day



## Oslo

# Weather and physical activity

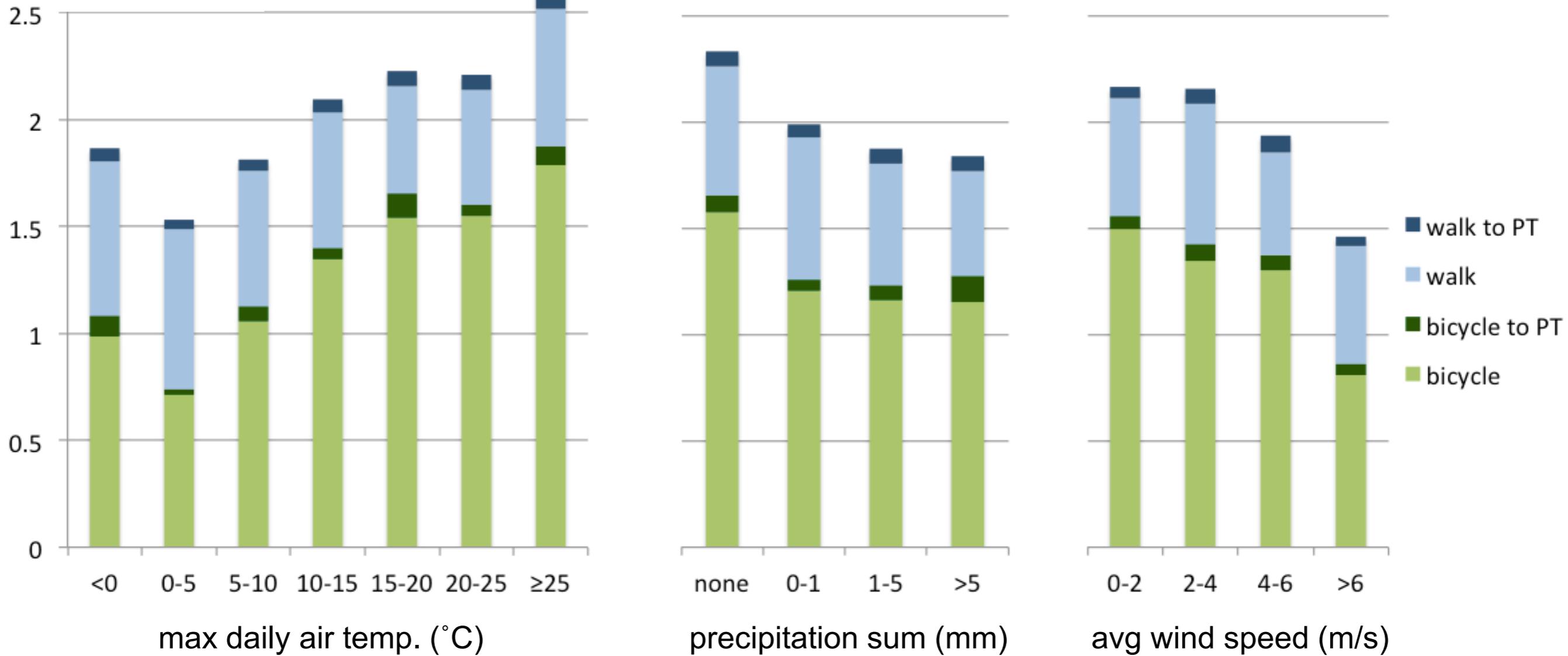
MET-hours/person/day



Oslo

# Weather and physical activity

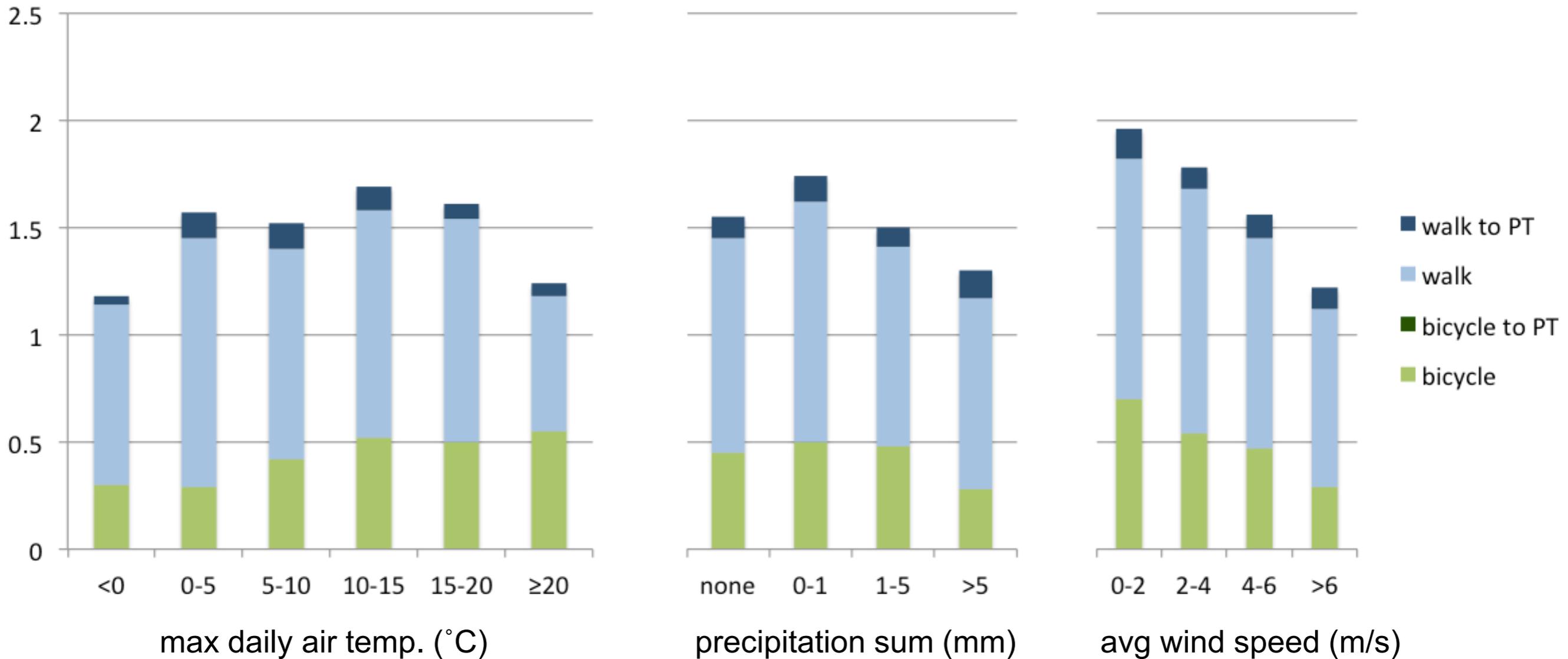
MET-hours/person/day



## Utrecht

# Weather and physical activity

MET-hours/person/day



## Stavanger

# Multivariate analyses (TOBIT model)

## Daily weather

(avg. between 6am - midnight)

- Air temperature in °C
- Air temp. squared
- Precipitation sum in mm
- Avg. wind speed in m/s

## Energy use for daily mobility

- MJ (fossil-based)
- MJ (electric)
- MJ (human)

## Physical activity from mobility

- MET-hours walking
- MET-hours walking to PT
- MET-hours cycling
- MET-hours cycling to PT
- MET-hours total

# Multivariate analyses (TOBIT model)

## Background attributes

- Age, gender, income, educ.
- Working hours, hh-type
- Car / bicycle ownership
- Weekend, school holiday
- Population density

## Daily weather

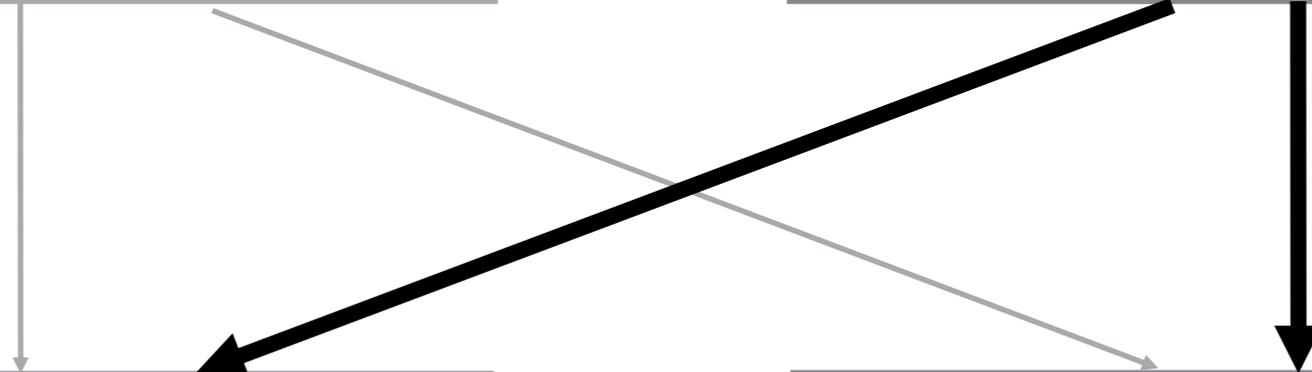
- (avg. between 6am - midnight)
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## Physical activity from mobility

- MET-hours walking
- MET-hours walking to PT
- MET-hours cycling
- MET-hours cycling to PT
- MET-hours total



# Multivariate results Utrecht

	External energy use (MJ per person per day)		Human physical activity (MET-hours per person per day)		
	fossil	electric	walking	cycling	total
Air Temperature (avg) in °C	-0.49***	1.28**	-0.05**	0.13***	0.04***
Air Temperature (squared)	n/a	n/a	n/a	n/a	n/a
Precip. (sum) in mm	0.00	0.59	0.00	-0.01	-0.00
Wind speed (avg) in m/s	0.89	-0.16	-0.06	-0.29***	-0.19**

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# Multivariate results Oslo

	External energy use (MJ per person per day)		Human physical activity (MET-hours per person per day)		
	fossil	electric	walking	cycling	total
Air Temperature (avg) in °C	-0.01	0.01	0.02*	0.74***	0.06***
Air Temperature (squared)	0.02	-0.01	-0.00**	-0.02***	-0.00**
Precip. (sum) in mm	0.68*	0.08	-0.02*	-0.03	-0.03**
Wind speed (avg) in m/s	-4.78***	0.02	0.01	-0.30	-0.02

# Multivariate results Stavanger

	External energy use (MJ per person per day)		Human physical activity (MET-hours per person per day)		
	fossil	electric	walking	cycling	total
Air Temperature (avg) in °C	-1.26	0.26	-0.03	0.54**	0.11
Air Temperature (squared)	0.06	-0.02	-0.00	-0.02	-0.00
Precip. (sum) in mm	-0.33	-0.47	-0.04*	-0.01	-0.05**
Wind speed (avg) in m/s	-1.00	-0.17	-0.09**	-0.21	-0.14***

# Multivariate results Stavanger

	External energy use (MJ per person per day)		Human physical activity (MET-hours per person per day)		
	fossil	electric	walking	cycling	total
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Wind speed (avg) in m/s	-1.00	-0.17	-0.09**	-0.21	-0.14***

# Conclusion & discussion

- Light, warm but not too hot, calm and dry atmospheric conditions have the ability to positively affect cycling and the selection of outdoor leisure destinations, and also boost physical activity gained from mobility, but not necessarily decrease fossil fuel
- Cold, wet and windy weather enhances car use and travel optimising strategies like trip chaining to reduce weather exposures
- Considerable regional differences in weather effects, related to differences in land use and transport regime, climate conditions, cultures, habits and adaptations
- Policy makers are advised to be cautious when translating research findings and policy solutions on weather and mobility from other geographical contexts

# Conclusion & discussion

## Research agenda...

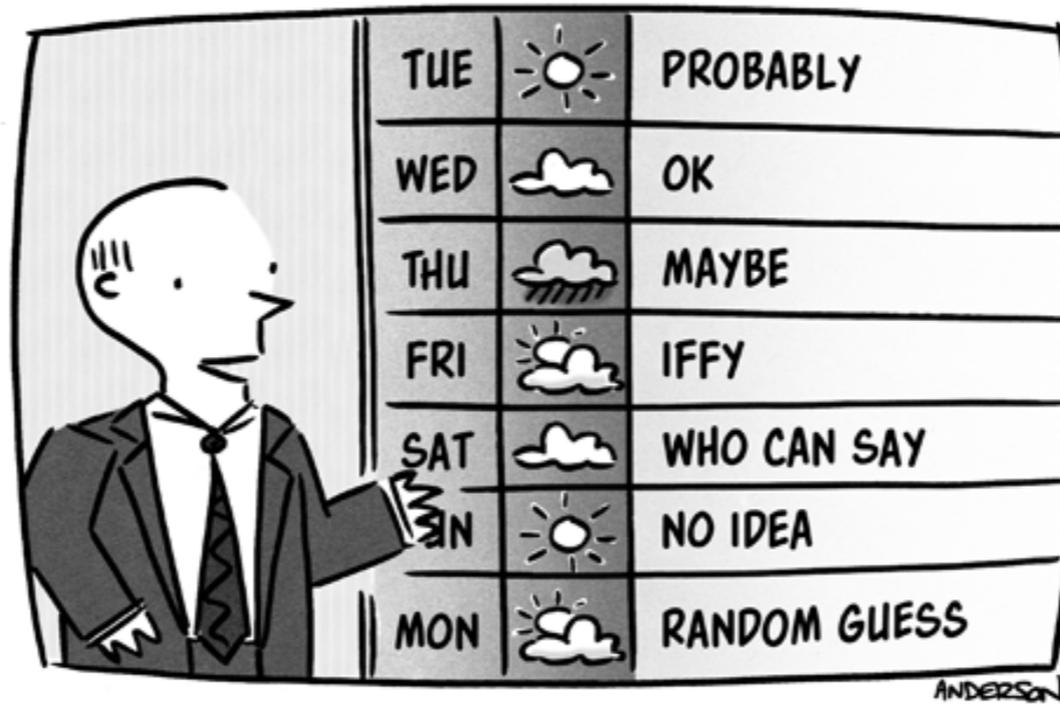
- Comparison studies to cover wider range of climates and (transport) cultures
- Also qualitative comparison studies that could provide insights on weather comfort and habits, adaptation and coping strategies related to weather
- Differential weather effects on socio-demographic/economic/cultural groups
- Explore alternative futures: climate scenarios, travel demand scenarios, (socio) technological innovation
- New transport modes: car/ride/bike sharing, e-bikes
- Long-distance (especially air) business and leisure travel

**...but we cannot change the weather, why do we study this?**

# Thank you!

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"And now the 7-day forecast..."

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