H_2 infrastructure

-Electric distribution and hydrogen production-

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and Samsýn

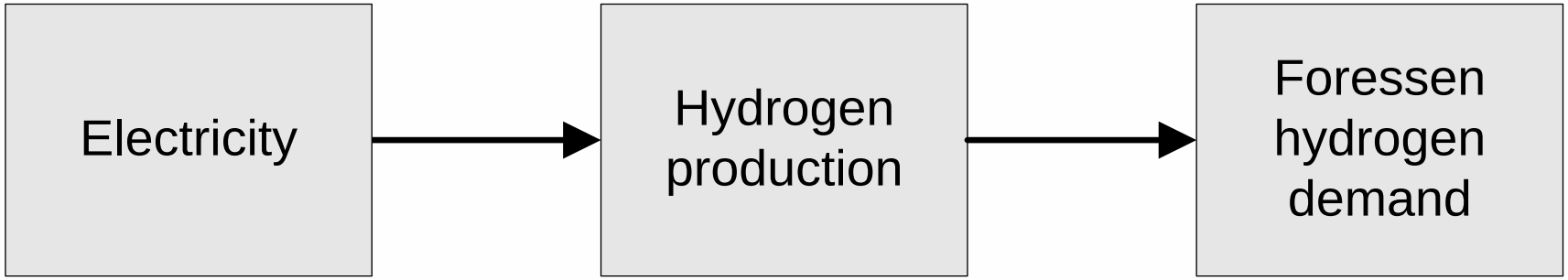
Objective

- Evaluate whether the current electric grid of 3 different locations could deliver the power needed to cover foreseen hydrogen demand
  - Reykjavík (Iceland)
    - The Reykjavík Energy service area
  - Þórshöfn (Faroe Islands)
  - Nuuk (Greenland)
- Examine if a similar approach can be applied in smaller locations such as Iquilik in Nunavut

Objective

- Data input
  - Electric grid
  - Hydrogen production
  - Geographical patterns
  - Population and number of cars

- Outcome
  - Understanding the correlation between electricity distribution and hydrogen production for expected hydrogen demand



Project procedure

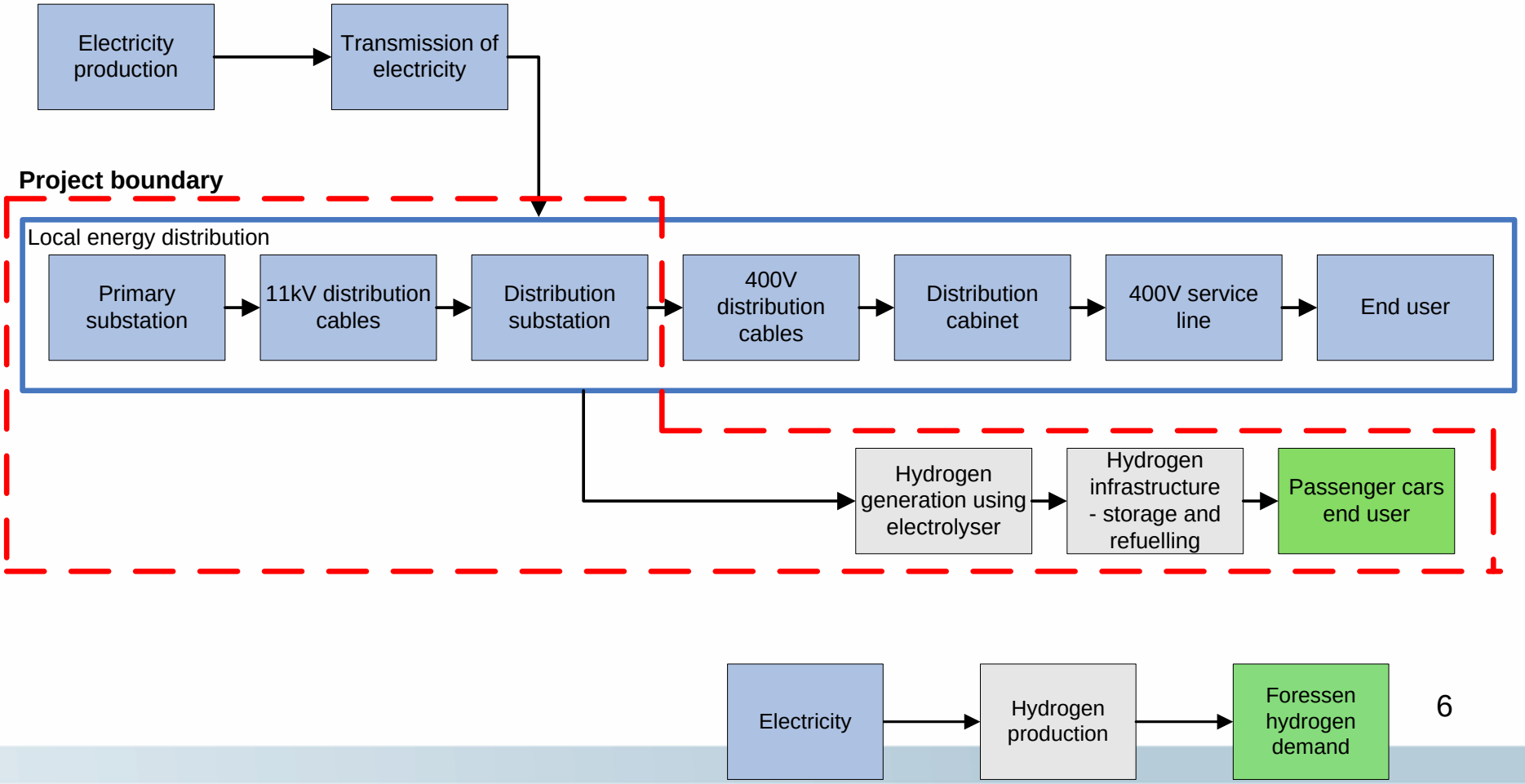
- Analyze the capacity of the electric grids
- Estimate the demand for hydrogen until 2030
- Find possible locations for the hydrogen stations
- Then use optimization model to find the best locations for the on site hydrogen stations

- The study excludes transport of hydrogen

Project boundaries

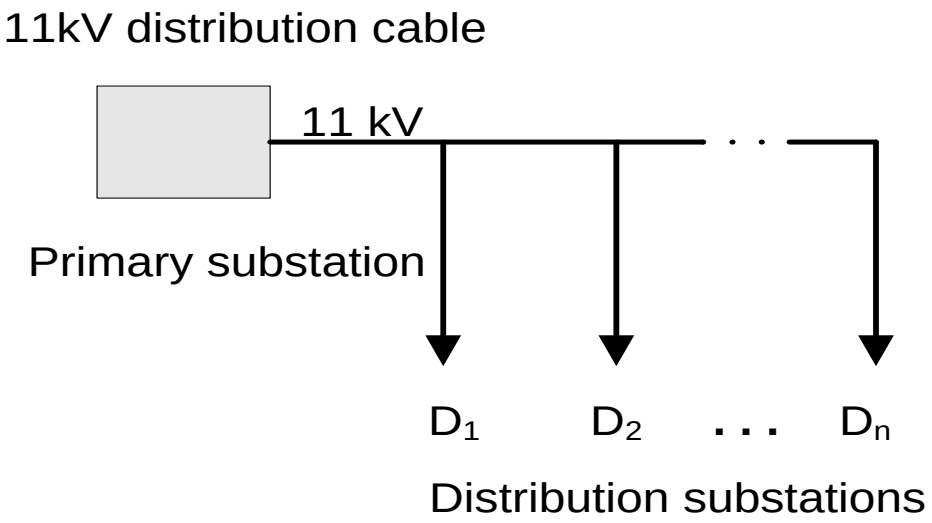
- Electrolysis
- Passenger cars (1-8 persons)
- 3 case areas
- Study time frame
  - 2008 - 2030
- Project duration
  - June 2007 to June 2008

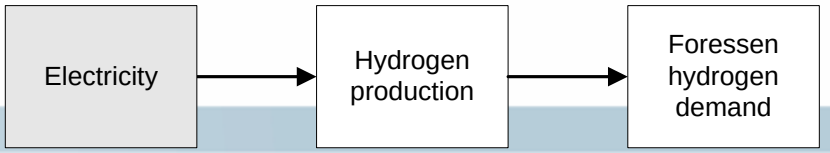
Project Boundaries



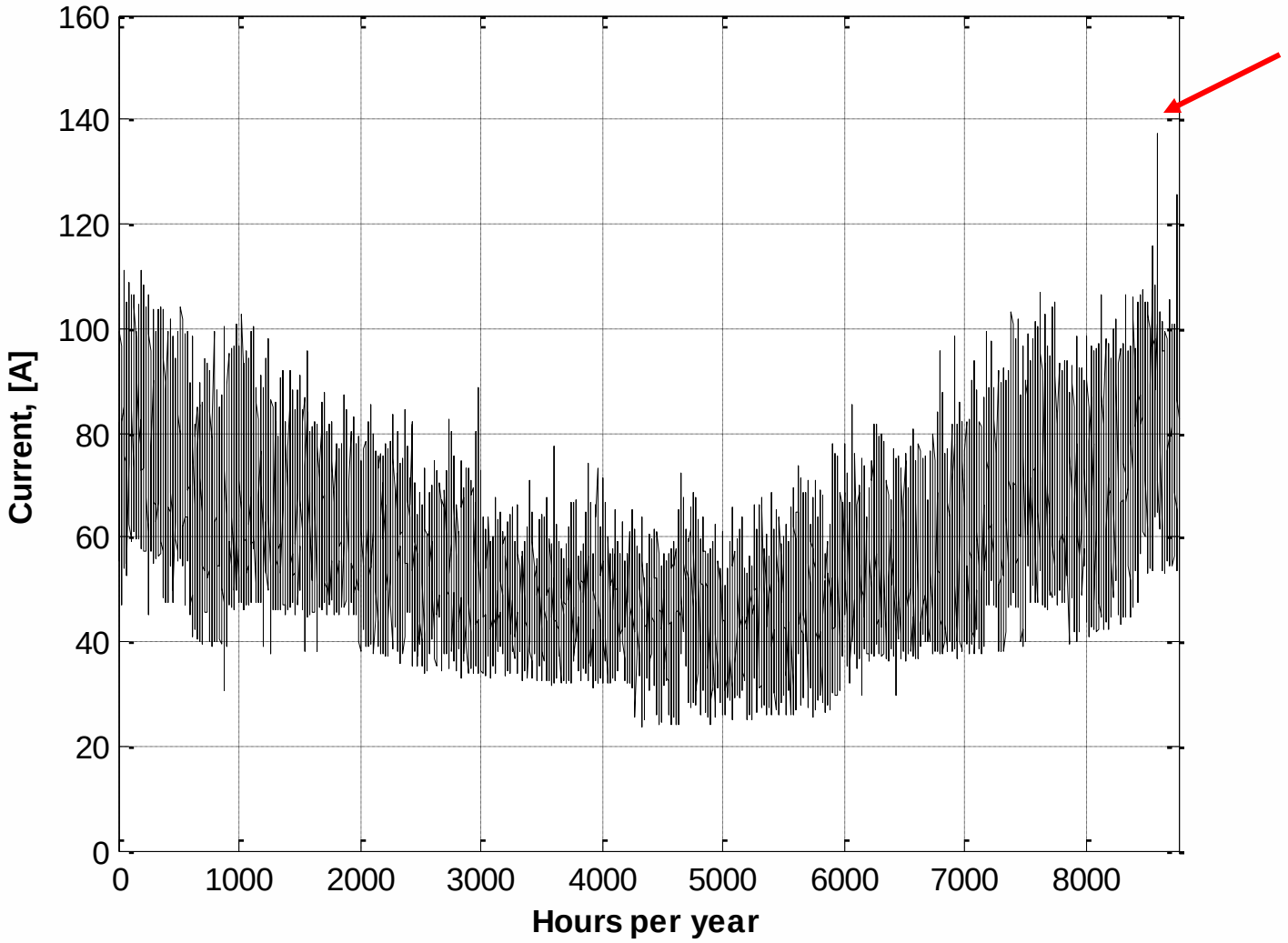
The electric grid

- From the primary substations 11kV cables connect a number of distribution substations and terminate in circuit breakers



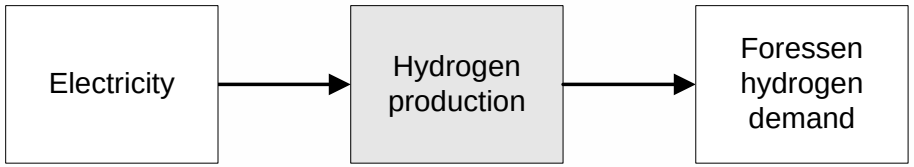


The electricity grid



On-site production stations

- Three possible hydrogen station sizes will be analysed
  - Production capacity of 130, 485 and 970 Nm^3/h
  - The current hydrogen station in Iceland has a production capacity of 60 Nm^3/h



Hydrogen stations

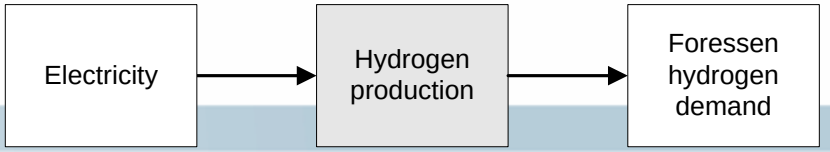
- How much current is needed to operate the hydrogen stations on full capacity can be calculated with this equation, solved for I

$$P = U * I * \sqrt{3} * \cos\varphi$$

- New 11kV distribution cable needed

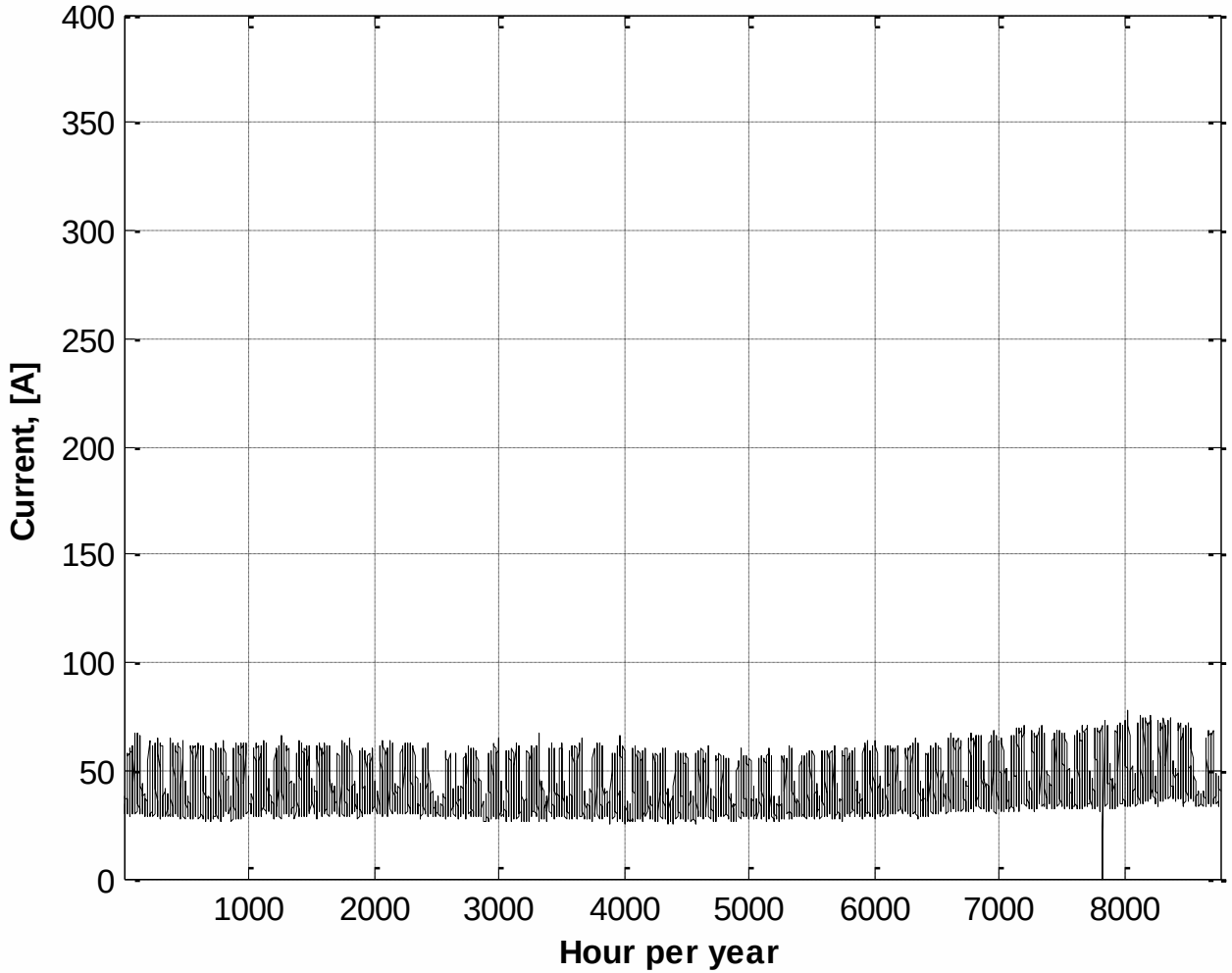
Production capacity	**130**	**485**	**970**	**Nm3/h**
Specific energy constant	5	5	5	kWh/Nm3
Installed power	0.65	2.43	4.85	MW
Current	**34.1**	**127.3**	**254.6**	**A**

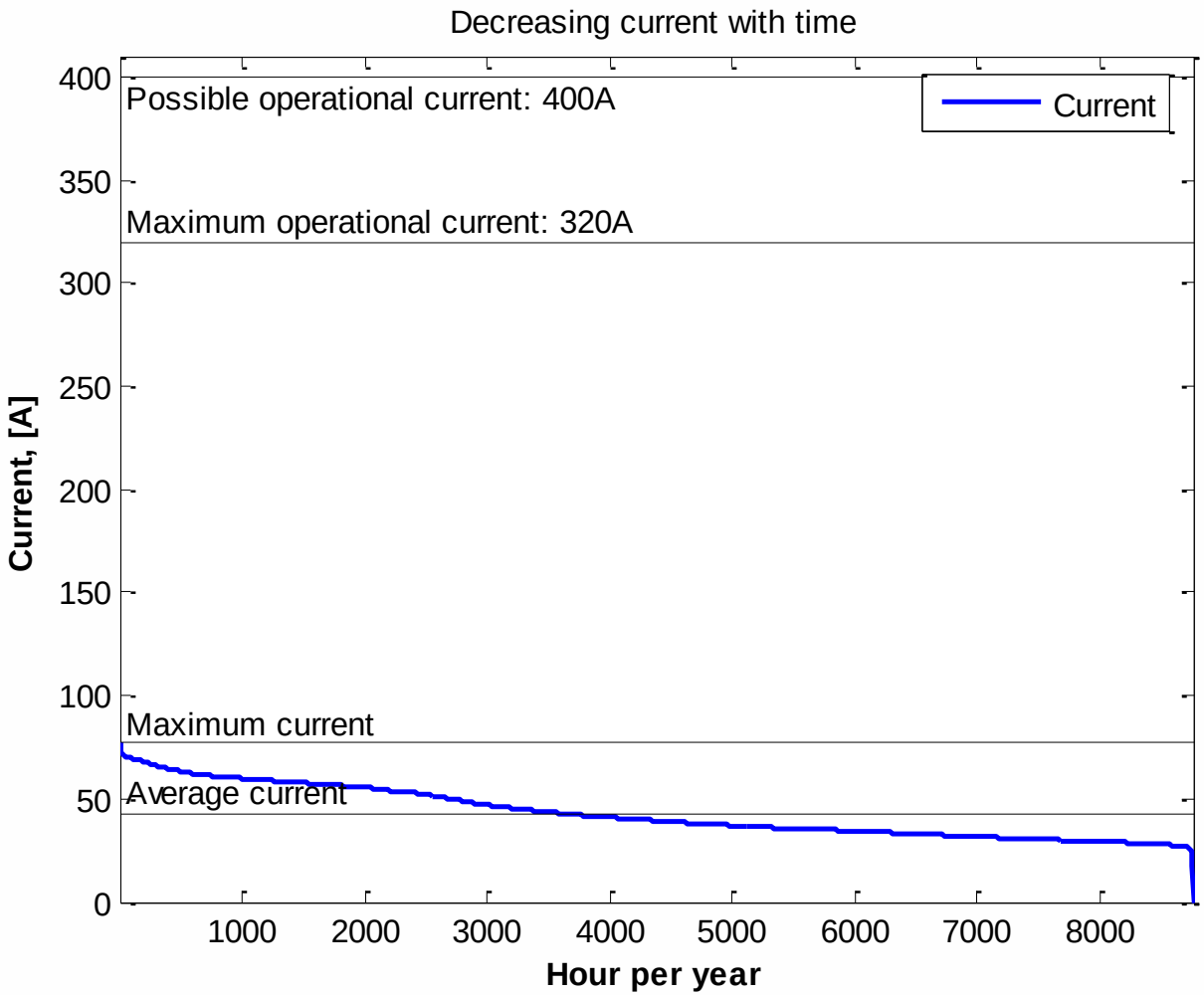
when the voltage is 11kV



11kV distribution cable

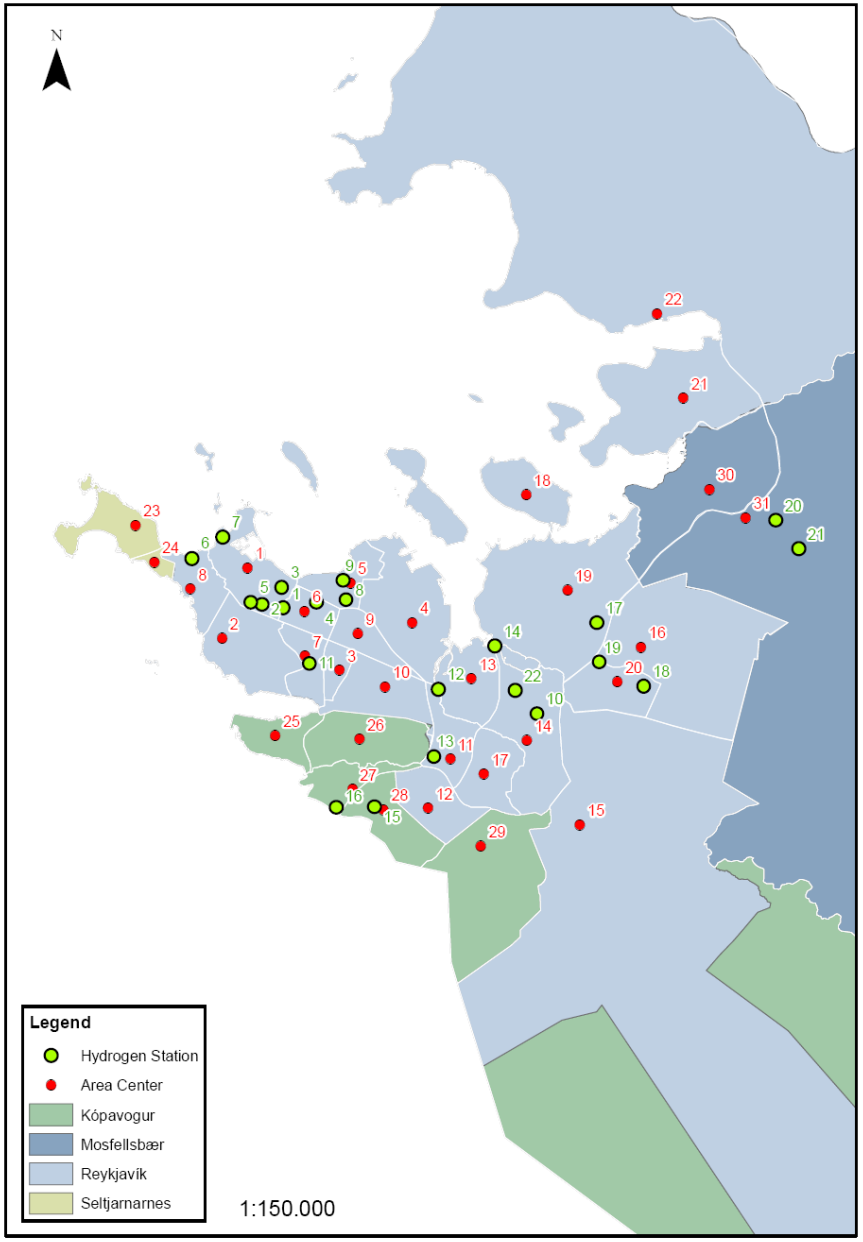
With maximum operational current of 320A



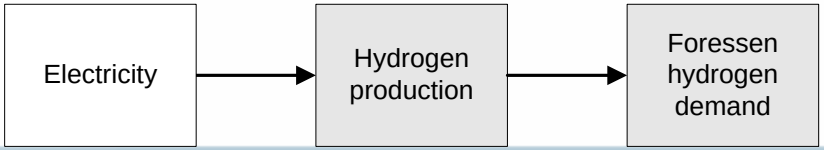


Maximum current = 77.4 A

Leftover current of (320*80%)-77,4 = 178,6 A

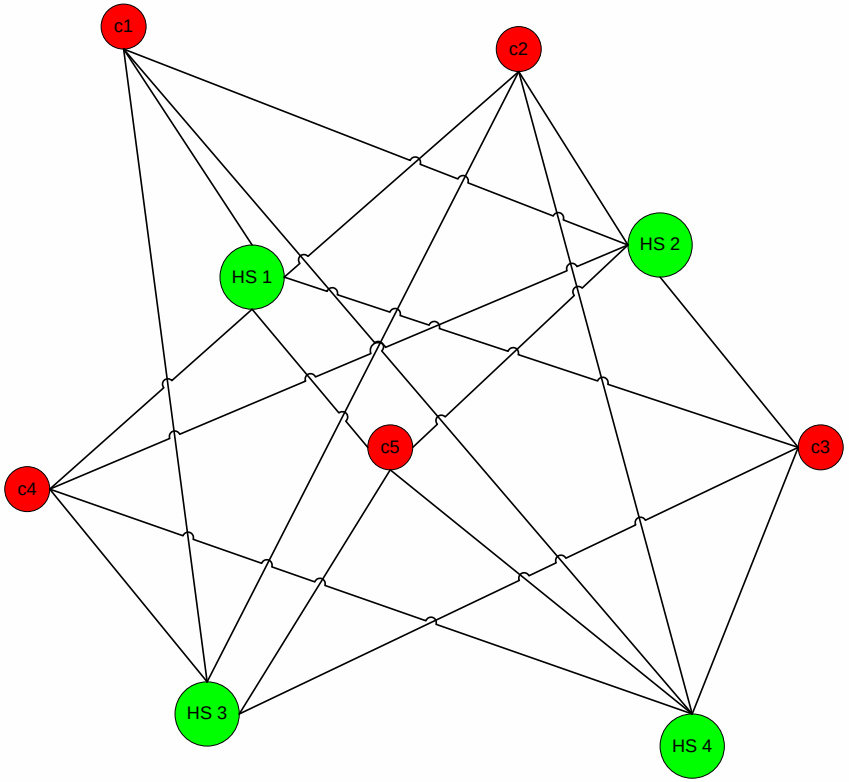


- 21 possible locations for hydrogen stations
- Hydrogen station number 22 is the current hydrogen station
- The overall region was divided into 31 demand areas



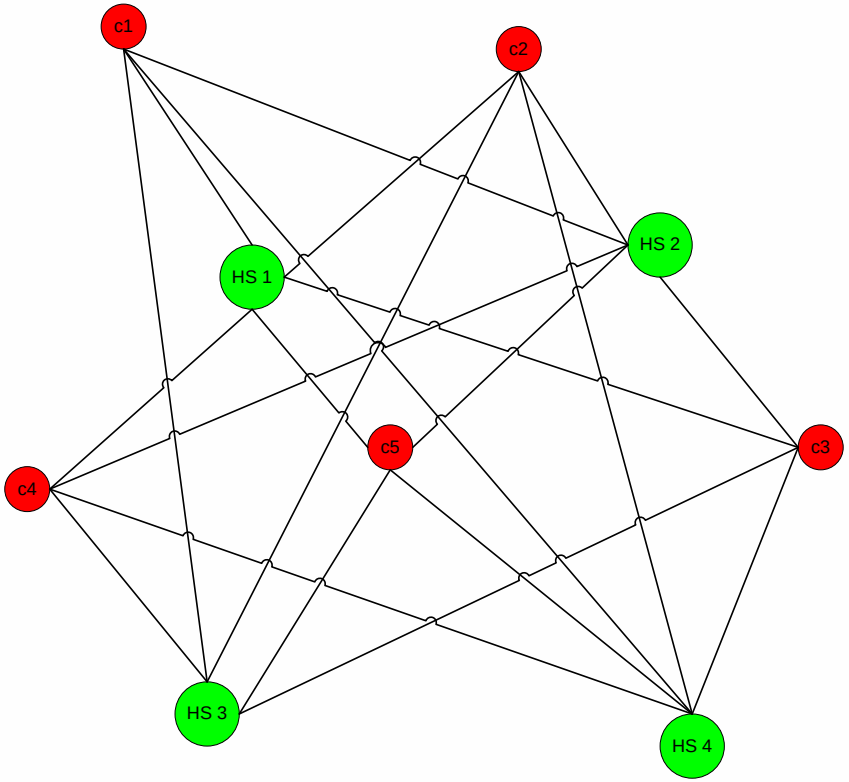
Driving time measurements

- The objective is to end up with a network of points similar to this, with defined
  - Possible hydrogen station locations
  - Area demand points
  - Driving time from the areas to the hydrogen stations
- Optimization is then used to find out at which location and of what size hydrogen station should be opened.



Customer choice

- The objective is to find locations to open a hydrogen station that minimizes the overall travelling time from the customers' homes.



Customer choice

- A survey was sent out to all students at the University of Iceland
- In the attempt to map up current customer behaviour

- Results
  - 74% claim that the most frequently use fuelling station is within a 7 minute drive from their home
  - 65% most frequently take fuel close to home

Location model

$$Z = \min \sum_{i=1}^{n} \sum_{j=1}^{m} kc_{ij} x_{ij} + \sum_{j=1}^{m} \sum_{k=1}^{u} f_{jk} y_{jk} \quad (1)$$

$$\text{s.t.} \sum_{k=1}^{u} y_{jk} \leq 1 \quad for\ j = 1,\ldots,m \quad (2)$$

$$\sum_{j=1}^{m} x_{ij} \geq d_i \quad for\ i = 1,\ldots,n \quad (3)$$

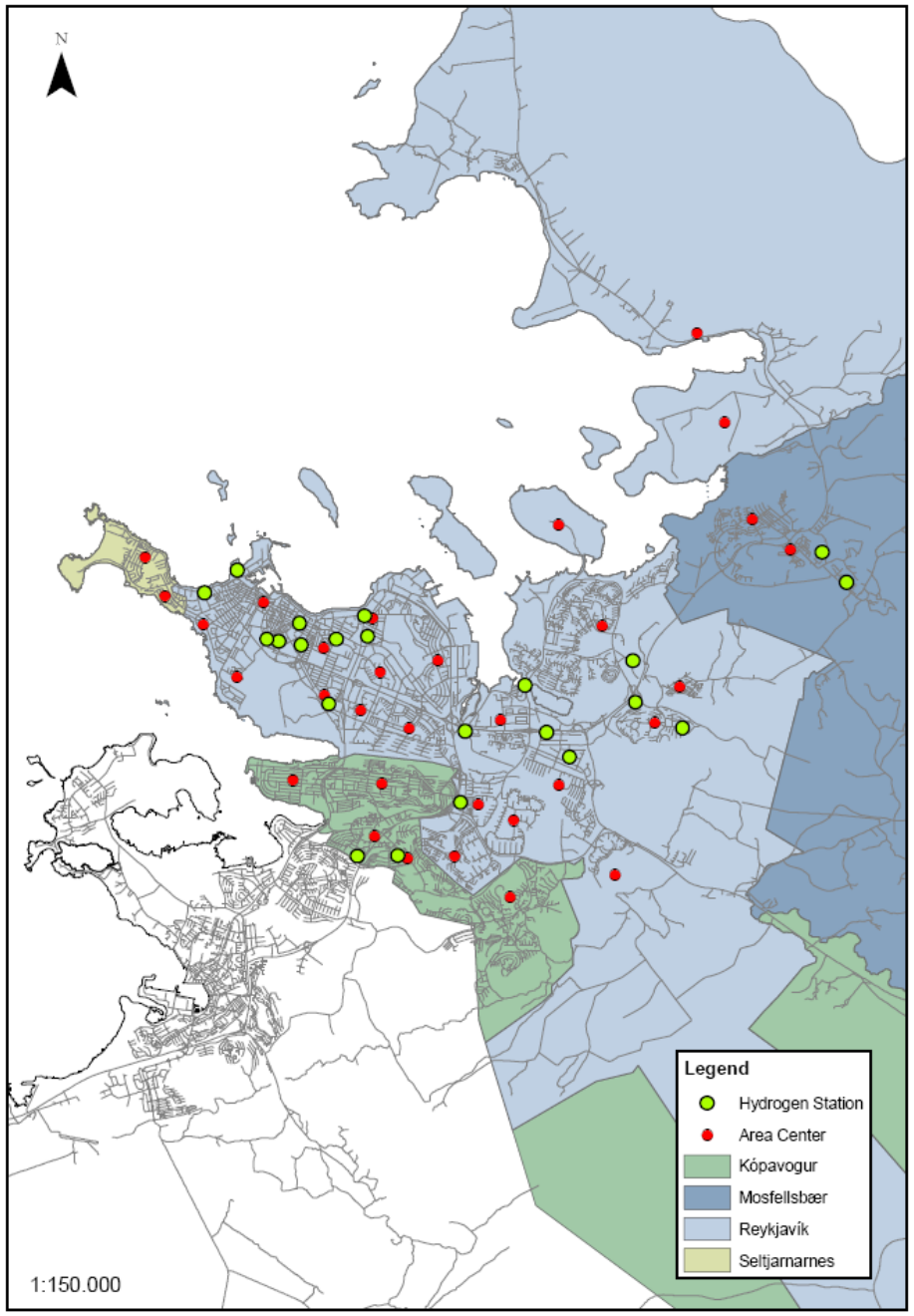
$$\sum_{i=1}^{n} x_{ij} - \sum_{k=1}^{u} y_{jk} s_k \leq 0 \quad for\ \ j = 1,\ldots,m \quad (4)$$

$$x_{ij} \geq 0 \quad and\ integer \quad for\ i = 1,\ldots,n,\ j = 1,\ldots,m \quad (5)$$

$$y_{jk} \in \{0,1\} \quad for\ \ j = 1,\ldots,m,\ k = 1,\ldots,u \quad (6)$$

- **Comments:**

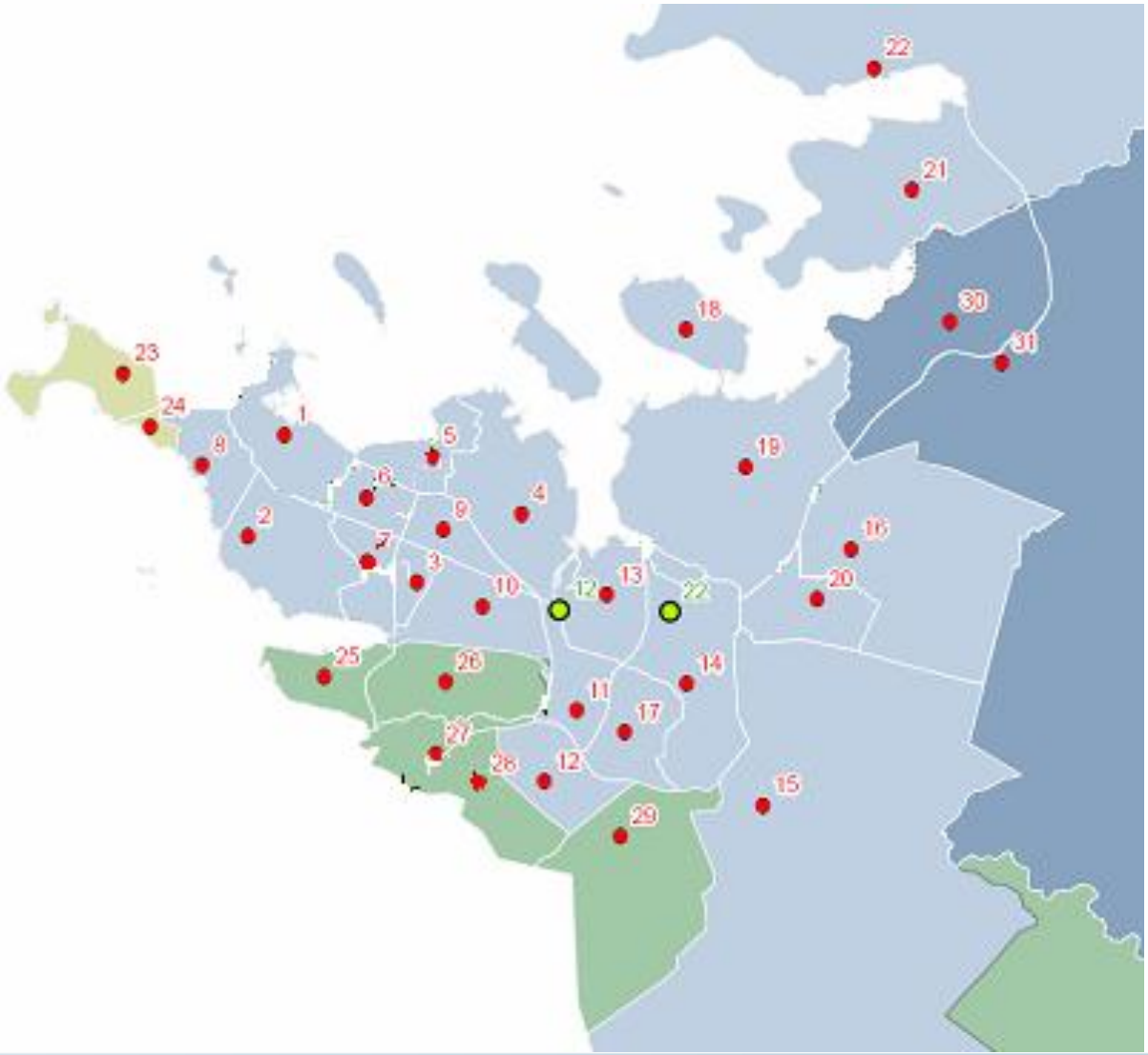
1. The objective function
2. There can only be one hydrogen station at each location
3. Satisfaction of the demand of client area i
4. There have to be enough hydrogen stations open to fulfil the needed demand
5. x must be a positive integer value or zero
6. y is a binary number



Results

- The study region has been divided into 31 areas and the weight areas centres found
- 21 possible locations for hydrogen stations

2012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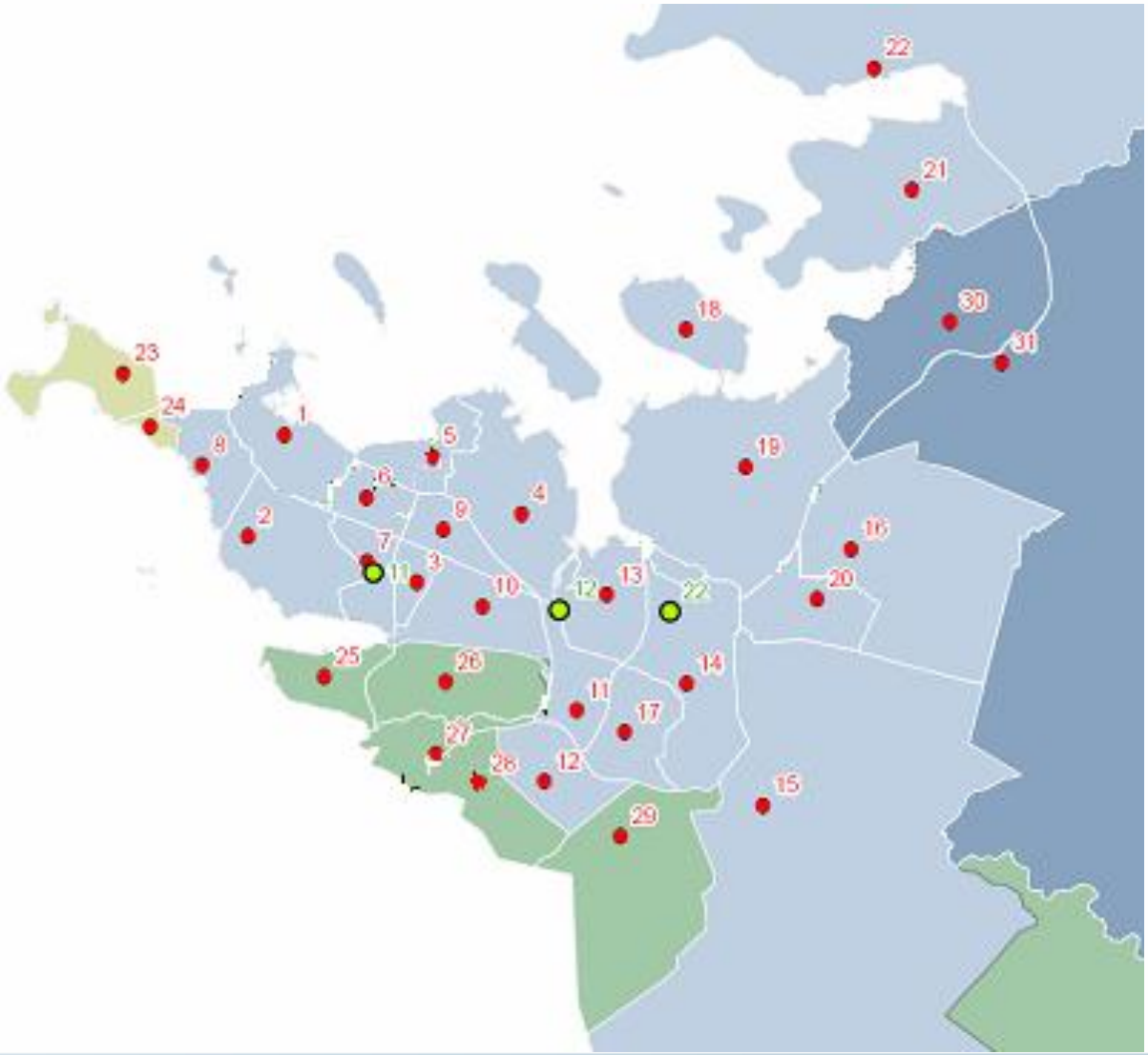
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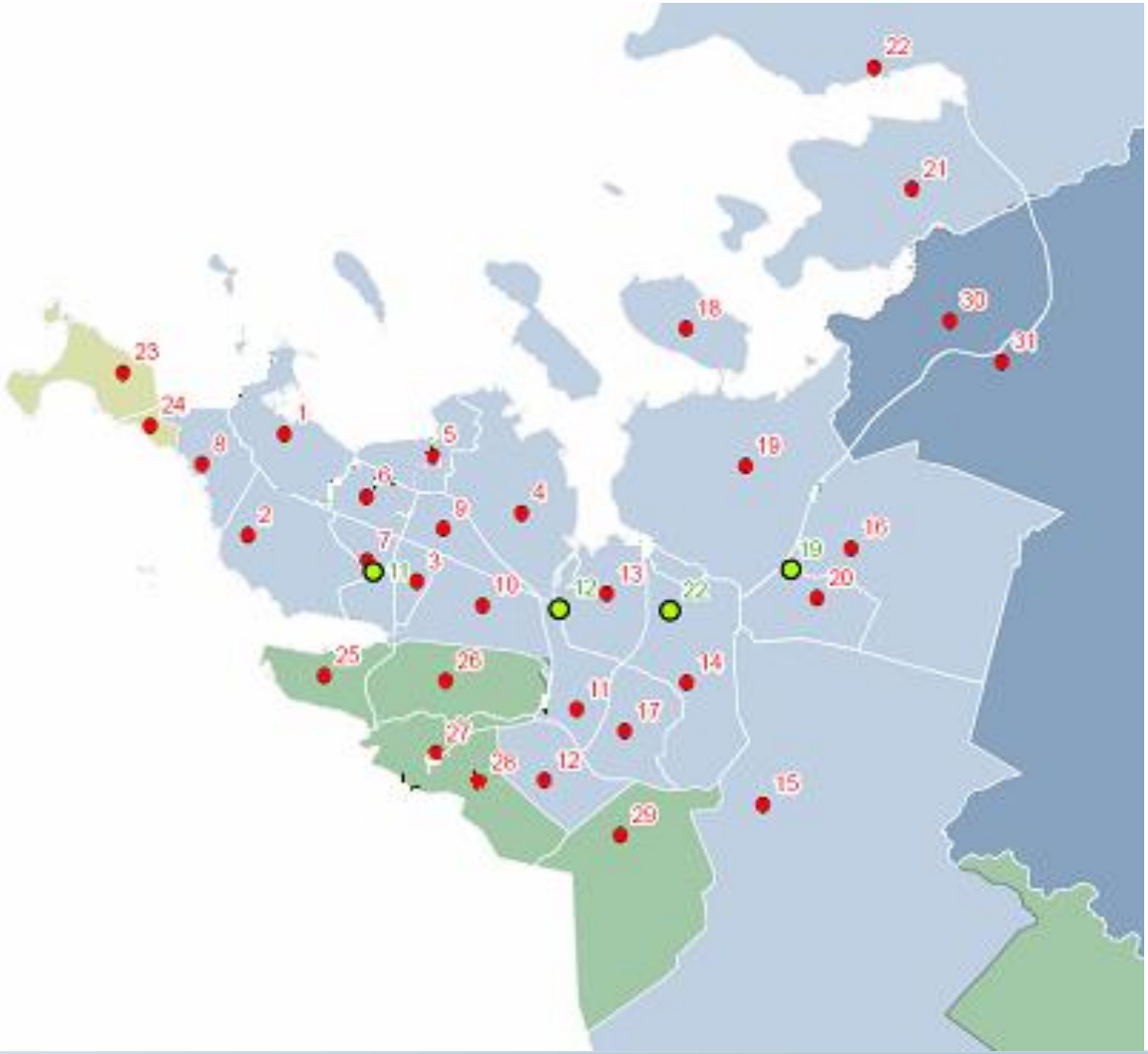
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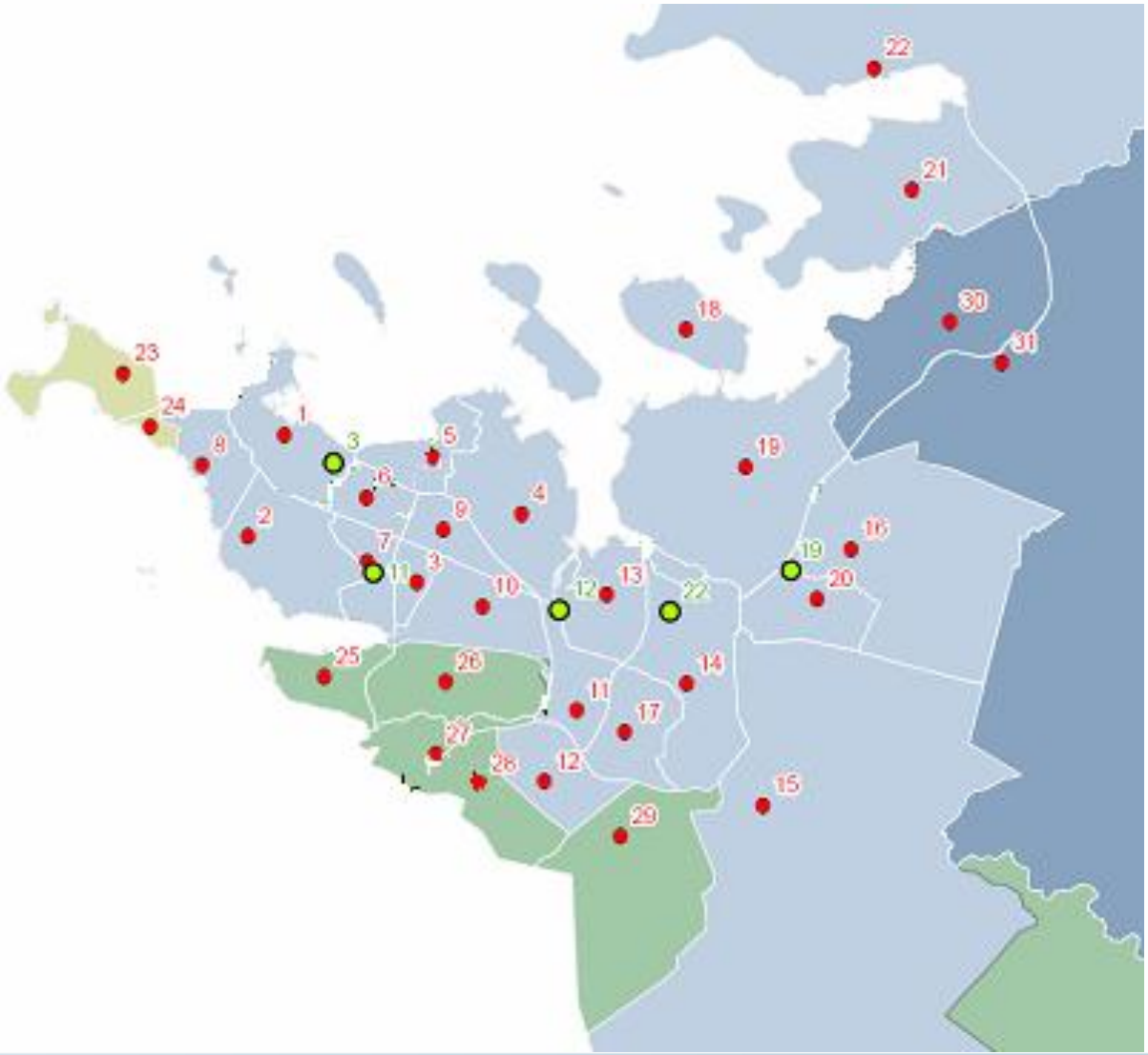
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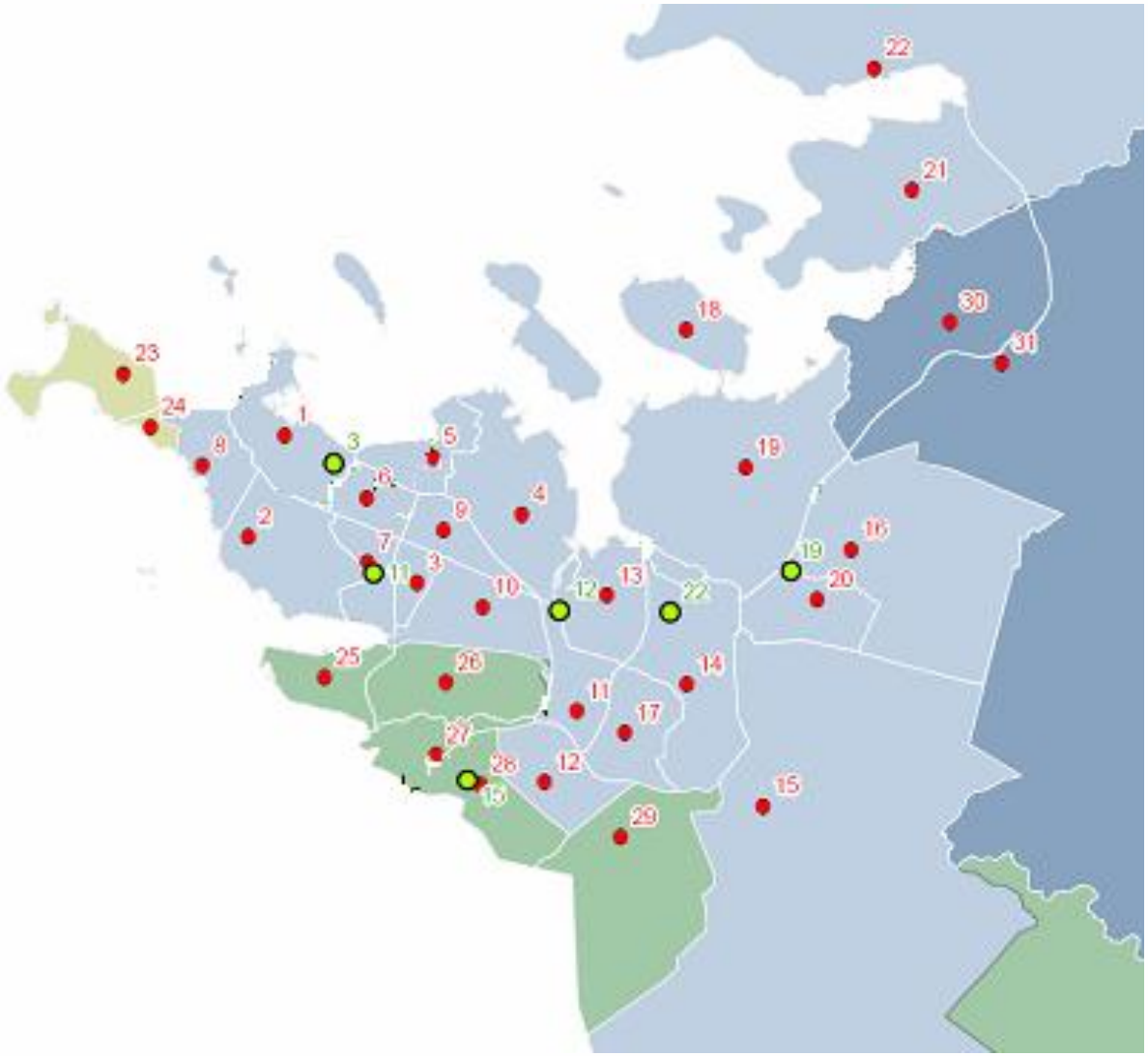
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Thank you for your attention