OPTIMIZATION OF THE ELECTRIC POWER SYSTEM OF MACEDONIA

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- Introduction
- The electric power system of Macedonia
- The model of the electric power system of Macedonia
- Typical examples
- Conclusion

Introduction

- Classification of energy models
  - The model analyses energy production and is based upon technical aspects of the energy system and is concerned with meeting the requirements for equilibrium between energy supply and demand
  - The users have to make assumptions about the values of the parameters
  - The engineering approach of bottom up is used
  - The model can be classified as optimization and simulation model
  - The linear programming technique is applied
  - Geographical coverage is national
  - The model is intended for the analysis of energy production and consumption in regions of Macedonia
  - Time period: short term
  - Input data: electricity demand and electricity generation and transmission capacities and prices.

- Our approach is based on the work: A. Quelhas, E. Gil, J. D. McCalley and S. M. Ryan, "A Multiperiod Generalized Network Flow Model of the U.S. Integrated Energy System: Part I—Model Description", IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 22, NO. 2, MAY 2007
- In this paper the authors presented the bottom-up model that addresses a medium term operational horizon (several months to 2–3 years) and follows an optimization methodology that captures the physical and environmental restriction of the coal, natural gas, and electricity flows.
- We have modified and extended this work in several directions to include short-term (on daily basis) analysis of the Macedonian power system.

The electric power system of Macedonia

- The electric power system of Macedonia is operated by four entities, namely:
  - AD **ELEM,** company for generation and supply of electricity,
  - AD **MEPSO – Skopje,** company for transmission of electricity and management with the electric power system of Macedonia,
  - The distribution company **EVN Macedonia** AD and
  - AD **TPP Negotino**, company for electricity generation.

Electricity generation

TPP	P_{min} [MW]	P_{max} [MW]	Fuel type
Bitola I	160	225	Lignite
Bitola II	160	225	Lignite
Bitola III	160	225	Lignite
Oslomej	90	125	Lignite
Negotino I	70	105	Heavy fuel oil
Negotino II	70	105	Heavy fuel oil
Total	**710**	**1010**	

- Basic parameters of TPPs

- Basic parameters of HPPs

HPP	Catch-ment	Number of units	Q_{inst}/unit [m^3/s]	H_{gross} [m]	Volume [10^6 m^3]	P_{inst} [MW]
Vrutok	Mavrovo	4	9	574	277	172
Tikvesh	Crna Reka	4	36	100	272	116
Globocica	Crn Drim	2	27	110,9	228	42
Shpilje	Crn Drim	3	36	95	212	84
Kozjak	Treska	2	50	102	260	88
Raven	Mavrovo	3	10,6	66	0	21,6
Vrben	Mavrovo	2	4,6	193	0	12,8
Total						**536**

Generation and transmission of electricity

Small HPPs		P_{inst} [MW]
MAK ROT program	Sapunchica	2,9
	Kalimanci	13,8
	Zrnovci	1,4
	Doshnica	4,1
	Pesochani	2,7
	Matka	9,6
	Pena	2,5
Other EVN	Babuna	0,7
	Belica	0,3
	Turija	2,2
	Popova Shapka	4,8
Other companies	Strezhevo	3,4
	Komunalec	1,2
TOTAL		49,6

- Basic parameters of small HPPs in the network of EVN Macedonia

- Basic parameters of high voltage power lines

Voltage [kV]	Length [km]
400	594
220	103
110	1480

MEPSO

MACEDONIAN ELECTRICITY SYSTEM OPERATOR

Electric and power system of the Republic of Macedonia
Planned situation with connection of future HPPs
Substations

SS 400/110 kV/kV
SS 220/110 kV/kV
SS 110/x kV/kV

Power lines

400 kV
Planned
400 kV
interconnection
220 kV
110 kV
Planned
110 kV PL

Power plants

Hydro PP
Thermal PP

June 2008

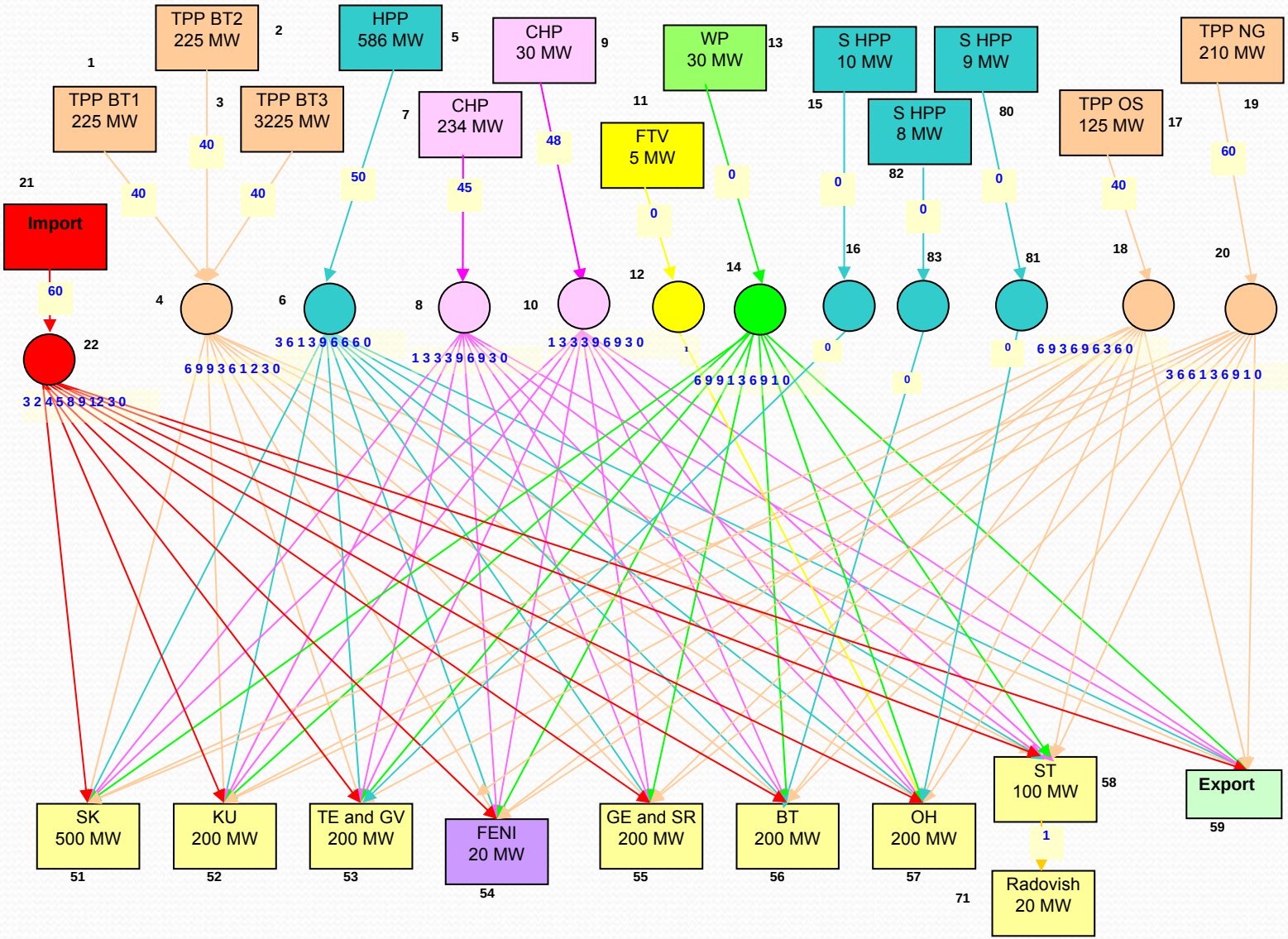
Generation and transmission price

- Average electricity generation price

Power plant	€/MWh
Lignite TPP	40
Heavy fuel oil TPP	60
Natural gas CHP (234 MW)	45
Natural gas CHP (30 MW)	48
HPP	50
Import	60

- Electricity transmission price (1-9 € per MWh)

Network diagram of the model



Mathematical model of the electric power system of Macedonia

1 $x_{1,4} \le 225$

2 $x_{2,4} \le 225$

3 $x_{3,4} \le 225$

4 $-x_{1,4} - x_{2,4} - x_{3,4} + x_{4,51} + x_{4,52} + x_{4,53} + x_{4,54} + x_{4,55} + x_{4,56} + x_{4,57} + x_{4,58} + x_{4,59} = 0$

5 $x_{5,6} \le 580$

6 $-x_{5,6} + x_{6,51} + x_{6,52} + x_{6,53} + x_{6,54} + x_{6,55} + x_{6,56} + x_{6,57} + x_{6,58} + x_{6,59} = 0$

7 $x_{7,8} \le 230$

8 $-x_{7,8} + x_{8,51} + x_{8,52} + x_{8,53} + x_{8,54} + x_{8,55} + x_{8,56} + x_{8,57} + x_{8,58} + x_{8,59} = 0$

9 $x_{9,10} \le 30$

10 $-x_{9,10} + x_{10,51} + x_{10,52} + x_{10,53} + x_{10,54} + x_{10,55} + x_{10,56} + x_{10,57} + x_{10,58} + x_{10,59} = 0$

11 $x_{11,12} \le 5$

12 $-x_{11,12} + x_{12,57} = 0$

13 $x_{13,14} \le 30$

14 $-x_{13,14} + x_{14,51} + x_{14,52} + x_{14,53} + x_{14,54} + x_{14,55} + x_{14,56} + x_{14,57} + x_{14,58} + x_{14,59} = 0$

15 $x_{15,16} \le 10$

16 $-x_{15,16} + x_{16,53} = 0$

17 $x_{17,18} \le 125$

18 $-x_{17,18} + x_{18,51} + x_{18,52} + x_{18,53} + x_{18,54} + x_{18,55} + x_{18,56} + x_{18,57} + x_{18,58} + x_{18,59} = 0$

19 $x_{19,20} \le 210$

20 $-x_{19,20} + x_{20,51} + x_{20,52} + x_{20,53} + x_{20,54} + x_{20,55} + x_{20,56} + x_{20,57} + x_{20,58} + x_{20,59} = 0$

21 $x_{21,22} \le 500$

22 $-x_{21,22} + x_{22,51} + x_{22,52} + x_{22,53} + x_{22,54} + x_{22,55} + x_{22,56} + x_{22,57} + x_{22,58} + x_{22,59} = 0$

51 $x_{4,51} + x_{6,51} + x_{8,51} + x_{10,51} + x_{14,51} + x_{18,51} + x_{20,51} + x_{22,51} = 500$

52 $x_{4,52} + x_{6,52} + x_{8,52} + x_{10,52} + x_{14,52} + x_{18,52} + x_{20,52} + x_{22,52} = 200$

53 $x_{4,53} + x_{6,53} + x_{8,53} + x_{10,53} + x_{14,53} + x_{18,53} + x_{20,53} + x_{22,53} + x_{16,53} = 200$

54 $x_{4,54} + x_{6,54} + x_{8,54} + x_{10,54} + x_{14,54} + x_{18,54} + x_{20,54} + x_{22,54} = 20$

55 $x_{4,55} + x_{6,55} + x_{8,55} + x_{10,55} + x_{14,55} + x_{18,55} + x_{20,55} + x_{22,55} = 200$

56 $x_{4,56} + x_{6,56} + x_{8,56} + x_{10,56} + x_{14,56} + x_{18,56} + x_{20,56} + x_{22,56} = 200$

57 $x_{4,57} + x_{6,57} + x_{8,57} + x_{10,57} + x_{14,57} + x_{18,57} + x_{20,57} + x_{22,57} + x_{12,57} = 200$

58 $x_{4,58} + x_{6,58} + x_{8,58} + x_{10,58} + x_{14,58} + x_{18,58} + x_{20,58} + x_{22,58} = 100$

59 $x_{4,59} + x_{6,59} + x_{8,59} + x_{10,59} + x_{14,59} + x_{18,59} + x_{20,59} + x_{22,59} = 0$

Mathematical model of the electric power system of Macedonia

- Adding new consumer - Radovish

58’ $x_{4,58} + x_{6,58} + x_{8,58} + x_{10,58} + x_{14,58} + x_{18,58} + x_{20,58} + x_{22,58} - x_{58,71} = 80$

71 $x_{58,71} = 20$

- Adding small hydropower plant – Ohrid

80 $x_{80,81} \leq 9$

81 $x_{81,57} - x_{80,81} = 0$

57’ $x_{4,57} + x_{6,57} + x_{8,57} + x_{10,57} + x_{14,57} + x_{18,57} + x_{20,57} + x_{22,57} + x_{12,57} + x_{81,57} = 200$

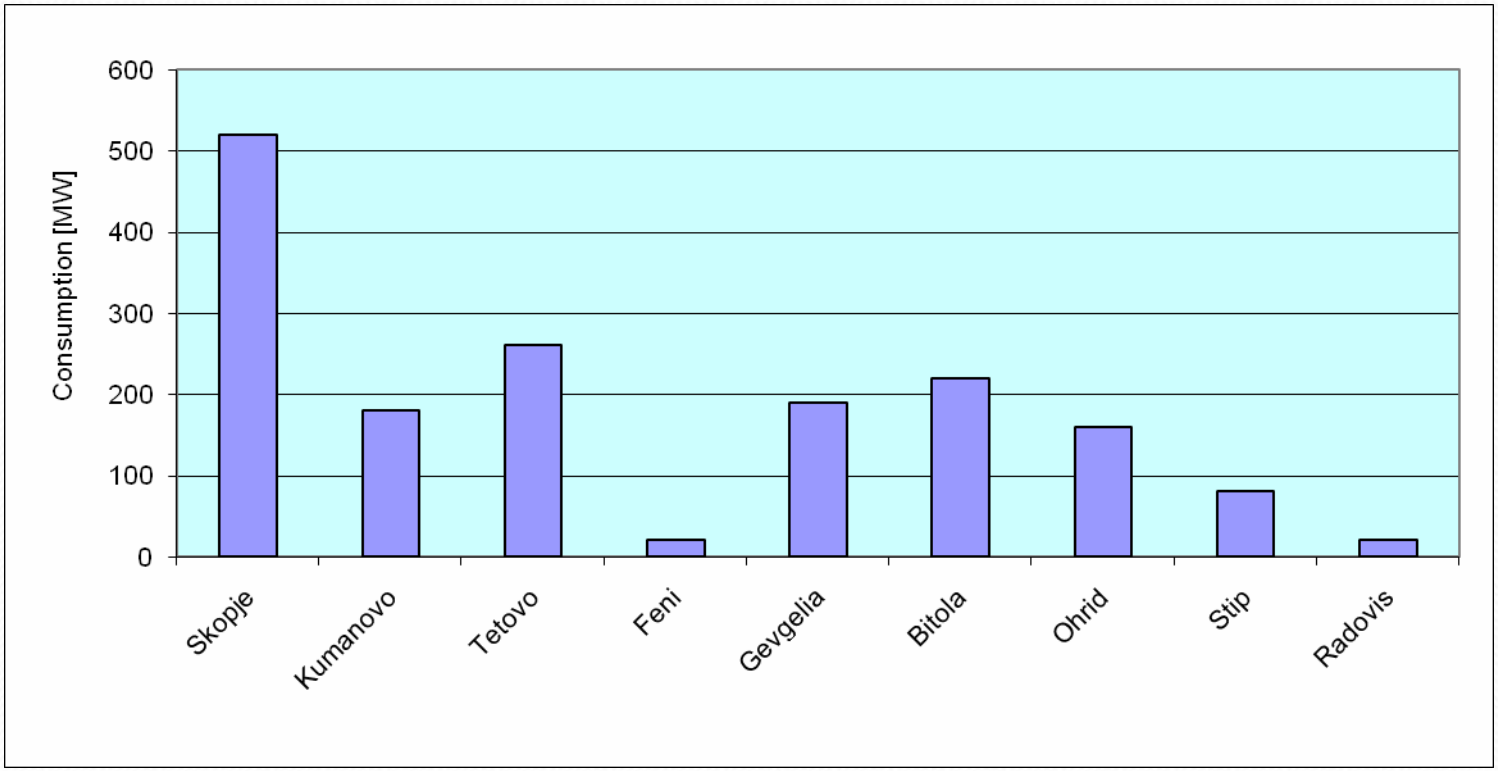
- The model solution

Program for winter day

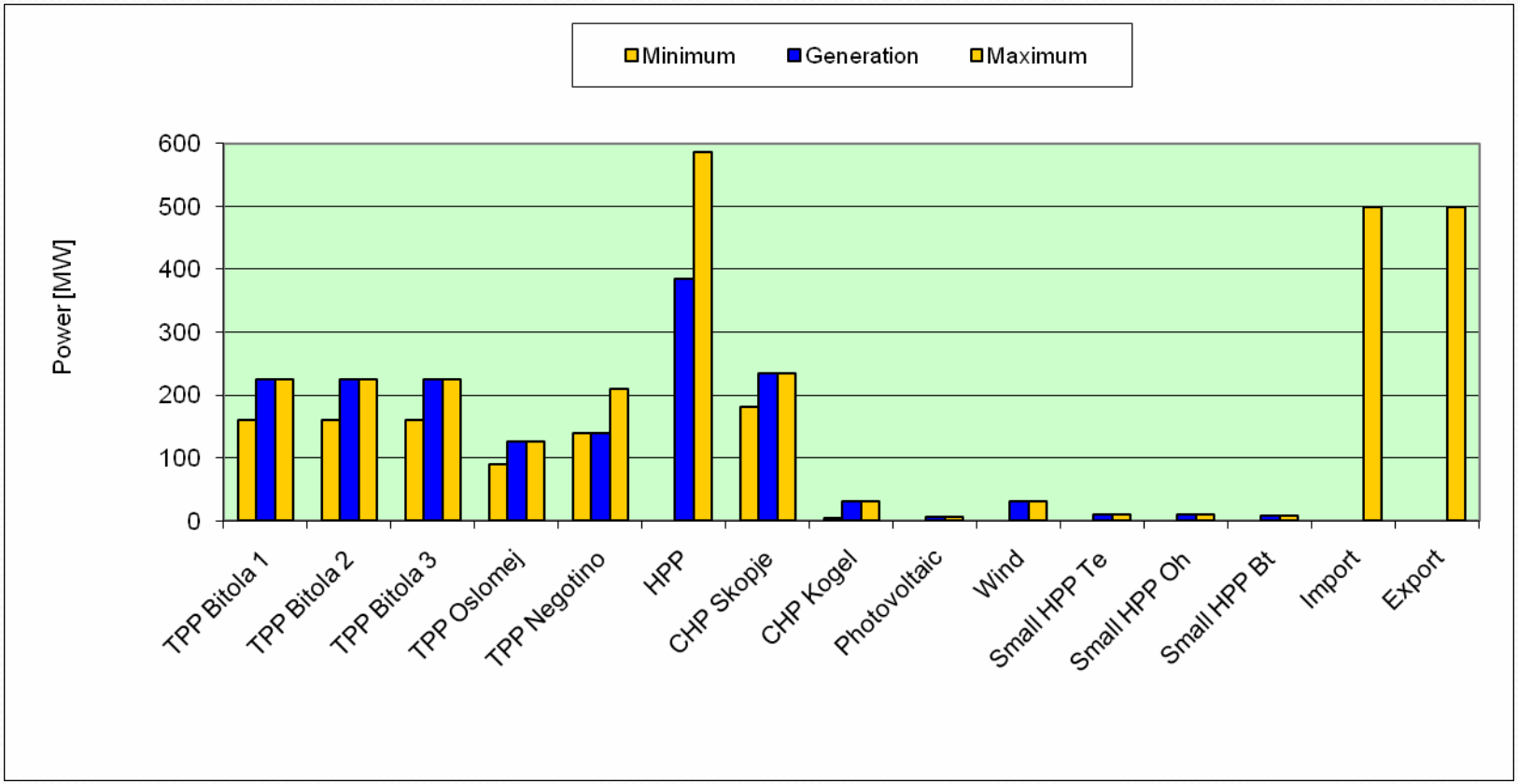
Typical examples

- Winter day
- Winter day 2, very high electricity consumption
- Winter night
- Summer day
- Summer night

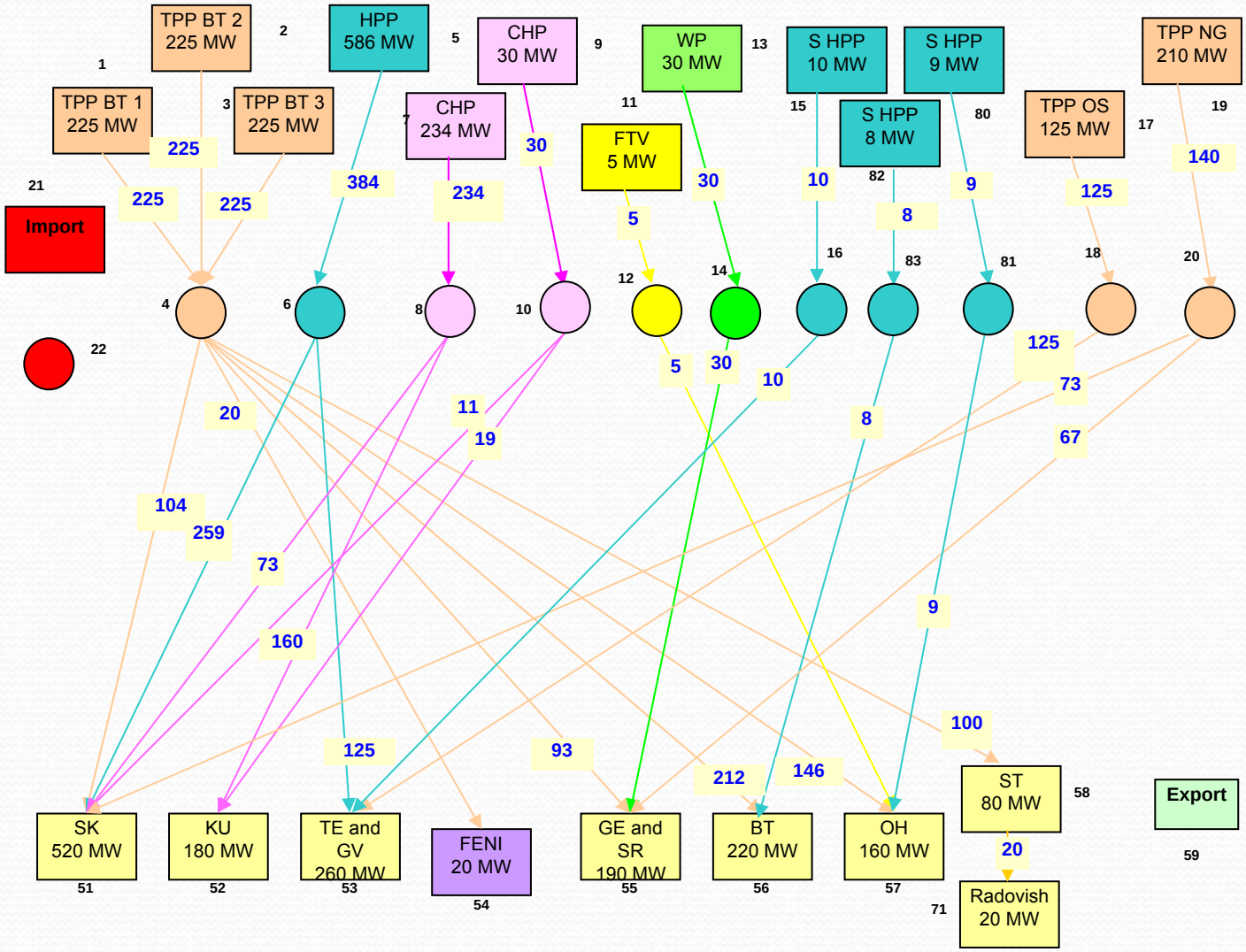
Consumption in a winter day



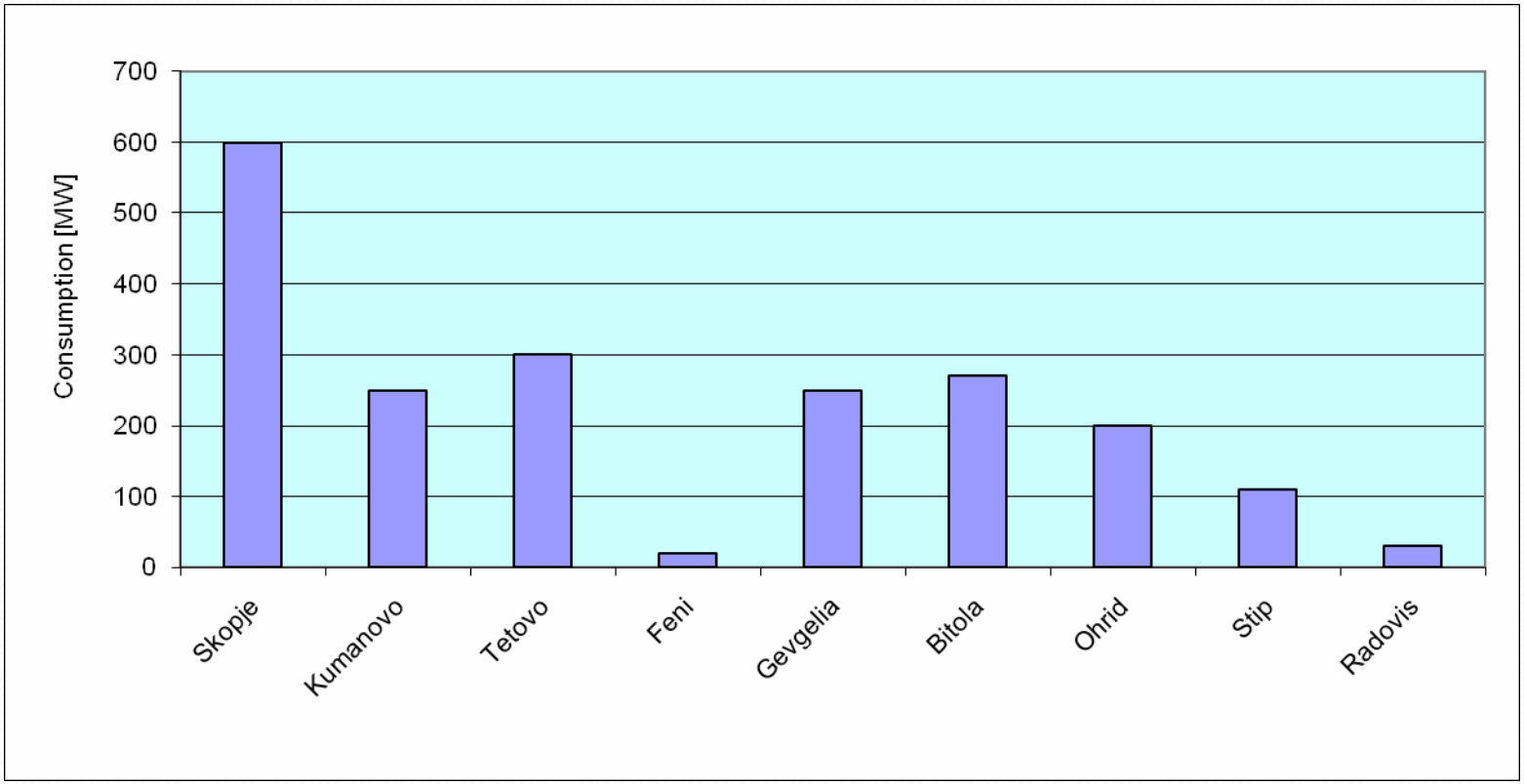
Electricity production in a winter day



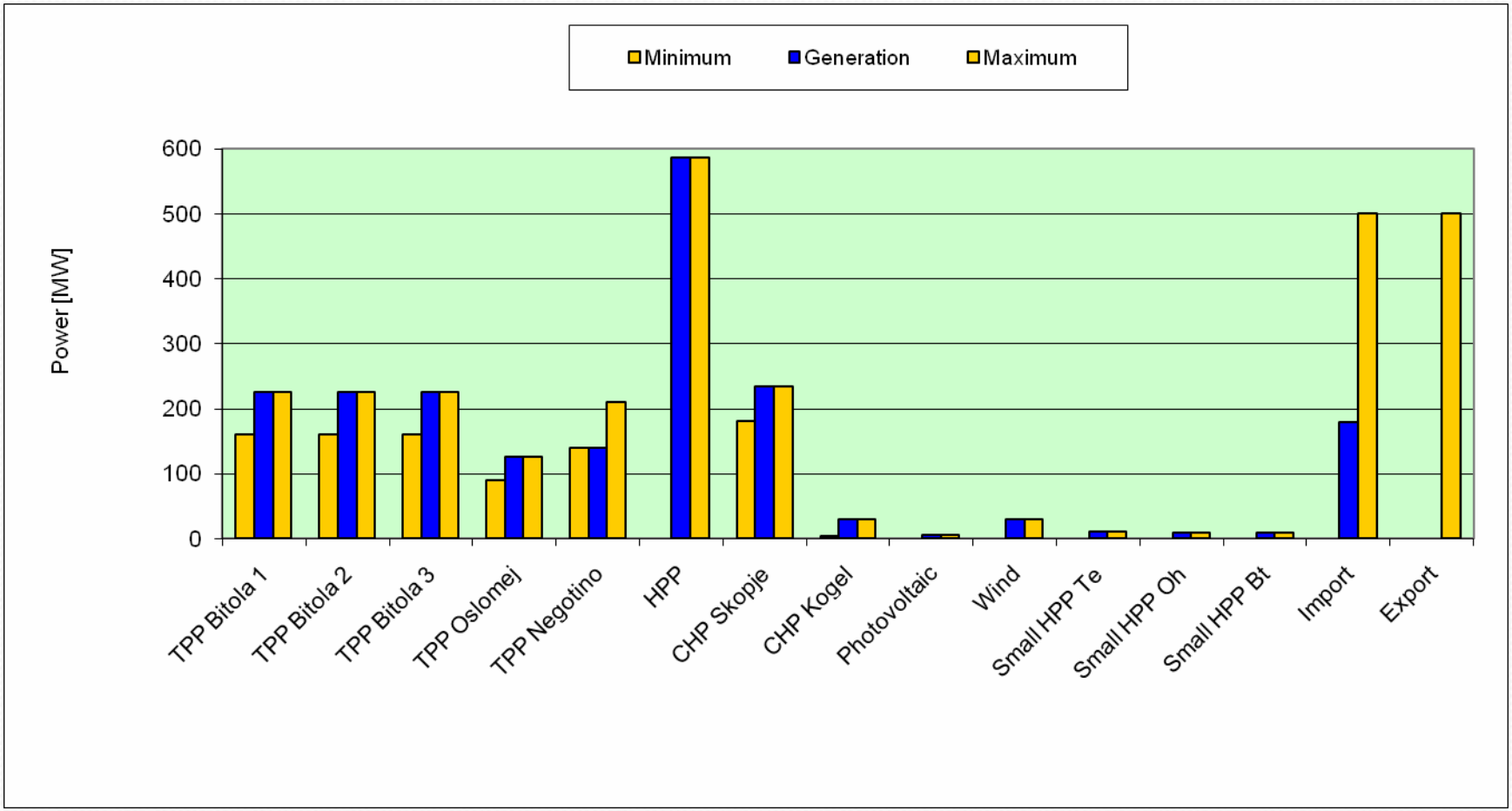
Link flow in a winter day



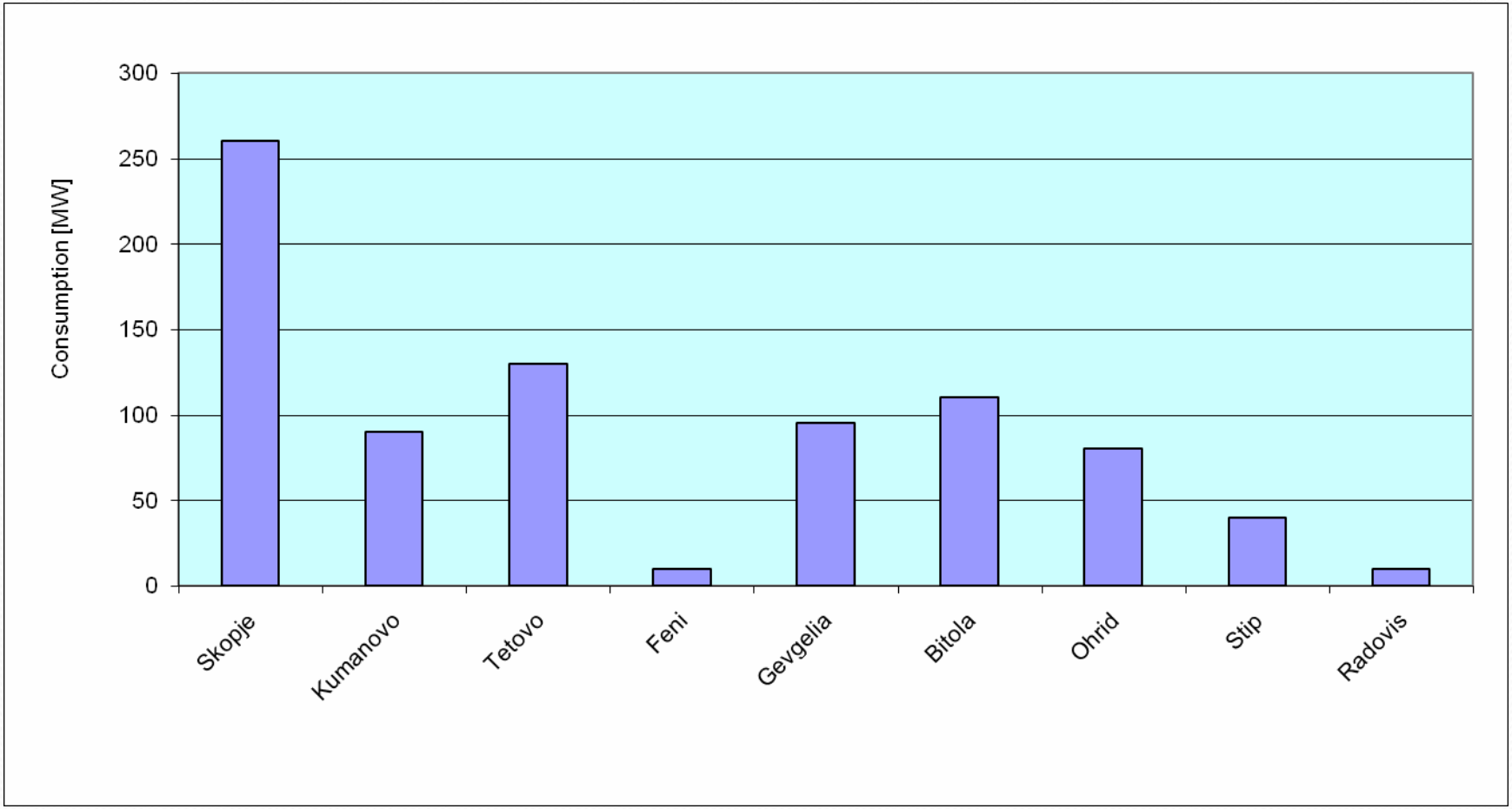
Consumption in a winter day 2



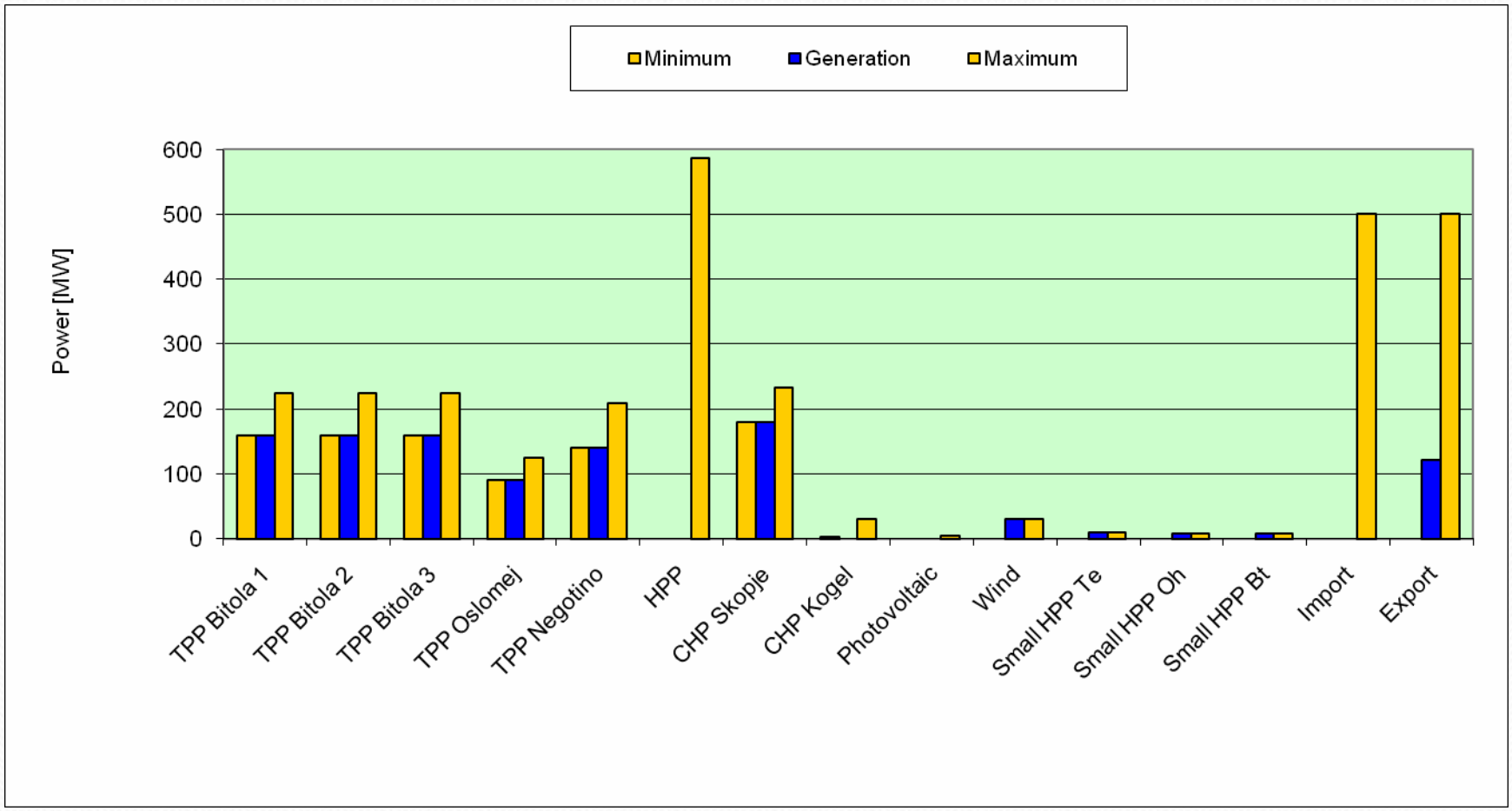
Electricity production in a winter day 2



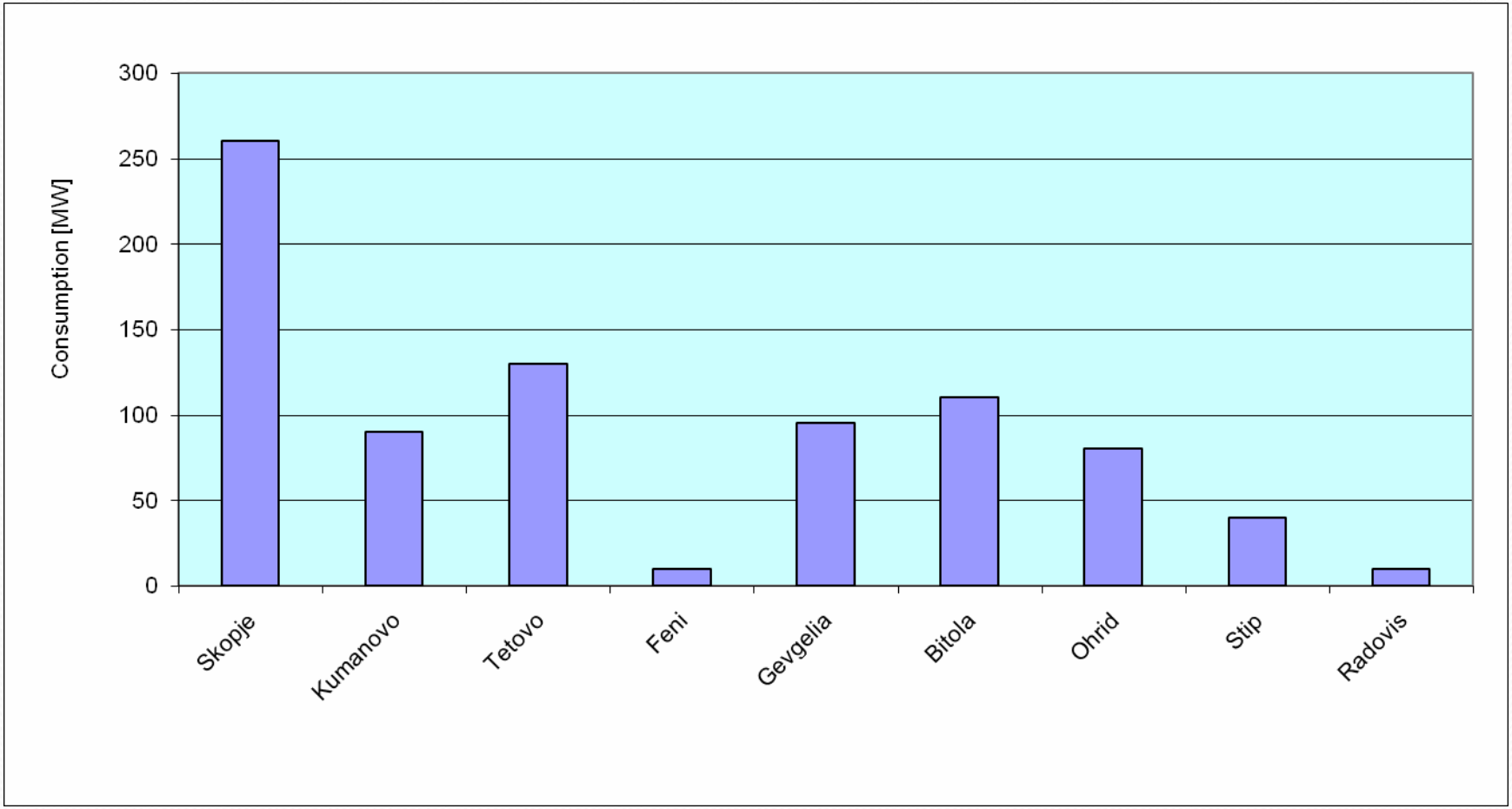
Consumption in a winter night



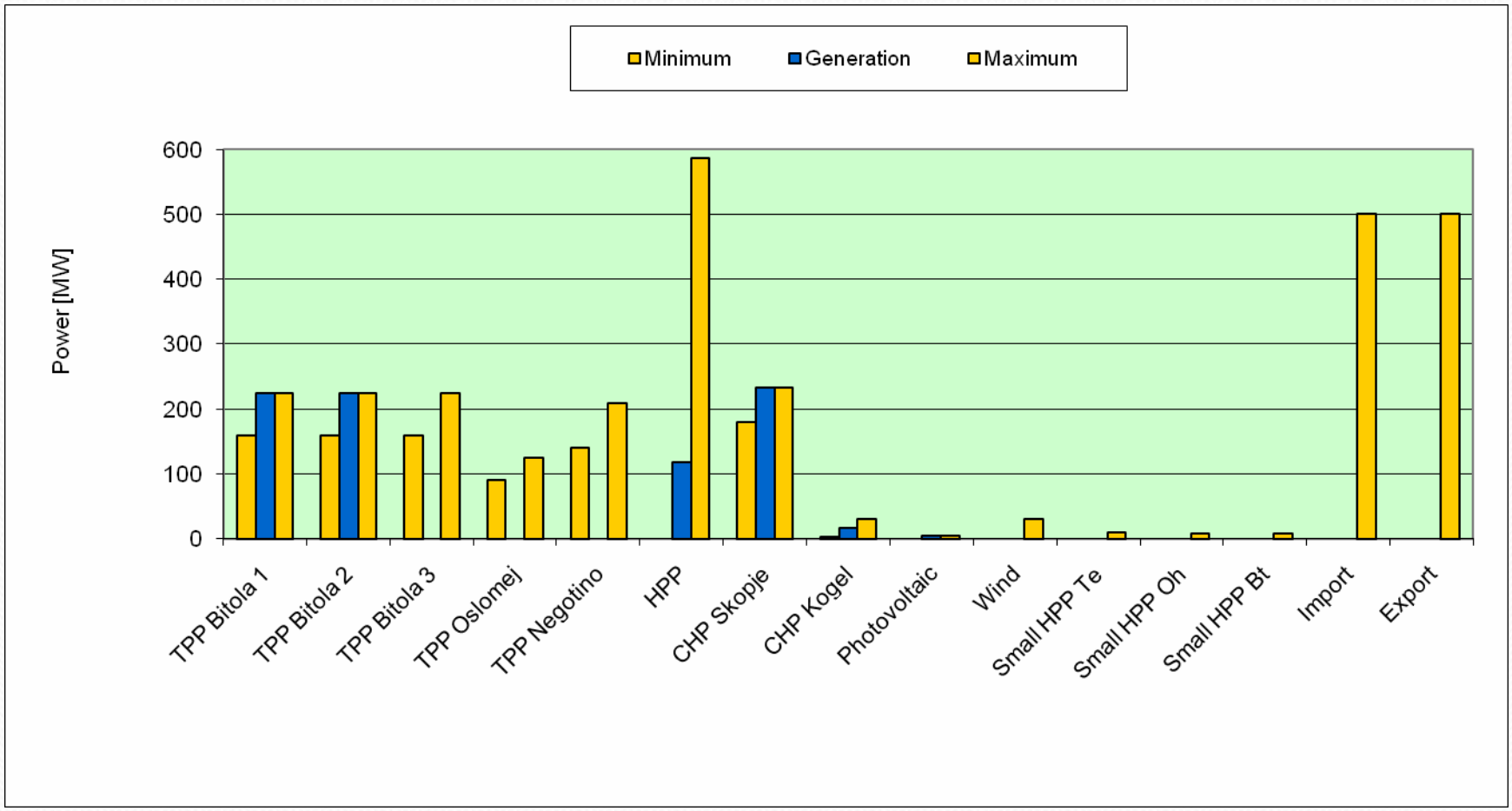
Electricity production in a winter night



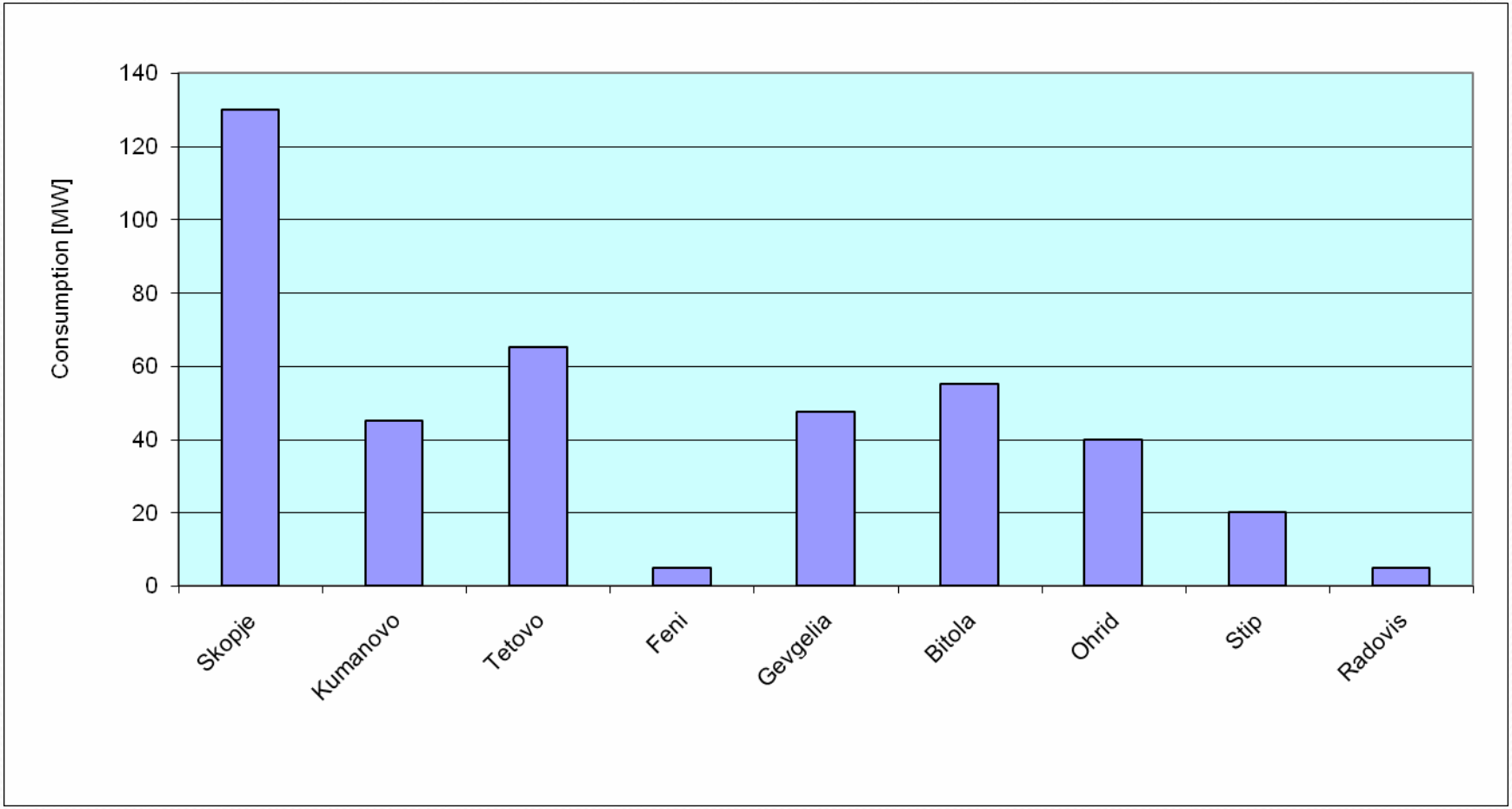
Consumption in a summer day



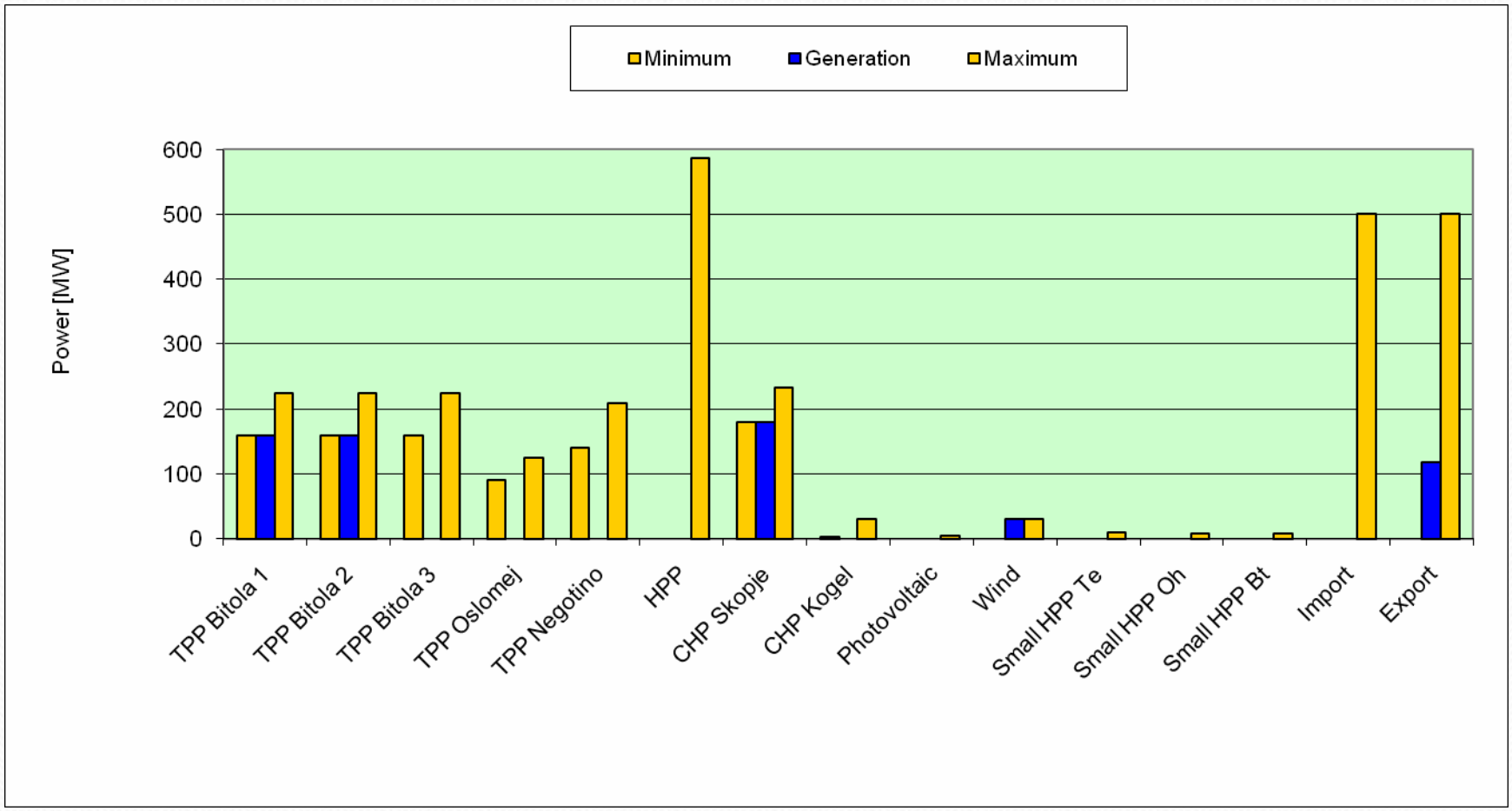
Electricity production in a summer day



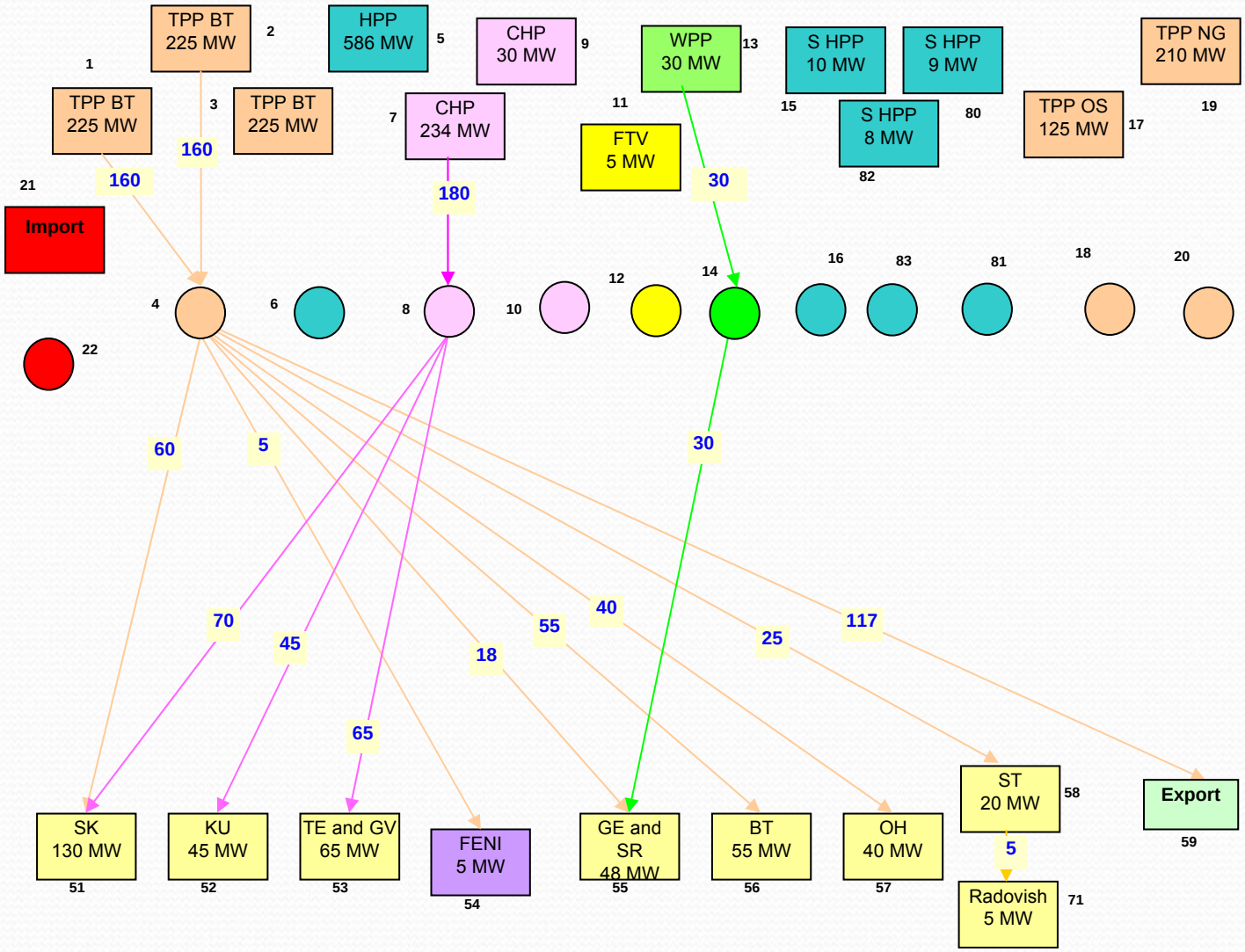
Consumption in a summer night



Electricity production in a summer night



Link flow in a summer night



Conclusion

- An original model for solving a multidisciplinary problem of Macedonian electric power system is developed that can optimize and analyze every (real) state of the system.
- Future works include
  - More detail analysis of the power system of Macedonia
  - Extending the model to larger regions and/or EU power grid
  - Extending the model to E^3 class of models (energy, ecology, economy)